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OPERATIONS RESEARCH OFFICE
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The Johns Hopkins University

Air Raid Warning in the Missile Era

by

Theodore Wang
Andrew Eckles
Brooks Ferebee
Edwin Fulcher
David Gerber
Richard Kossow
Eugene McDowell
Leroy Smith

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PREFACE

The wartime role of the Army depends on the effectiveness of coordinated defense measures in the zone of interior. Thus the Army is obliged to maintain a strong interest in civil defense, if only to anticipate and to assess the Army's probable poststrike tasks and capabilities. Furthermore the Army is charged by executive order to coordinate with and to assist in the planning of civil defense. A critical element of civil defense is the national warning system, which is examined in this study.

Since the pattern of Army warning is based on concepts and techniques that are related to—in some cases identical with—the concepts and techniques of civil defense warning, a review of the latter serves to guide the Army in the optimization of its own warning program.

"Alerting" usually means "signaling to attract attention." "Warning" usually means "describing the imminent danger and advising appropriate defense action." The words "alerting" and "warning" are used loosely and interchangeably both in practice and in this report. In some instances either word is used to imply both meanings; in many instances distinction is immaterial. However, in the existing national defense system the basic concepts of alerting and of warning are treated as clearly separate entities, and the corresponding procedures are executed by different means (the former primarily by sirens, the latter primarily by radio). It is believed that in this report the intended interpretation of the terms employed to depict alerting or warning is evident from the context.

It should be recognized by the reader that warning is only one element of the major passive defense triad of warning, shelter, and education. The effectiveness of the contribution of each element depends on the contribution of the other elements. No other implication is intended in this report, which deals with warning exclusively.

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Thanks are extended to metropolitan area civil defense directors around the country and to Washington area residents who kindly responded to inquiries submitted by this office.

Finally, appreciation is expressed to the entire ORO staff, whose tolerant cooperation made possible the middle-of-the-night telephone survey that is described in this report.

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SUMMARY

PROBLEM

To study and make recommendations on metropolitan air raid warning systems, and to draw deductions on warning that may be useful to the Army and the other military services.

FACTS

Effective warning is critical to all tactical passive defense; it is especially critical under the missile threat. Civilian warning procedures are applicable to the design or improvement of Army warning systems. Warning of the civilian population is of direct interest to the Army because of close Army-civilian interactions. No previous thorough investigation of warning is known to have been undertaken by any agency.

DISCUSSION

This paper treats warning by (a) examining the significance and the requirements of warning in the missile era, (b) examining the whereabouts of persons to be warned, (c) studying existing warning facilities to determine their effectiveness, and (d) recommending improved warning facilities deemed necessary.

CONCLUSIONS

Civilian and General

1. The present national warning system is regarded as basically unsound in that it provides alerting (coded signaling) and communications (warning information and advice) through two distinct operations that are independently administered and controlled.

2. The present national alerting communications net permits serious transmission delays.

3. Persons in most target cities are indoors over 90 percent of the time.

4. The present outdoor sirens do not effectively reach persons indoors; nor do the sirens suitably affect those persons reached.

5. A nationwide centrally controlled NEAR (National Emergency Alarm Repeater) system, which could provide effective indoor alerting, is regarded as a significant and urgently needed advance in alerting procedures.

6. A necessary *warning* complement to NEAR *alerting* is a nationwide, centrally controlled radio and television broadcast system. (Such a system can be made completely automatic by incorporating NEAR-type units directly within broadcast receivers.)

7. Reassessment of CONELRAD indicates that it is no longer needed as a means of denying navigational aid to enemy carriers. This, coupled with the requirement for fast, broad dissemination of warning information by radio and television, points up the need for discontinuing CONELRAD now.

8. A practical outdoor supplementary warning element is a voice-operated public address system.

Military

9. Army units, aside from those involved in active Continental US (CONUS) AA defense, experience delays up to about 15 min in the reception of their warning. (Although the missions of these units are in general not immediately pressing, their passive action cannot be deferred since survival in each case is a prime requisite to the ultimate accomplishment of the mission.) Other military service units within CONUS have warning problems similar to those of the Army.

RECOMMENDATIONS

1. The Army should adopt the NEAR system in order to alert each of its installations simultaneously and with minimum delay.

2. In recognition of the ambiguities inherent in coded alerting, the Army should complement and support its NEAR alert system with directly related clear-language, radio-transmitted warning communications to every local installation.

3. In the interest of over-all national economy and effectiveness the Army should support where possible the Office of Civil and Defense Mobilization (OCDM) in the sponsorship and development of an integrated NEAR signal-generating system on the regional and local electric utility networks.

4. The Army should transmit the findings of this report to the Department of Defense (DoD) and to the other services with the recommendations (a) that the NEAR system be adopted as standard for use by all military installations within CONUS and (b) that the Federal Communications Commission (FCC) be directed to discontinue CONELRAD operation now.

5. The Army should urge and wherever possible assist OCDM in the following: (a) to merge or to coordinate closely its operations of alerting and warning; (b) to emphasize and to promote rapidly universal indoor warning; and (c) to relegate outdoor warning to its proper secondary position.

AIR RAID WARNING IN THE MISSILE ERA

PROBLEM

The problem undertaken by this study is to examine critically the status of civil air raid warning in major target areas of CONUS (particularly the new warning system in the Washington, D.C., metropolitan area), to ascertain the warning implications for CONUS Army installations, and to make such recommendations as are deemed necessary.

SIGNIFICANCE OF WARNING

The purpose of civil defense warning is to evoke a response that will save lives. To ensure response a warning system must provide not only a fast-acting and clearly detectable alarm but also a description of the actions necessary to minimize the danger. The warning must be such as to stimulate this action by a high percentage of the population within the available period of time.

Regardless of the efficiency of the process that activates the alarm signals, persons who perceive but are not promptly affected by air raid alarms may be quite as unwarned as they would have been if the alarms had been inoperative. Failure to recognize this fact can lead to misconceptions concerning the effectiveness of warning systems and can promote unfounded optimism concerning warning capabilities.

The question may be raised of the value of warning under existing conditions when anticipated warning times may be too short for many persons to take survival action and when the outlook for those who survive is often considered bleak at best. However, it is recognized that even limited warning time is valuable, contributing not only to deterrence of nuclear war but to national survival if deterrence fails.

Warning is only one essential component of passive defense. In order to be genuinely effective, good warning must be supported with good shelter. Nevertheless, warning that evokes immediate response can be helpful in saving an appreciable number of lives, since even if formal shelter is either inaccessible or nonexistent, warning still permits such action as: (a) waking members of the household, (b) assisting sick and dependent persons, (c) shutting off utilities, (d) moving away from windows and away from other frangible items, (e) grabbing emergency supplies and going to the predetermined structurally strongest nearby refuge area, and (f) being attentive to official advice.

REQUIREMENTS OF WARNING

The concept of two tactical alternatives, one for hours of warning and the other for minutes of warning, originated several years ago when the only seriously threatening means of enemy weapon delivery were subsonic aircraft. This concept is now outmoded.

Of course there is still the possibility of a relatively long strategic warning period in the event that an enemy buildup of forces is observed. Furthermore there is the possibility that the US could be involved in a limited war abroad; this could serve to maintain the nation in a constant state of readiness for the precipitation of a global nuclear war. However, strategic warning of a nuclear attack based on prestrike information is not to be confused with tactical warning, which is associated with the detection of a committed strike action. In any event, warning system design must serve the worst possible case—surprise attack. It is in the context of surprise attack on CONUS that the present study is conducted.

Any indication of the distant approach of enemy aircraft (which might normally take hours to arrive) conveys no information concerning the possible projected release from these aircraft of high-speed air-to-ground missiles; it conveys no information about the possibility of unobserved poised enemy ICBM bases; and it conveys no information about the possibility of undetected enemy missile-launching submarines or of disguised merchant ships approaching US shores. In other words, in the present era there can be no reliable reckoning of the time available between detection of one element of an attack and possible strike by other undetected elements.*/

Within the next few years, before ballistic-missile-detection facilities become operational, it is possible that the first local warning could be either the blinding flash from a close nuclear detonation or a report that another target area has just been struck. After missile-detection facilities are established the maximum warning period might be as long as 30 min—or it may even be zero. This situation emphatically demands that the entire warning process—detection, transmission, and completed response—must operate in a few minutes at most.

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*/Furthermore there can be no reliable estimate of the time between a strategic warning and the beginning of an attack. Nevertheless current national and local civil defense policy still advocates alternatives (of evacuation or shelter) depending on the time that will be available.

The critical time limitation requisite to organize preattack tactical defense leads to stringent requirements of warning for target areas [*] In every target area a major portion of the population must be alerted within a restricted time period. Quantitative evaluations of the percentage of persons to be warned and the corresponding time interval allotted can be established by a rational approach that recognizes the objectives of national policy and the limitations of national resources. An outline of an approach to such a procedure is presented in App E. However, no actual analysis of this specific problem is attempted here because it is felt to be outside the scope of the present study. Instead values have been arbitrarily selected that are believed to represent a fair compromise between (a) the ideal and (b) the minimum accomplishments that make for national survival. For the purpose of this it is tentatively proposed as a basic stipulation that the physical characteristics of warning must be such that 90 percent of the population within each target area receive and perceive the warning within 30 sec of the original determination of a warning status

Although good warning must affect a predominant fraction of all persons as quickly as possible, the warning must be continued for an extended period (or until it is disrupted by enemy action) in order to alert stragglers and to provide additional information and advice.

Implicit in the basic stipulation are certain fundamental requirements of the warning system's facilities (in addition to the limitation on cost). These involve properties of the warning that relate to physical characteristics and other properties of the warning that relate to perceptual characteristics, as outlined below. (There are no sharp differences among the requirements; rather there are certain obvious overlaps and interdependencies.)

Physical Properties

(a) The communication of warning from national headquarters to each individual must be essentially instantaneous.

(b) The warning broadcast must be wide in coverage, serving nearly all US residents It must reach persons indoors or outdoors, awake or asleep

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[*] Target areas are localities containing probable aiming points. The requirements of warning are less rigorous for other areas, in which delayed fallout may be the major concern.

(c) The warning system must be technically reliable: it must be by design assuredly operative well over 99 percent of the time; it must be nearly impossible to false-alarm on a national scale and highly improbable to false-alarm locally; and it must be sufficiently difficult to sabotage so as to render a sabotage attempt unprofitable to an enemy.

Perceptual Properties

(a) The warning must be lucid and distinctive. It must admit of immediate interpretation by all normally responsible persons.

(b) The warning message must be informative. A simple alert is necessary but definitely not sufficient.

(c) The alert and the warning must be closely integrated in time.

(d) There must be emphatic confirmation of the validity of the warning.

(e) The warning must be effective under conditions of total surprise. The warning reaction must be independent of the need for any previous strategic information.

(f) The warning must be immune to compromise in effectiveness through possible tests, false alarms, or misuse.

PRESENT ALERT TRANSMISSION SYSTEM

The present national alerting system includes a widespread aircraft-detection net, a central data-processing unit, a national dissemination net, local dissemination nets, and individual community alerting services. Privately owned radio broadcast stations play a secondary role in providing limited warning information after the initial alert.

The North American Air Defense Command (NORAD) is responsible for the operation of the detection facilities. Data from various detection sources are processed continuously by the semiautomatic ground environment (SAGE) system in several sectors throughout the country. These sectors are linked with NORAD headquarters by extensive communications networks. The system serves to alert the higher echelons of both military and civilian facilities of aircraft attack. Developments are under way to provide similar alerting for missile attacks.

If on the basis of all available intelligence NORAD decides that a hostile action is in progress against CONUS, a condition of "air defense emergency" is declared. Simultaneously NORAD establishes an appropriate status of "air defense warning"—Yellow, Red, or White. Yellow means that an attack is probable, Red means that an attack is imminent, and White means that no attack is probable. At any time during a condition of air defense emergency NORAD may direct the implementation of CONELRAD, which is a control system for radio and television stations intended to deny to the enemy navigational guidance from broadcast signals.

The OCDM maintains continuously staffed warning centers at several NORAD stations. In normal operation each of the OCDM warning centers is responsible for alerting states within its own geographical area, but in the event of failure any one of the warning centers can substitute for any one or for all of the others, or the OCDM National Operational Headquarters (code name LOWPOINT) can perform the job. In addition to the warning centers and LOWPOINT, OCDM maintains seven regional administrative offices throughout the country. These plus a classified location are included in the warning system to serve if necessary as replacements for defective links in the system. The classified location acts as the warning point for the Washington metropolitan area.

Communication among the various OCDM agencies and the state warning points is accomplished through what is known as the National Warning System (NAWAS). It consists of a network of full-period land-line telephone circuits leased from the American Telephone and Telegraph Company. All communication over this system is by voice. NAWAS is comprised of two independent but interconnectable systems—the warning circuit and the control circuit. The warning circuit serves all points of the system and is designed exclusively for dissemination of alerting information. The control circuit serves only the OCDM offices and is designed for communication of tactical and of administrative information with OCDM.

Decision to disseminate an alert is made at the OCDM national warning center at Colorado Springs on the basis of information supplied by NORAD. The national warning center directly advises every state warning point of the initial alert. Each of the three major warning centers then provides follow-up information to all the state warning points in its area, giving specific estimated warning times for individual cities. The communication process to this point requires at present about 1 1/2 min. After the announcement each warning center takes roll call of the state warning points, and an attempt is made to reach points not responding. If necessary, resort is made to radio or to public telephone

If CONELRAD is implemented at any time this information is disseminated over NAWAS in the same manner as is the alert.

There is at least one state warning point in each state, and within each state there are subsidiary warning points responsible for specific localities. OCDM furnishes the equipment that ties the state warning points to NAWAS, but OCDM exercises administrative control over only the single warning point serving Washington, D.C. All other warning points operate under state and local jurisdiction. The state warning points disseminate the warning message to lower levels within their areas over existing commercial communications facilities.

In many states the warning points act independently of political authorities, but in certain communities approval of a specific local official is necessary, and this can incur delays of minutes or conceivably of hours. Alert signals in large cities are commonly activated centrally, but in some localities the signal-activation points must be reached by public telephone, which provides additional opportunity for delay.

Inasmuch as the threat is of national scope and concern there is need for unified alerting action throughout the country. The very limited potentially available time imposes the requirement that at least the initial alarm should proceed in a single step without intervening delays from the federal level directly to the individual recipients within every target community. However, except in the single case of the metropolitan area of Washington, D.C., OCDM currently has no authority to operate warning systems below state level, so that in general the warning transmission is relayed through at least two politically autonomous echelons. This situation, which involves delay at each exchange, was tolerable prior to the missile era but is intolerable now. There is now an imperative need for expediting warning transmission. Appropriate legislation should be drafted if necessary. Consonant with unique local conditions each community could and should maintain some control. However, if this control impedes the delivery of the initial alarm then federal action should take precedence.

The Army warning network provides direct and immediate communication from the national alerting system to each of the armies and to each lower unit directly affiliated with the CONUS AA defense system. However, all other units are alerted by the individual armies, which are limited to the use of teletype and telephone facilities, the latter in many instances involving conventional commercial telephone circuits with their attendant delays. For example, the First Army, with headquarters in New York, reports that it is currently obliged to alert approximately 100 subordinate units, and the completed process may require about 20 min. 1/ At some stations the Officer of the Day (OD) must be located before the warning can be authenticated at that local station and before passive action can be initiated. This procedure may require only seconds if the OD happens to be standing by the message center or minutes if he happens to be temporarily inaccessible. The other military services employ similar patterns of warning.

DISTRIBUTION OF PERSONS TO BE SERVED

Basic to the design of local warning outlets is a knowledge of the statistical whereabouts of the persons for whom the warning is intended. Specifically, in recognition of the auditory nature of major warning broadcast devices, it is appropriate to determine within each target area the time spent indoors and outdoors.

Such a determination was made for Washington, D.C., from information supplied by the Bureau of Census and by the Washington Board of Trade. The details of this computation are found in App B. The final values are given in Table 1.

Table 1

POPULATION DISTRIBUTION IN VARIOUS WARNING CATEGORIES, WASHINGTON, D.C.

Category	Percent of total man-hours per week
Indoors	
In buildings	
Awake	63.0
Asleep	30.0
Subtotal	93.0
In vehicles with closed windows	2.0
Outdoors	
In open	4.5
In vehicles with open windows	0.5
Subtotal	5.0

Passengers in vehicles were assigned to subcategories designated "indoors" or "outdoors," in accordance with whether the vehicle windows were estimated to be closed or open (determined by the season of the year) Simple tests of audibility in vehicles confirmed the rough general assignment of passengers in closed-window vehicles to the indoor category and passengers in open-window vehicles to the outdoor category. However, a distinction was made between persons in vehicles with closed windows and persons inside structures because certain promising indoor warning devices that operate on utility electric-power circuits are available to fixed structures and are not available to mobile units. Because of the special problems of alerting sleeping persons the indoors category was provided with subgroups of "awake" and "asleep."

Persons in Washington, D.C., are indoors on the average of 93 percent of the time. Admittedly the data involved are of limited accuracy; furthermore, they are averages and do not represent specific individuals within corresponding categories. Nevertheless, it is evident that there is a strong need for indoor alerting and only a secondary need for outdoor alerting. This is in contradistinction to the emphasis placed on outdoor warning devices, such as sirens, in the Washington, D.C., area to date.

Since most communities of the country are of comparable or cooler climate than Washington, D.C., the outdoor-indoor distribution of man-hours for Washington (Table 1) is generally appropriate for other metropolitan target areas within CONUS. Most of these areas have adhered to the Washington, D.C., pattern of installing outdoor devices.

It should be noted that the importance of the individual warning case is not exclusively dependent on total man-hours in the particular category. Another factor to be reckoned with is what might be called "demand load," in analogy with public utility service terminology. Whereas the automobile case in Table 1 measures only a few percent in over-all man-hours, automobile warning presents a high demand load during the morning and evening rush traffic hours so that its relative importance, although still considerably less than that for the indoors case, nevertheless is greater than its simple man-hour figure would suggest. *

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* The fact that the rush hour is staggered both within individual cities (various businesses close at different times) and across the country (four time zones) means that there is no single short-duration rush traffic period that an enemy might be able to exploit in an all-out surprise attack on CONUS.

LOCAL-AREA-WARNING BROADCAST DEVICES *

Indoor Devices

A warning system based on the use of the telephone has been proposed; it would cause all telephones in an area to ring simultaneously in a particular sequence indicative of an air raid warning. The alarm would be intermittent because of the necessity of maintaining telephone service in key locations during an attack. The public would be instructed not to pick up their telephones but to follow prearranged plans for survival.

This system has the advantage that no additional indoor device would be needed in any place that already has a telephone. However, it has a number of disadvantages, a major one of which is that many households do not have telephone service (30 percent in the nation). Another drawback is that because of the coded character of the warning the signal can be confused with the conventional telephone ring. A clear-language recorded message in connection with the warning ring is conceivable but impractical; without elaborate and expensive modifications the telephone system could saturate so as to deny the warning message to most subscribers.

There are currently available several models of commercially produced radio receivers that are designed to trigger an alarm if and when the station to which they are tuned executes the formalities associated with CONELRAD operation (carried on-off followed by 1000-cps tone). (These formalities are described more fully later.) The cost of these special radio receivers is between about $50 and $150. It is estimated that professional modification of an existing radio receiver to perform the same function would run at least $25. One disadvantage of these units is that they would sound no alarm unless and until CONELRAD is invoked. Their relatively high cost and certain unresolved technical problems are other drawbacks.

A simple and effective resonant relay that can trigger an indoor alarm has been developed for operation from utility power lines. This device (NEAR) has been produced for OCDM by the Midwest Research Institute The relay responds to a voltage of a specific frequency other than the standard power-line frequency whenever this voltage is superimposed on the power network The present plans call for a relay-operating frequency of 240-cps. This frequency was selected in order to effect a compromise between the features of (a) high attenuation on power lines associated with high frequencies, and (b) poor discriminatory characteristics of resonant relays operating at low frequencies (near 60-cps). The proposed alarms consists of a loud and compelling buzzer clearly distinguishable from a telephone bell or any other common sound.

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* In addition to sirens.

The practicability of the technique has been demonstrated in tests on actual power systems in two areas: Grand Rapids and Battle Creek, Mich. The cost of an individual receiver unit is estimated to be between $5 and $10 when mass produced. The cost of the stand-by power consumption of a single receiver is comparable to that of an electric clock, well under $1 per year. It is estimated that a nationwide NEAR-system central-station signal-generating network would run between $40 million and $60 million.

Outdoor Devices

Outdoor public-address systems employing voice transmission are currently installed in at least two cities in the country. The most thoroughly tested is that in Hoboken, N.J., which has been in operation since 1952. This system consists of about 200 speakers mounted on utility poles about 20 ft above street level. Most of the speakers are of 5-w rating with a few as large as 60 w each. Auxiliary gas-engine-driven generator sets are located at several points within the network to provide emergency power. The speakers are controllable either locally or from a central headquarters. They serve a total area of a little over a square mile, which includes most of the city of Hoboken, population 50,000.

Salina, Kans., a community of 30,000 persons, has recently (1959) installed an outdoor loud-speaker warning system consisting of 12 large horn units.

A promising outdoor sound source for certain applications is the speech-modulated air horn, which is currently under development by the Stanford Research Institute at Menlo Park, Calif., for OCDM. This type of device, which is claimed to provide adequate voice quality for warning, has the advantage of good engineering efficiency (of the order of 40 percent), and makes possible high-power (kilowatt) speech units at a much lower cost than that of the conventional diaphragm speaker. However, because of echo and shadow effects of congested buildings, it is believed that the use of multiple-distributed low-power speakers, similar to the Hoboken system, is preferable for the downtown areas of large cities.

Some small towns are using aerial fireworks explosions to signal the approach of tornadoes, and consideration has been given to applying a similar scheme for air raid alerting. There are several problems related to explosives that need to be investigated before their value for air raid alerting can be determined. This study limited its concern to an examination of the physical characteristics of sounds from certain commercially available fireworks (see App C).

CONELRAD

System Operation

Radio and TV broadcast facilities can play an important role in warning communications. CONELRAD, which uses a limited portion of the radio spectrum and no television, is intended to provide a compromise solution to the conflicting concerns: (a) denial of enemy air-navigation information, and (b) provision of friendly defense information.

The activation of CONELRAD, as presently established, is effected by the commanding officer at any one of several air defense control centers (Air Force installations) who alerts by telephone approximately 75 radio broadcasting stations, which are designated "basic key stations." Each basic key station in turn alerts by telephone several relay key stations. There are approximately 300 relay key stations throughout the country. The average time to complete all the calls to the key stations is reported by the FCC 2 to be 2 min. As long a time as 10 min has been required on occasion to reach specific stations as a result of busy telephone circuits.

On receipt of the telephoned alert each of the key stations proceeds as follows:

(a) Discontinues its normal program
(b) Cuts the transmitter carrier from the air for 5 sec
(c) Returns the unmodulated carrier to the air for 5 sec
(d) Cuts the carrier from the air for 5 sec
(e) Returns the carrier to the air
(f) Broadcasts a 1000-cps tone for 15 sec
(g) Broadcasts the following message:

> We interrupt our normal program to cooperate in security and civil defense measures as requested by the US Government. This is a CONELRAD radio alert. Normal broadcasting will be discontinued for an indefinite period. Civil defense information will be broadcast in most areas at 640 or 1240 on your regular radio receiver.
>
> I repeat. We interrupt ....

(h) Removes transmitter from the air for the duration of the alert or returns to the air under the CONELRAD system.

Between steps (g) and (h) civil defense information is permitted to be broadcast within the limitation of 1 min total time

Every radio and TV station in the US is required to monitor continuously one of the key stations. On receiving the alert transmitted by the key stations, the other stations follow the same standard broadcast procedure. Then all television stations and most radio stations shut down. Those radio stations that remain on the air under CONELRAD operate in most areas in clusters of three or more. The power is adjusted so that each station transmits a signal of about the same intensity as that of the other stations within its specific cluster but not to exceed 10 kw. Each station in the cluster broadcasts simultaneously a common program on the same frequency, either 640 kc or 1240 kc. Station call letters are not announced. The objective is to present a confusing radio-homing picture to an incoming enemy weapon carrier.

Actually the stations within a cluster are not on precisely 640 or 1240 kc but are offset from one another in frequency by a few cycles per second. The offset is essential in order to eliminate dead zones that could be caused by destructive interference between out-of-phase signals from two stations in the same cluster. The result is a rumbling heterodyne signal superimposed on the regular program; nevertheless the transmission quality is believed to be adequate for warning purposes.

In peacetime, radio broadcast service to any given area is designed for a 20-to-1 ratio between the power of the desired signal and that of the local background interference. CONELRAD is designed on the basis of a 3-to-1 ratio of desired signal to interference. Accordingly the CONELRAD broadcast reception is poorer than normal and some areas may have no CONELRAD reception at all.

Some stations have provision for switching almost instantaneously to CONELRAD, and others are acquiring this ability. In many stations, however, there are delays of several minutes in beginning CONELRAD operation because of the requirement of switching oscillator crystals, tank circuits, and antenna systems. There could be delays of an hour or more if engineering personnel are not on duty when CONELRAD operation is declared. This could be the case with many stations if the emergency arose late at night.

During the delay occasioned by the transition of specific stations to CONELRAD operation, anyone within the areas served by these stations would receive no broadcast signal on radio or on television. This lack of communication, which in certain areas could temporarily be the only indication of an attack, cannot reliably be expected to stimulate immediate and appropriate defense action.

In recognition of these present shortcomings CONELRAD is being steadily improved in technical capability under the instigation of FCC. Plans are being promoted to provide considerably improved coverage and to expedite the activation of the entire system.

The broadcast stations in the CONELRAD net serve voluntarily with no compensation for staff time, for special equipment required, for operating expenses, or for advertising revenue that might be lost during CONELRAD test periods. According to the broadcast industry, as represented by John Meagher, Vice-President of Radio, the National Association of Broadcasters, [3] the industry is pleased to participate in CONELRAD and as a patriotic service to abide by the desires of FCC, DoD, and OCDM. According to FCC, as represented by Defense Commissioner Robert E. Lee, [4] some "mild coercion" has been needed to rally appropriate industry support. In spite of the costs of CONELRAD operation the broadcasting industry does not presently desire federal subsidy, apparently because of the fear that such an arrangement could conceivably provide an opening wedge for ultimate federal domination of the broadcast programs. Currently there is no legal obligation for broadcast stations to participate in CONELRAD, although recognition of the power of FCC to regulate licensing seems to be a strongly persuasive influence.

The Case against CONELRAD

A matter that might be regarded as weakening the effectiveness of CONELRAD in navigation-denial without contributing to its transmission of warning information is that CONELRAD operation is not practiced by either Canada or Mexico (with the exception of two stations in Windsor, directly across from Detroit) Some of the Mexican stations are of the superpower type, presenting unusually strong signals well into the US.

Some indication of the degree of public awareness to CONELRAD may be obtained from the results of a 1958 ORO poll of 322 Washington area residents. Washington area residents, by virtue of living in the nation's capitol, might be assumed to be at least as well informed and prepared as the average citizen. The following item is cited directly from the ORO report on the poll.[5]

> Although radio stations in the Washington area periodically test CONELRAD by going off the air for approximately a minute (after having made an announcement to this effect) and the majority of new radio sets that are sold have two CONELRAD stations, 640 and 1240 kc, marked, only 43 percent of those interviewed showed a knowledge of CONELRAD. When asked where they would tune in the radio for information, about 4 out of 10 persons said they would spin the dial or tune to a local radio station; 2 out of 10 professed complete ignorance

A matter of serious concern is that no systems analysis examining the communications program of the combined civil and military defense system, including the overlap and interaction of the civil and military interests, has ever been presented openly. The present streamlining of CONELRAD to peak efficiency of technical operation is a tribute to the diligence of the FCC as well as a tribute to the cooperation of the broadcast industry and of OCDM. However, CONELRAD's improving technical efficiency could serve to obscure the possibility that CONELRAD might be fundamentally unnecessary and that it might weaken civil defense more than it strengthens military defense.

On 3 Dec 59 John J. McLaughlin, Administrative Assistant to the Secretary of the Air Force, went on record in an address to the broadcast station managers and civil defense directors of the country: 6/ "If those charged with the responsibility of defending the US from hostile attack could be assured that the enemy would not use domestic radio stations for navigational aid, there certainly would be no need for CONELRAD." The obvious implication is that the only significant concern of the Air Force is for the possible use of commercial broadcasts to serve incoming carriers with navigation and terminal guidance. No one can assure that the enemy will never employ broadcast assistance for navigation. On the other hand it can be demonstrated that it is impracticable for us to discontinue normal broadcasting simply to counter the possibility that the enemy might on occasion choose to utilize our broadcasting.

CONELRAD was useful when it was first conceived a decade ago against aircraft-delivered kiloton bombs. At that time it made an appreciable difference in the damage effected on a target city whether a bomb hit directly on or 3 miles away from the aiming point. At that time it might have been helpful to an enemy plane to be able to home on a specific broadcast station. However, the same difference in accuracy, of 0 to 3 miles, makes an essentially negligible difference in the damage effect to a target city with modern megaton weapons. For example, a 10-MT bomb with a 3-mile* circular probable error (CEP) presents approximately a 95 percent probability of devastation of the entire Washington metropolitan area (about 250 sq mi) by blast and fire.[7] Also a bomb of similar size by its fallout radiation could produce approximately 95 percent deaths among the personnel in the area who happened to be in apartment buildings or in structures of equivalent shielding if the bomb burst 40 miles upwind from the center of Washington, and approximately 95 percent deaths among those in frame houses or equivalent shielding if the burst point were 120 miles away.[8] The answer to the problem of survival of metropolitan areas does not lie in the attempt to deny sophisticated navigation to the enemy because the enemy can obviously wreak formidable havoc on cities even if he plots his course with a magnetic compass.

An enemy aircraft navigator might be inclined to withhold the use of his radar transmitter in order to prevent his own radar signal's contributing to a revelation of the plane's position to an observer on the ground. However, the present availability of nonradiating infrared display systems in aircraft lessens the need of radar for locating areas as large as cities or Strategic Air Command (SAC) air bases.

On the other hand certain prime targets for the enemy are quite small and more difficult to locate by either radar or infrared than US cities or SAC airstrips; these are US intercontinental ballistic missile (ICBM) bases. The enemy might be tempted to assign bomber aircraft to ICBM bases, particularly the hardened ones, which require close-in strikes of high-weight bombs for their destruction. And here radio broadcast information could reasonably provide useful navigational confirmation to the bomber aircraft. However, there are other factors to be considered. Any indication of the presence of one or more aircraft on the way (either those specifically assigned to the ICBM bases or others) would trigger an alert of the missile sites. The missiles should then be off by the time the assigned bomber aircraft arrived, and any bombs dropped on missile bases should fall on empty silos. Although a limited number of Soviet bomber aircraft possess the capability of end-running the present extremities of the CONUS early-warning radar line, it would remain a problem for these aircraft to reach inland to the missile bases undetected. If it is deemed essential some effort might be devoted to extending the US coastal radar line in order to lessen or preclude the possibility of an end run around the line.

In any event, CONELRAD is of no concern at all to enemy ballistic missiles since radio terminal guidance is not feasible in such systems. CONELRAD is of marginal use to enemy cruise missiles, which are known to have other and quite satisfactory navigation means (for example, inertial guidance and also television transmission of the target image back to the controlling aircraft)

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* "Miles" referred to in this discussion are statute miles (5280 ft).

The CONELRAD plan allows limited operation of broadcast stations in the standard a-m band but completely shuts down all TV and f-m radio stations because, it is said, these stations might not only give navigational guidance to the enemy but they might also adversely affect the control of our own defensive and offensive missiles. However, the facts are as follows: (a) A limited number of incidents of interference have occurred but the problem has been resolved by appropriate modifications in missile-control design. Evidence in support of this is the continued testing of our missiles in the face of continued transmissions on all regular broadcast channels. Furthermore the requirement is clear for our missile design to avoid any such possibility of interference in order to prevent interference by relatively simple clandestine transmitters following the onset of an enemy attack. (b) The particular frequency bands of most f-m and TV broadcasting are especially unsuited to navigational purposes for air weapons carriers since the dimensions of the carriers or of their components (fuselage, wings, engine nacelles, tail structure, and control surfaces) are of the same order as the wave lengths involved. Because of the specific phase relations of the secondary radiations from these various components there is produced distortion of the observed radiation pattern (intensity vs direction), which pattern is intended to identify the line of the transmitting station. The nature of the distortion depends on the attitude of the flying object in space so that practical compensation is unattainable, and navigational errors of from 10 to 20 deg may be incurred. This vitiates the use of passive radio navigation for the range of frequencies of most f-m and TV broadcasting.

The CONELRAD effort to deny navigation aid can, in principle at least, be weakened by enemy-agent operation of CONUS-based radio transmitters, which would serve as outstanding beacons against the CONELRAD-cleared broadcast background. Anyone can construct or procure adequate transmitters without arousing suspicion. Further, the operation of the transmitters requires no personnel. They need only be started whenever CONELRAD is activated and then left to run by themselves. Such transmitters could and certainly would be located but their elimination might require more time than would be available under the circumstances.

It may be that CONELRAD represents a plan for making available the present broadcast spectrum for special defense services in an emergency. If it is true that these channels are needed for emergency use, then the facts should be presented candidly and an optimum distribution should be made accordingly.

A decade of experience in living with the threat has demonstrated that the American public fails to comprehend the nature of modern civil defense requirements and that most persons would be relatively unprepared if an attack occurred today, next year, or the year after. Under these circumstances, in the event of an imminent strike on CONUS it would be important to be able to reach persons directly through means that are natural to them—if possible through the normal broadcast facilities that serve their homes regularly—and to exploit this service to the limit of its capacity. CONELRAD currently restricts the effectiveness of this effort.

On balance, the requirement is manifest for the discontinuance of CONELRAD in this, the missile era.

ACOUSTICS OF LOCAL WARNING DEVICES

The transmission of an acoustical warning involves: (a) source, (b) intervening media, and (c) competing sounds (background). For the case of both source and recipient indoors the acoustical requirements are relatively straightforward to compute, requiring primarily consideration of a source sound level relative to background. For the case of the source outdoors the problem is considerably more complex. This section presents data on background noise and on the transmission of a signal between a source and a recipient. These data set certain requirements for the source.

Background Noise

Data on indoor background levels are provided by Seacord's report of a study conducted by the Bell Telephone System.[9/] The project involved 1700 locations in Chicago, Philadelphia, Cleveland, and New York. Some of the pertinent results are portrayed in Fig. 1, where the left line applies to residences with an operating radio receiver, television receiver, or phonograph, and the right line applies to business establishments. The ordinates represent summer-winter average values. In general, according to Seacord, the background noise in residences, stores, and offices runs a few decibels higher in summer than in winter because during the summer outside sounds enter buildings through open doors and windows. Consequently an indoor warning device should be designed to be effective against the higher sound levels of summer. However, an outdoor warning device that is intended to be heard indoors would have approximately constant year-round level requirements since both its signal and the noise generated outdoors experience reduced attenuation on entering buildings in the summer through open doors and windows.

The character of outdoor noise in any particular city is, of course, related to the specific functions of that city.[10/] However, a close correlation in several cities between outdoor noise and traffic volume has been found.[9/] Accordingly in many target areas traffic surveys

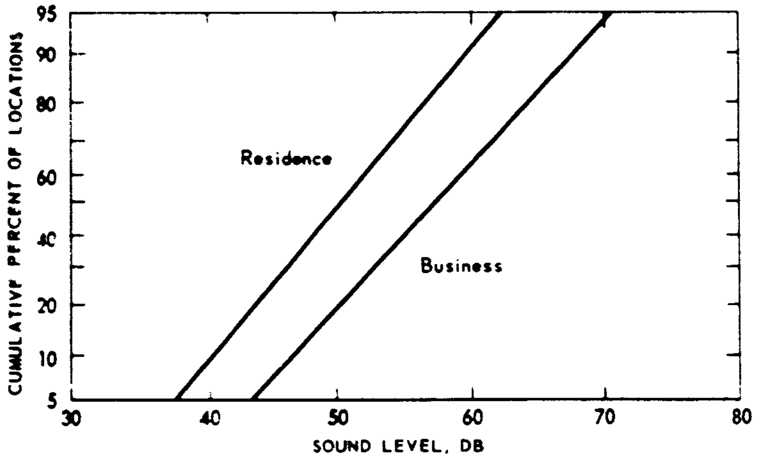

Fig. 1—Interior Noise (Annual Average Levels)[9]

can be employed to provide measures of outdoor noise at various points in the area. The procedure is illustrated in the analysis of the Washington, D.C., warning system in App D.

When background levels have been assigned to all the possibly occupied regions of a specific target area, then within that target area a theoretical evaluation of potential warning audibility can be made by comparing at each region the expected sound level of the desired warning signal with that of the competing background noise.

Transmission

The expected level of the desired signal at the receiver depends not only on the strength and directional properties of the source but also on the reflecting, refracting, diffracting, scattering, and absorbing properties of both the intervening atmosphere and the intervening terrain and structures. Considerable work has been done on examining certain of these basic elements in sound propagation, but much is still unknown regarding particular aspects of this complex problem. At present broad estimates of over-all effects are all that are possible.

The literature contains reviews of effects of sound propagation due to (a) ground absorption, (b) humidity, fog, and rain, (c) temperature refraction and wind refraction, and (d) air turbulence. 11/—20/ It is shown that in the frequency range below 1000 cps and over distances of less than a mile from the source, air turbulence is the principal cause of attenuation, and ground absorption can also be of importance. Molecular absorption is shown to be under 1 db per 1000 ft.

The refraction of sound waves due to temperature differences in the atmosphere with altitude can cause the sound to bend upward so as to completely miss remote points, effectively producing sound shadows beyond certain distances. This temperature refraction by itself can be computed to be generally negligible as long as the source is reasonably elevated. The daily average lapse rate near the surface of the earth is about $3^{o}F$ per 1000 ft. Application of Snell's Law together with the velocity-temperature relation for sound then shows that the shadow edge is well over 1000 ft removed from the source for every 10 ft that the source is above the observer.

Ingard,[13] Baron,[15] and Wiener et al[18] have considered shadow effects produced by wind-refraction phenomena. The most serious shadow problem occurs when effects of wind and temperature gradients combine additively. Baron has demonstrated experimentally that wind refraction alone is of negligible concern for steadily sounding single-frequency sources that are well distributed in space, since the loss in sound intensity reaching an observer from some directions is compensated by that arriving from other directions. However, such compensation is not to be anticipated in a system in which the sources rotate or the signals vary in frequency.

Some sound is absorbed by grass, foliage, and relatively porous surfaces; sound is reflected from pavements, structures, and other hard surfaces.

Obstructions contribute to the production of sound shadow; on the other hand, diffraction and scattering processes serve to compensate somewhat for these shadow effects. Reported values of intensity loss in shadow areas of large obstacles run from 15 to 25 db.

The most important of the sound-attenuating factors—air turbulence—is the most difficult to evaluate quantitatively. Wiener et al.[18] examined air turbulence along with other factors at some length and indicate no obvious relation between the frequency of the observed sound variations and the frequency of occurrence of the presumably associated fluctuations in wind velocity. However, they report several cases of 5-db variations under generally stable atmospheric conditions and 15- and 20-db variations under turbulent conditions. Benson and Karplus[19] state that even with considerable meteorological apparatus they were unable merely to measure turbulence in a manner suitable for acoustical studies.

The existence of limited pertinent data precludes determination of the precise character of sound transmission in cities. The best present procedure appears to be to employ estimated average attenuation values. Physicists of the National Bureau of Standards[20] and others have suggested attenuation figures for Washington, D.C. (which figures should also be applicable to other cities of comparable size) of 10 db per 1000 ft due to absorption and scattering effects of all kinds, and 10 db for shadow effects. To these losses must be added 6 db per distance doubled (corresponding to spherical divergence of the wave front from a point source) plus the attenuation associated with passage through the walls of structures in the case of an observer located indoors.

Relative to attenuation through structures, Volkmann and Graham[21/] have made some measurements on the transmission characteristics of a brick-veneer house with windows closed and with no storm windows. Their data are reproduced in Table 2.

Table 2

ATTENUATION THROUGH WALL OF BRICK-VENEER HOUSE[21/]

Frequency, cps	Attenuation, db
30	18
40	11
60	11
80	10
100	14.8
150	14.5
250	9.5
300	12.5
375	12
500	25
700	26.8
1000	17.5
2000	30
3000	33
4000	30.8

PERCEPTION OF WARNING SOUNDS

An individual's detection of a warning sound depends not only on (a) the physical character of the sound to which that individual is exposed (exposure) but also on (b) psychological and physiological factors, which relate to the individual's state of mind and to the nature of his auditory system (perception). The physical phenomena that affect exposure were treated in the preceding section on acoustics. In this section some aspects of perception are considered.

Previous studies on perception as they relate to the detection of siren signals by alerted subjects exclusively are reported by Volkmann and Graham [21] and by Baron [15] No study is known in the literature on the perception of unalerted subjects As warning-system design must be based on perception by unalerted subjects, it was deemed necessary to provide an experiment to test this area

The details of this experiment are presented in App F. The procedure and results are described briefly here. A total of 63 subjects participated, and they were examined independently one at a time. Communication was excluded between those who had already been examined and those who were yet to be examined. Each subject was confronted with a simple exercise, which consisted ostensibly of an easy psychological test. Some subjects were informed at the beginning that an air raid siren would sound at some time during the period; each of these was directed to signal at the precise moment when he first heard the siren. Other subjects were told nothing about a possible siren sound. The soundproof test room was provided with simulated background noise provided by three distributed loud-speakers reproducing recorded noise. A fourth speaker hidden behind a window curtain provided for good reproduction of an independently controlled standard civil defense wailing "take cover" siren signal. The ratio of siren-signal level to noise level was fixed for each of a selected group of individuals. For the first group the siren signal was 20 db below the noise; for each succeeding group the signal was raised by 10 db in level until for the last group the signal was 20 db above the noise.

Eighty percent of the alerted subjects responded to the siren at its lowest level, and all the alerted subjects responded at higher levels, with most of the responses coming within 2 sec of the start of the siren. In no case, up to the highest sound level, did any unalerted subject reveal the faintest externally observable sign of having heard the wailing "take cover" siren signal, which ran from 42 sec to well over a minute continuously; however, a high percentage of the unalerted subjects did reveal in later questioning that they had heard but had attributed no significance to what they interpreted variously as either passing emergency vehicles or (two subjects) a genuine air raid siren. (One of the two subjects even remarked, "You hear things like that all the time ")

The experiment must be regarded as a preliminary one, which might—if the requirement is deemed to justify the effort—be followed by more refined tests.

Pending further studies of this type, which should ultimately convey a reasonably precise measure of perception, it is concluded that under the present circumstances no measurement of alleged response potential is meaningful for the existing siren warning system of any particular target area. Much of the siren response by unalerted observers that is attributed to existing siren systems apparently stems from the interaction of individuals with one another, plus the fact that any alarm that persists for a sufficiently long time is likely to attract attention merely through its nuisance characteristic. If one sensitive person who can be seen by others exhibits an obvious concern for a siren, it is possible that the concern will diffuse and that many persons will ultimately be alerted where few might have been alerted otherwise. Hence if a siren sound continues for a long period—perhaps for a minute or for a few minutes—it will ultimately evoke a spread of reaction through person-to-person diffusion. However, in the missile era, when survival could require response that is measured in seconds, not in minutes, warning-system design cannot afford the luxury of dependence on prolonged nuisance or on relatively slow diffusion to produce reaction. Reaction to a warning must be immediate and spontaneous within each and every individual.

Perception by Sleeping Persons

Perception requirements for sleeping persons pose special problems. As an introductory investigation to provide some information on the requirements of a night warning system ORO undertook a night telephone survey among its employees. Preliminary information for the survey was collected by means of a questionnaire sent to all ORO personnel. Recipients of the questionnaire were notified that on an unspecified date between midnight and 6 A.M. they would be called on the telephone unless they specifically directed otherwise. The following information was requested in the questionnaire:

(a) Number of telephones, including extensions, in household.

(b) Position of the telephone nearest an occupied bedroom.

(c) Any modification of the telephone bell to ring more or less loudly than standard ring intensity. (According to the local telephone company the standard ring intensities of all telephones currently in use in homes in this area are roughly equivalent. Measurements of ring intensity were made in the homes of several ORO personnel. It was found that the ring intensity at a distance of 12 in. from the telephone is 100 to 105 db. The intensity at different locations within the same room as a telephone measured from 65 to 80 db. The intensity in an adjacent room or hallway measured from 55 to 65 db. The intensity of sound of adjustable telephone bells differs considerably from these standard ring intensities.)

Of the 500 persons who received questionnaires, 292 returned them in time to be included in the survey. Sixty of these were not called: 40 because they specifically requested they be excluded, 10 because they had no telephone, 5 because their listed numbers had been disconnected, and 5 because of oversights in calling. In addition 7 persons called were omitted from the analysis: 5 because they had been absent from home on the night of the survey and 2 because their phones had been modified to ring more loudly than standard ring intensity.

The final sample used in the analysis included 225 cases. These were divided into groups according to the position of the telephone nearest an occupied bedroom. Group A consisted of persons for whom the nearest phone was in the bedroom, Group B of persons for whom the nearest phone was in an adjacent room or hallway on the same floor, and Group C of persons for whom the nearest phone was on a floor other than the bedroom floor. The number of persons with softened and standard phones in each of these groups is given in Table 3.

Table 3

RESIDENTIAL TELEPHONES OF ORO PERSONNEL

Group	Softened ring	Standard ring	Total
A	61	39	100
B	69	33	102
C	19	4	23
Total	149	76	225

The calls in the survey were made between 2 A.M. and 4 A.M on Tuesday, 5 Aug 58, 6 days after distribution of the questionnaire Each of the callers made the calls for an entire group.

"Answer time" was defined as the interval between the time of the first sound made by the telephone and the answering instant. Each ring of the telephone lasts for 2 sec and is followed by a 4-sec interval of silence. The 6-sec period including one ring and one interval of silence was used as the unit for measuring the answer times; observers recorded answer time as the number of elapsed ring-silent periods. The values obtained by counting ring periods are subject to a random error that was neglected when the data were converted from ring periods into seconds.

Each of the groups was allowed a predetermined amount of time to answer. Two minutes was allowed for Group A, 3 min for Group B, and 4 min for Group C. Persons not answering within these times were recorded as "no answer."

It was anticipated prior to the actual telephoning that the answer time for the softened ring would be noticeably longer than that for the standard ring under otherwise comparable circumstances. However, as it turned out there was no significant difference; accordingly, modified and unmodified telephones were combined in the tabulation of the results.

The distribution of answer times for Group A is presented in Fig 2. Median time of answer was 16 sec. Ninety-one percent of the persons called answered in the first 30 sec; 94 percent in the first minute. Four percent failed to answer within 2 min. Data from Group A most nearly represent the time necessary for persons to awake from sleep, since the time spent in transit was minimal.

Answer times for Group B are shown in Fig. 3. Median answer time was 23 sec. Seventy-five percent of the answers occurred within the first 30 sec, 93 percent within the first minute. Six percent failed to answer within 3 min. The fact that the distribution of answer times for Group B is closely similar to that of Group A but shifted several seconds along the time axis suggests that times to awake from sleep may be essentially the same for the two groups with the principal difference in the reaction of the two groups being the results of time in transit.

Data for Group C, although probably less reliable because of the smaller number of cases than for Groups A and B, indicate much larger reaction times for persons with phones on nonbedroom floors. The median answer time of this group was 35 sec. Only 35 percent of the cases answered in the first 30 sec and 69 percent in the first minute. It is significant that 17 percent failed to answer within the 4 min allowed. Because of the unknown amount of time spent in transit it is impossible to estimate the degree to which the remote location of the telephone affected the time necessary to wake from sleep.

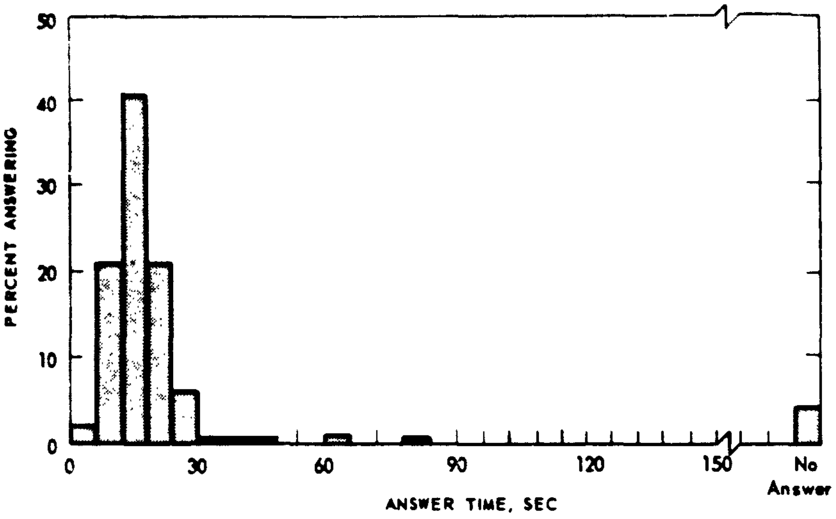

Fig. 2—Night Telephone Reaction, Group A

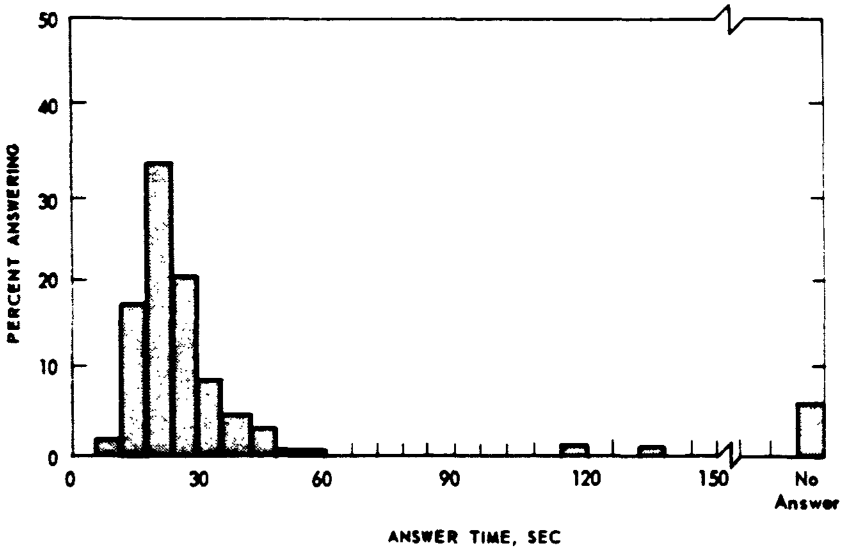

Fig. 3—Night Telephone Reaction, Group B

The results of the sleep survey indicate that an alarm system comparable in stimulus to that of a telephone bell in the same room [*] can produce a 90 percent probable reaction in about 24 sec for healthy adult individuals. It must be recognized, however, that with only one alarm per household there would be an unknown additional time involved if the person hearing the alarm were responsible for waking other members of the household. Thus, in a city completely served by such an alarm system with only one unit per household, 90 percent waking of all inhabitants could possibly run to several minutes. Accordingly the designers of any indoor system should take cognizance of the need to wake directly as many persons as possible. To meet the requirements of modern warning the system should provide an alert of character and strength superior to that of a nearby telephone bell within each and every bedroom. (It will be recalled that the earlier mentioned requirements of warning allotted only 30 sec altogether for alarm, confirmation, and reflection.)

Perception by Hard-of-Hearing Persons

Existing and proposed acoustical warning devices overlook one entire class of persons—the deaf and the partly deaf. It is difficult to estimate the number of these cases since many of them are not a matter of record. However, Dr. Powrie Doctor, Editor of the American Annals of the Deaf, estimates that about 1 person in 2000 is deaf and that 3 to 15 million persons in the US have impaired hearing. [22] A significant incidence of deafness occurs in persons of age 65 and older so that any acoustical warning system discriminates correspondingly against this segment of the population. It is interesting to note that modern medicine by continually extending the average life span is thereby extending the number of persons of reduced hearing. Electronic hearing aides, which serve many persons during the day, are invariably removed when the individual retires at night. This fact accentuates the already difficult general problem of night warning.

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[*] This stimulus is well developed. Most persons have been trained by experience to react spontaneously to the sound of a telephone bell.

CRITIQUE OF EXISTING WARNING

While providing moderate service to persons outdoors, outdoor warning devices, such as sirens, offer only limited service to persons indoors, who are the majority

Both audio engineers and OCDM specialists associated with warning acknowledge these general results with the observation that outdoor sirens are primarily intended for outdoor coverage only and that special indoor devices are essential. However, in spite of the restricted capabilities of outdoor sirens it has nevertheless become the established policy in nearly every target city in the country to employ outdoor sirens almost exclusively with the hope of incidentally securing adequate indoor coverage from them. The support for this policy of employing almost exclusively outdoor devices to serve an almost exclusively indoor audience appears to stem partly from tradition and expedience (outdoor sirens were used for air raid alarms in WWII, good sirens are currently available); partly from political considerations (there are some unique political problems to be faced in installing warning devices inside homes); partly from oversight (it has not heretofore been recognized that in target areas indoor man-hours outweigh outdoor man-hours by a ratio of about 10 to 1); but perhaps mostly from lack of any previously pressing requirement (warning times were sufficiently long in the bomber era that outdoor sirens might then have been generally adequate).

Sirens have had far more testing, deliberate and accidental, than any other type of warning device. Unfortunately this very testing is responsible for some of the present public indifferences to sirens. Persons have been expected to be unconcerned for so long a period whenever the air raid sirens have sounded that one might say now that the public has been effectively conditioned to be unconcerned whenever the air raid sirens sound. Siren usefulness has been compromised.

Examples of such situations are numerous. An extreme case of "wolf-cry" conditioning was provided by the 5-min sounding of all the air raid sirens in Chicago and Evanston, Ill., at 10:30 P.M. on 22 Sep 59 in celebration of the winning of the American League Championship by the Chicago White Sox Baseball Team.

Incidentally a number of Chicagoans turned to their telephones to check on the nature of the alarm, and an Illinois Bell Telephone Company spokesman, cited by the Chicago Sun Times the following day, stated that the telephone load probably represented an all-time high for a short period.

(Similar occurrences of telephone inquiries usurping local telephone systems have been observed in other instances of false alerts In the event of a genuine alert such action might interfere seriously with telephone fanout procedures that are now commonly employed to disseminate air raid information to many communities and to military echelons.)

The Chicago Daily News of 24 Sep 59 quotes Fire Commissioner Robert E. Quinn (who, in his capacity of acting civil defense director, was responsible for triggering the alarm) as saying that "pamphlets giving full instructions on what to do in the event sirens are sounded were distributed to all homes by the Fire Department about a year ago. These people never read the pamphlets." The Commissioner referred specifically to the failure of persons to tune to CONELRAD frequencies on their radio receivers.

Samplings of reactions to unexpected siren alarms are suggestive of what the public might do in a genuine alert. In general, observations of such reactions to date have revealed a state of public apathy and confusion. Reports of specific surveys following unexpected alarms are presented in App G.

Some estimate of the statistical response time of individuals to a siren type of alarm is reported by Liggett of the Stanford Research Institute (1957)[23] and illustrated in Fig. 4. The designations A, B, and C refer, respectively, to cities having the best, moderately good, and typical civil defense programs, the curves show the percentage of persons who might be expected simply to verify the alert within the specified time. Verification time, says the Stanford report, "is the total length of time from the sounding of the sirens until the people start to take the recommended defense action." (Underscore added.) "Few, if any cities," the report further states, "could now be classed as city A." Most cities are regarded by the report as being of type C.

According to Liggett a principal cause of the indicated delays was assigned to the then prevalent especially slow establishment of the CONELRAD radio procedure by the associated radio stations. As has been noted, effort has been directed recently toward reducing some of these delays However, it is believed that curve A of Fig. 4 still represents the optimally attainable case under the present warning system, a condition that is not inconsistent with observations on public indifference to siren signals (see App G)

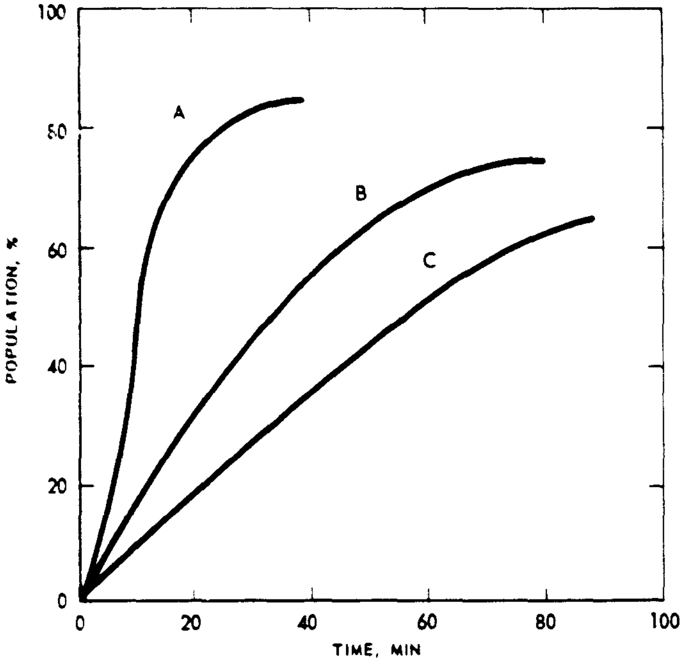

Fig. 4—Time Required Simply to Confirm an Alert

A, city with best civil defense program; B, city with moderate civil defense program; C, city with typical civil defense program.[23]

The susceptibility to compromise by extended testing and by false alarms is not confined to sirens. It is characteristic of any class of warning device that transmits only a coded signal and hence fails to communicate clearly and directly the full essential context of the warning message. */ A warning device may sound a special attention-getting alarm, but, if effective response is wanted, this alarm must be immediately and automatically followed by clear-language information, and the transmission of information should be inherent in the warning service that provides the original alarm. Independent action on the part of the intended recipient ought not to be required for the individual to confirm the alarm. The individual should not be expected to take such an elementary step as turning on a radio receiver because he may not spontaneously do so. In short the warning alarm should not be separated from the clear-language warning communication if positive defense response by a high percentage of individuals is to be assured within the very brief allotted period following detection of the first elements of an attack. This is particularly true under conditions of surprise attack.

For persons asleep audibility of sirens within any metropolitan area is a dubious quantity. In order to obtain adequate rest persons who live in a city condition themselves to ignore the nocturnal sounds of police, fire, and ambulance sirens. The sounds of air raid sirens are sufficiently similar to the sounds of the other sirens so that air raid sirens too can expect to be discriminated against by the subconscious minds of sleeping persons. This is a matter of some import in view of the fact that the sleeping period represents about one-third of the average person's existence.

Failure of sleeping persons to hear or to heed a siren and the limitations of the CONELRAD system when broadcast station operators are off duty mean that the effectiveness of the present warning system is compounded at night. The invitation of the enemy to strike at night is obvious if one of his objectives is to deny warning to civilians.

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*/An interesting historical example of the failure of coded warning is related by Balloch in an ORO report on the 1953 Holland flood disaster. 24/ Here it is pointed out how the standard rural warning device in the Dutch area at the time—the tolling of church bells—conveyed only an admonition of danger. By the time the exact nature of the danger had ultimately been communicated hundreds were dead or homeless. As Balloch describes it, coded warning is equivalent to a simple shout of "Look out" without specifying what to look out for and what to do about it.

The following shortcomings are now apparent in the existing warning system:

1. Delays in transmission of the alert through relay handling from national to state to local levels.

2. Delayed public response to warning as the result of (a) separation of coded alert signals and clear-language confirmation and advice, and (b) compromise of sirens through false alarms, continued testing involving no public participation, and confusion of air raid sirens with other emergency sirens.

3. Inadequate coverage due to primary dependence on outdoor alert devices to serve a predominantly indoor audience.

4. Delays involved in transmission of CONELRAD activation information to broadcast stations, and delays involved in switchover procedures by the broadcast stations in transferring from regular operation to CONELRAD operation.

There is need for enactment of the following procedures:

1. Integration or at least intimate coordination of alerting and warning.

2. Elimination of all relay points and human intervening operations, and the development of direct automatic transmission of the warning from the inception point at national headquarters to the individual member of the population wherever he is.

3. Introduction of features designed to provide a compelling aspect of warning in contrast to the existing presentation that can be accepted, rejected, ignored, or overlooked.

LIMITATION OF SIREN WARNING TESTS

The results of experimental tests of siren systems (either deliberate tests or false alarms) have been employed in the present study exclusively. for indications of response behavior and not for indications of audibility. There are some unresolved problems associated with siren audibility tests conducted to date that limit their validity or usefulness or both.

The first problem, one that has been almost invariably overlooked, involves the dimension of time Once a siren is detected by a person, if only for an instant, it is fairly easy for that person to continue hearing the siren even though the sound conditions vary; however, without that first spark of recognition it is possible that the person may remain oblivious to the signal indefinitely There are two ways of obtaining that initial impulse: (a) through independent observation and (b) through observation of the reactions of others In either case the probability of hearing the siren is a monotonically increasing function of the duration of the signal. Relative to independent observation, the statistical nature of the noise background, together with fluctuations in the intensity of the siren, are such that in sufficient time some interval occurs when the signal-to-noise ratio is appropriate for the initial perception. Relative to observation of others, the process of transference of interest is analogous to any diffusion process, which requires only initiation of an event at one point plus some interaction among the elements of a population to cause the spreading of the event. Because of this dependence of audibility on the duration of the signal, and because of the missile-era requirement that detection by most persons occur within the first few seconds of an alert, it is essential to take cognizance of the time of observance of the siren by each subject in any audibility test. There is no evidence that this has ever been done in any audibility evaluation test to date. Furthermore, it is not easy to accomplish.

Persons who are not preadvised to participate in a test are also apt not to make any observance of the instant within seconds—or even within minutes—of their perceiving an alarm. In the case of a 12:55 A.M Washington suburb false alarm described in App G, individuals were asked the exact time at which they first heard the siren In general the responses were of the type: "About one o'clock," or "about two o'clock," or "1:30 when I first looked at my watch."

On Saturday, 14 Feb 59, at 11:55 A.M. all sirens in the Washington, D.C , area were sounded for 1 min in a deliberate test. Most ORO employees with the exception of building guards did not work on that day and hence were distributed throughout the Washington metropolitan area (many in their homes) at the time of the test Within 1 hr prior to the time of the test 46 ORO employees were contacted by telephone and asked specifically to listen for the sirens. The other employees who were not so advised might or might not have learned of the approaching siren test from newspaper announcements. On the following Monday a survey was conducted among ORO employees to determine how many had heard the siren test. Of 373 respondents to the survey inquiry 15 indicated that they had been out of town at the time of the test Returns from the remaining 358 were distributed as follows. 32 of the 46 previously alerted persons, or 70 percent, heard the sirens; 113 of the other 312 persons, or 36 percent, heard them. In other words, of the group that had been specifically alerted to listen the percentage of persons who reported hearing the sirens was twice as great as in the remaining group

In order to obtain statistically meaningful results from experimental tests it is desirable to conduct test soundings under a variety of weather conditions, and it may be important (as well as disconcerting to the populace) to conduct tests in the middle of the night. No night audibility test on an actual system is known to have ever been conducted. */ And to secure the desired tests would only serve to degrade further the effectiveness of the existing system for the occasion of a genuine alert.

Finally, it may be futile to seek accuracy of audibility data beyond that which a theoretical treatment provides. This is because outdoor warning is of low importance in comparison with indoor warning and because indoor warning can be accomplished most effectively with indoor devices.

To summarize:

(a) the results of tests on outdoor systems are deceptively optimistic without recognition of the reaction times of the respondents;

(b) it is difficult to determine the respondents' reaction times significantly;

(c) test results obtained from preinformed subjects are unrepresentative;

(d) night test data are important to have yet impracticable to obtain;

(e) the act of testing degrades the usefulness of the system; and

(f) it is not worth while to conduct audibility tests on a system that is of low importance and that can be demonstrated by other means to be ineffective.

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*/It is believed that the ORO night telephone survey described in this report represents the extent of available significant experimental data related to night warning.

DESIGN OF IMPROVED WARNING

A significant advance in alerting potential would be effected by a nationwide adoption of the NEAR system. Such a system would satisfy many of the requirements of missile-era warning through its provision of widespread, reliable, nearly instantaneous indoor alerting in a practicably attainable manner. However, unless and until CONELRAD is discontinued there would remain the serious defects of suboptimum warning coverage and of poor correlation between alerting and warning.

Proposed Warning Modification

In anticipation of the discontinuance of CONELRAD there is proposed in this section a system that attempts to fulfill all the major requirements of modern warning. The system makes no claim either to complete novelty or to engineering refinement; however, it does claim engineering feasibility. The major objective here is to provide a base for discussion and a stimulus to improved warning design.

The suggested plan is as follows. The present national detection and data-handling facilities would be retained. However, the alert network would feed warning information directly from the national centers to the lowest local outlets by federal control, bypassing all the presently existing intermediary stations. The local warning system within each target area would consist basically of a NEAR unit in every indoor position where persons are apt to be at any time.

Each local unit not only would sound an alert but through its relay action would also turn on one or more broadcast (a-m radio, f-m radio, and TV) receivers at full undistorted volume, tuned to the loudest continuous-service broadcast station operating in that specific area. (Approximately 96 percent of all US homes have at least one radio receiver; 87 percent have at least one TV receiver. These are over-all national figures; the percentages are higher within the metropolitan areas that constitute major target centers. 25/)

Certain TV receivers that employ thermal delays for extending picture-tube life require 30 to 40 sec for attaining full volume. Such delays could be circumvented by various schemes, one of which is the continuous operation of power-tube filaments.

It is proposed that the design of the warning device allow the individual to retune the receiver for clearer reception on the same station, or to tune it to another station (a) in case it is desired to so verify the message, (b) in case the preset station fails to broadcast after the alarm has sounded, or (c) in case the receiver fails to function satisfactorily on the preset station. In any event the receiver would initially be tuned at full volume to the strongest station.

If CONELRAD operation by the broadcast services is not to be abolished then CONELRAD activation should at least be deferred for a specified emergency period, tentatively selected to be 3 min, following the detection of an attack. By techniques described below, during these first 3 min of a Red alert period all broadcast services would be tied in with the central warning headquarters, which would disseminate information and advice directly to the nation as a whole. At the end of this 3-min period CONELRAD might proceed without special formalities. It may be noted that the proposed 3-min period is no longer than the time interval presently required from the detection of an attack until the secondary stations complete their final announcements before shutting down to begin the switchover to CONELRAD operation (1 1/2 min for the key stations' procedure and 1 1/2 min for the secondary stations' procedure, plus the time required for transmission of the CONELRAD alert from national headquarters to key stations). A 3-min emergency period is selected in the proposed plan in order to allow 1/2 min for warning and for immediate defense response by 90 percent of the target-area population, and 2 1/2 min additional to alert the stragglers and to provide supplementary information to the majority.

Every radio and TV station would participate in the warning broadcast during the station's routine operating hours. Further, certain selected broadcast transmitters in each area would operate stand-by continuously; and in the event that an alert occurred during hours when these stations' programs would normally be off the air their carriers would be activated automatically for the 3-min emergency period by means of radio monitoring receivers. (It is possible that these receivers might be the same ones that every broadcast station in the country is now required to have as a part of the CONELRAD program.) The usual limitations would be imposed relative to the prevention of overlap between two stations on the same frequency. This could be accomplished by means of a time switch on the monitoring receiver.

It may be desirable in the interest of economy to confine after-hours stand-by transmission for the next few years to certain radio stations alone as there are already in operation in almost every major target area several 24-hr radio stations but few 24-hr TV stations. If TV stations in the major target areas ultimately go to extended operation—or if the number of radio receivers in homes declines significantly—then at that time the television stations could also be involved in the continuous stand-by procedure. However, any deliberate postponement of continuous TV service should be minimized because of the recognized advantage of this medium (in addition to—not in place of—a-m and f-m radio).

The warning communication would feed from the central detection center by duplicate facilities of hot wire and radio link to the key broadcast stations and to the wire systems of the several national broadcast networks. The warning communication emanating from the key stations would then at each local station feed from the output of the local monitoring receiver directly into the local transmitter for broadcast, incidentally overriding any program previously in progress at the local station. Operators in stations that have national broadcast chain hookups could, alternatively, for possibly improved-quality output, select the wire-line transmission from the network service instead of the radio transmission, both being presented simultaneously from the national center. */

Thus, broadcast stations throughout the nation would automatically—in many cases independently of any local station operations—carry the warning message originating at the federal warning center; and all persons indoors (in other words statistically over 90 percent of metropolitan area residents) would automatically, without resort to any required action, find themselves (a) alerted by an alarm and (b) tuned in at full volume to the optimum station serving the particular location.

The initial warning message would be selected appropriately from a set of previously recorded pronouncements by the President of the United States indicating briefly the state of affairs and the proper procedure for individuals to follow. The TV broadcast of the President's message should be expected to convey more force than the corresponding radio broadcast because of the dynamic impact of the clearly identifiable visual image of the nation's leader. A simple sound transmission on the other hand might not be construed as authentic and urgent without further check.

After the President's broadcast message might follow other taped video and radio messages featuring governors and mayors within their respective local communities. In each case the program would be selected from a previously recorded set of appropriate messages, with special emphasis on the TV transmission because of the intimate appeal and assurance that this medium provides.

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*/A network wire-line signal and a key-station radio signal may not be in phase when received at a specific local station as a consequence of different transmission speeds of the two signals. In general, however, this is immaterial since no attempt is made to correlate the two signals or to employ synchronous transmission on the same frequency from two stations.

Incidentally, no commitment is intended here either for or against the use of TV for postattack service. The limited number of existing battery-operated TV receivers would appear to preclude the practical use of TV in the event of widespread power failure. On the other hand TV could provide an element of morale to those who are confined within shelters wherever suitable power—even of the hand-cranked generator type—may be available.

In order to ensure attainment of broad indoor coverage in the most economical manner it is recommended that after some specified date manufacturers of broadcast receivers of all types be required to equip each line-operated receiver with a built-in resonant relay providing for the warning functions described here. Ultimately on this plan every line-operating receiver could be equipped with an alarm at an additional cost that is not much in excess of the presently estimated cost of a simple NEAR unit alone. The major over-all cost of such a system, which lies in the large number of individual home units, would then be absorbed in a relatively innocuous manner in the purchase price of each new receiver, and effective air raid warning would be promoted through the sale of new broadcast receivers.

During the transition period, and also during the indefinite future for those who do not wish to buy new receivers, the independent NEAR alarm unit would represent the only investiment needed to take full advantage of every aspect of the system except automatic switching of the receivers. Any receiver not equipped for automatic switching would still provide the expedited warning program on every operating channel, although the receiver would be required to be turned on by hand.

Since the suggested warning relay on a broadcast receiver would not contribute to the normal broadcast reception an argument might be advanced that it is not proper to burden the receiver-manufacturing industry with this requirement. In this connection it may be noted that the safety disconnect switch that is standard equipment on the rear panel of every TV set also has a primary function of minimizing casualties, and it too contributes nothing to the broadcast reception. Actually the availability of a warning unit on a broadcast receiver is a selling point. With the public steadily becoming more conscious of civil defense this feature could result in a demand for new receivers.

It may also be noted that federal legislation is not new for governing manufacturers in the production of specific features on household items. The recent federal legislation on refrigerators is an example in point. Following the reported deaths of many children who were accidentally locked in refrigerators, Congress provided for mandatory design in all newly manufactured refrigerators of locks that will open from the inside under the application of less than a 15-lb force, or less than a 5-in.-lb torque through an angle of 45 deg. 26/

An alternative approach to effect the adoption of the proposed warning in home receivers is through the development of life insurance underwriter codes.

In either case—direct action affecting receiver manufacturers by the establishment of federal standards or indirect action through insurance codes—there would remain a transition period of possibly a decade before new receivers with warning features could replace most of the old receivers without these features. Accordingly it would appear that some supplementary action might be required in order to limit the transition period to a reasonable time.*/ It may be that a strong civil defense educational program could accomplish the desired end by promoting voluntary procurement by individuals of either new receivers or conversion kits. The radio and TV industry and also the life insurance companies of the US should be willing to defray some portion of the educational costs through advertising since these companies stand to profit by the ensuing sales of new equipment and by the reduction in postwar casualty claims that good warning would provide.+/

An indoor system of the proposed type, which sounds an alarm followed by a loud broadcast program, can be tested only with prudence, if at all, since just as with sirens indiscreet testing could seriously lessen the potential impact of a genuine alarm. It may be that the most effective procedure is never to test the intact system either nationally or in a specific geographic area but rather to test individually and regularly only such components as are deemed necessary to ensure reliability, reserving full operation exclusively for a genuine alert. However, if for some reason full-scale testing is determined to be required, then it is recommended that during such a test all persons should be expected to execute simple, definite defense measures that are prescribed for them as part of a deliberate training program. (See the suggestion for Army participation in developmental testing in the "Army Implications" section.)

The proposed system is particularly effective if there are several alert-equipped receivers on the premises. Then any genuine alarm is emphatically indicated by the combined action of all receivers, while any fault within an individual receiver is conspicuous by the distinction of its behavior from that of the other receivers.

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*/In 1962 Russia will possess an estimated 300 or more long-range missiles. 27/

+/The major life insurance companies of the US recognize their legal liability, and they are responsibly planning to meet their obligations to whatever extent this may be possible following a nuclear attack. 28/

In the interest lessening the possibility for compromise by accidental alarms that affect an entire area, the warning system should be monitored continuously in every area of the country, and recorded announcements (both video and audio) should be broadcast automatically throughout whatever area is involved on the occasion of any accidental operation of the receiver-activation process. It is technically possible to provide electrically for both the monitoring and the released announcements without any intervening human element. The procedure would be analogous in method of operation to the canned "Sorry, wrong number" announcement that a telephone user receives nowadays when he dials an unassigned number.

The suggested general scheme of automatically operating broadcast receivers by a superposed odd-frequency voltage on the power line can be employed—although, it is believed, not to optimum effectiveness—under the existing CONELRAD system. In this arrangement each a-m radio receiver is automatically turned on full volume tuned to a CONELRAD frequency. The system admits of easy conversion to the preferred plan (wherein all broadcast stations carry warning advice on their normal frequencies) by simply modifying the selected warning channel on any individual receiver whenever the CONELRAD termination occurs.

The suggested warning scheme would serve not only all persons indoors but also incidentally an estimated one-fourth to one-third of all automobile passengers. Current statistics 29/ indicate that 75 percent of all automobiles on the road in the US today are equipped with radio. Hence the occupants of one-fourth of all automobiles would be warned if it happened that one-third of the car radios were in operation at the time of an alert; over one-third would be alerted if half the car radios were in operation.

Auxiliary Warning

For deaf persons a special adaptor with a NEAR-type unit could operate (a) a bright intermittent light (on-off action provided by a simple bimetallic flasher button) and (b) a bed vibrator consisting of an electric buzzer attached to the bed frame. The use of a bright light is a standard technique to attract the attention of deaf persons

Supplementary to the indoor system for any metropolitan area would be a distributed network of low-power speakers mounted on busy street corners and at certain other points of pedestrian congestion. The loud-speaker system would duplicate the indoor warning program by providing an alarm signal backed up immediately by the clear-language information and advice from the national center.

An economical wire system for feeding audio signals to an outdoor speaker system is available in most major target cities through the network of fire call boxes. In Washington, D. C., for example, there are 1800 fire call boxes tied by wire lines to central fire stations. Most of these boxes are at street intersections, ideally located to feed warning speakers. These boxes normally contain simply circuit-closing switches and no auxiliary electrical equipment so that it should be technically feasible to transmit audio signals directly over the associated lines without resort to carrier techniques.

An outdoor speaker system is considered to be only ancillary to the main indoor system for air raid warning service. However, there are certain peacetime applications that make an outdoor speaker system independently attractive for an urban area. The Hoboken, N. J., loudspeaker system, for example, has a record of having been successfully employed to prevent a large threatening race riot, to control traffic during emergencies, and to warn persons outdoors of an impending hurricane, as well as to provide music at the Christmas season.

An outdoor speaker system can easily be tested periodically and extensively by using music without danger of compromising its effectiveness for air raid service and without offending the local community.

By way of presenting good coverage and possibly some redundancy the national alert and advice would be directed not only to standard radio and television channels and to street-corner speaker facilities but also to Muzak-type canned-music service (in restaurants, offices, industrial plants, markets, etc.), existing public-address units(in schools, factories, theaters, stadiums, transportation terminals, and other gathering places), and vehicular radio services (in taxicabs, police cruisers, commercial cars, trains, boats, and airplanes).

General Aspects of Proposed System

The design and administration of the entire warning program would be coordinated with psychologists, sociologists, and other students of human behavior. Their advice would be sought on such matters as evaluation of behavior patterns for basic design input data (see App E); development of guide criteria for the release of warning from the national headquarters (in order to ensure the certain release of valid warning and the certain prevention of false warning); preparation of scripts for warning announcements; determination of the nature of tests, including the extent of public participation therein; and development of a public education program.

Sirens would play no role in the proposed system. It is recommended that existing sirens be retired following the installation of an acceptable warning system such as the one described here. Retirement of the sirens would prevent their interference with the broadcast message from the outdoor replacement system, and it would effect an economy in the saving of costs of siren maintenance and line rental.

It is to be stressed that fundamental to the proposed warning plan is a modification of certain elementary warning philosophies. As has been noted it is current standard passive defense practice to regard alerting and warning as distinct entities, wherein the former implies coded alarming and the latter implies clear-language advising. In the proposed plan these roles are firmly merged. The limitation of available time simply does not permit the possible delay incurred through separation of the operations.

Once again it should be observed that warning by itself cannot guarantee survival. Survival requires both warning and shelter. The threat of nuclear blast exposure to persons in the cities is serious but it is impracticable to advocate blast shelters as long as it is uncertain or unlikely that these shelters could be reached in time for persons to escape the blast. A warning system that can produce reaction times within seconds would render feasible a program of blast shelters within at least parts of metropolitan areas and by so doing would contribute significantly to the defense posture of the nation.

ARMY IMPLICATIONS

Many of the basic concepts and techniques described in this study apply to Army installations as well as to civilian communities. The pattern of existing military warning in general and of Army warning in particular follows the broad model of the conventional civilian warning system. In the Washington, D.C., area many military installations are served directly on their sites by units of the civilian system.

In addition to its need for good warning at Army camps, posts, and stations the Army has a vital interest in good civilian warning because of important interactions between civilian and military defense. Some of these interactions are indicated below.

(a) The Army, which can be expected to sustain manpower losses in the initial exchange, will require a substantial number of recruits from the civilian population to bolster the fighting components for retaliation against the enemy.*/

(b) The Army will require extensive civilian manpower for providing logistical support at an accelerated pace.

(c) Many Army personnel and their families live off base; there are some Army personnel away on leave at any time.

(d) Members of the National Guard and of the Army Reserve normally live in civilian communities.

All these persons (a to d) are dependent on adequate civilian warning for survival.

(e) Increased numbers of civilian survivors in good condition means lessened civilian demands on the Army for such items as medical first aid, fire fighting, decontamination, engineering reconstruction, and civil-affairs-military-government help; hence it means release of more Army facilities for primary combat missions.

(f) Assurance that civilians have been adequately warned to seek shelter allows the Army commander opportunity to attack low-flying enemy carriers with nuclear AA weapons without imperiling the lives of civilians on the ground below.

The Army is authorized and encouraged to coordinate not only with the other military services but also with OCDM in areas of overlapping interest. 30-32/ Accordingly it is recommended that:

(a) The concepts described in the present study be applied as needed toward the optimization of warning systems in Army installations. In particular the Army should adopt the NEAR system of alerting throughout. Furthermore it should complement and support the NEAR alert system with directly related radio-transmitted warning communications in clear language to every local installation.

(b) The Army transmit the findings of this report to the DoD and to the other services with the recommendations: first, that the NEAR system

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*/During WWII the Army drew from the civilian population over 8 million men, or about 30 times the Army's total pre-Pearl Harbor strength (267, 767).

be adopted as standard for use by all military installations within CONUS; and second, that the FCC be directed to discontinue CONELRAD operation now

(c) The Army urge (and wherever possible assist) OCDM. first, to merge, or to coordinate closely, its operations of alerting and warning; second, to eliminate echelons in the national-to-local level in warning communications; third, to emphasize and rapidly to promote universal indoor warning; and fourth, to relegate outdoor warning to its proper secondary position.

Finally it is recommended that parts of one or more Army posts serve as proving grounds for developmental testing of new warning facilities. Military bases have excellent discipline and close coordination among their personnel so that control is much better than it is in civilian life. One or two false alarms or middle-of-the-night tests in a civilian community can have serious deleterious psychological effects on the community's attitude toward warning. On the other hand, on a military base, as a result of the firm discipline, the personnel can confidently be expected to continue responding to alerts independently of the circumstances. It should be a relatively simple matter to educate military men to accept the limited inconveniences of experimental conditions when it is known that they are in the process of availing both military and civil defense of imperatively needed warning improvements.

Appendix A

NATIONAL SURVEY

Appendix A

NATIONAL SURVEY

Introduction

With the objective of broadly examining existing warning systems around the country the letter below was sent on 22 May 59 to each of the civil defense directors in the 72 critical target areas listed by the OCDM.

> In connection with a study of active-passive defense interaction which the Operations Research Office is currently completing for the Army, we are interested in examining existing air raid warning capabilities. By "warning" we mean both alerting and advice, consistent in time and in nature with modern enemy capabilities of ICBM and IRBM weapon delivery such that the recipients could, and very probably would, take optimum defense action.
>
> We would appreciate it if you would favor us with:
>
> a. a brief description of your warning installation;
>
> b. an evaluation of its capability in terms of the percentage of the time that it can be reliably expected to warn (not simply be received by) 90 percent of your population;
>
> c. the basis for your evaluation.

The significant features noted in the 44 answers received are described in the following sections.

Warning Devices

Sirens constitute the major warning element of every city replying.

Evaluation

Ten of the replies appeared to be unobjectively enthusiastic and overly optimistic about their warning system's capabilities as exemplified by remarks such as "the public can be alerted in a matter of seconds with 100 percent coverage, day or night," with no supporting evidence.

Only 13 replies offered any quantitative measure of audibility coverage and provided documentation for it. Of these only two indicated that empirical data were collected and employed in an engineering or theoretical analysis. Eight were apparently based on a limited number of civil defense exercises—previously announced daytime tests with records provided by individuals who had been consciously listening for the signals. (Several who made no quantitative analyses drew qualitative conclusions from such exercises.) One of the quantitative evaluations was based partly on an accidental sounding of a siren. Five were based upon "experience," "guess," or "estimate." In no case was an evaluation based on what appeared to be a scientifically sound analysis.

Five replies indicated that audibility coverage in general was inadequate. Two others indicated inadequate outdoor audibility coverage. In 10 cases indoor audibility coverage was cited as inadequate. The replies received include such comments as: "These sirens cannot be heard in *some* buildings." "The siren signal is audible in all locations within this area except inside *certain* buildings." "Persons inside *some* public places during the sounding of the sirens failed to detect the warning." (Incidentally in this connection the last FCDA Annual Report [33] in commenting on the warning status of principal cities states that "outdoor devices may not be heard in *some* buildings and homes.") (Underscores added by the present authors in each case.) "Sirens are for outdoor warning and nothing more." "If you are including in your 90 percent of the population those indoors, then we are in trouble."

Major Weaknesses

There was a recognition by nine civil defense directors of the need for an indoor device. "What really is needed is an individual indoor warning device for each home or residence." "Ninety percent of the population will never be effectively warned until each home, office, and industry is capable of receiving warning signals supplemented by actual voice advice and instructions simultaneously, or nearly so."

Three civil defense directors expressed concern about CONELRAD as is exemplified by the following remarks: "Should an attack come at night, due to the fact that our CONELRAD cluster stations are silent, the time in developing our capability to inform would be increased considerably." "Once CONELRAD goes into effect, our ability to give advice to the public is seriously handicapped by the inherent limitations of the CONELRAD system. The answer to the problem does not seem to lie with the extension of the CONELRAD system."

Concepts

Only nine replies indicated a concept of warning time consistent with the missile era. Most of the replies that gave any value or hint of the time factor indicated that the systems were designed for warning times ranging from several minutes to several hours. In many outlying communities the message to sound the alert is received by relatively slow telephone "fan-out" procedures.

Only 18 replies appeared to recognize individual reaction as the measure of warning effectiveness (including those that merely repeated "warn, not simply received by" from the letter of inquiry and those that mentioned public education). Of these, 12 implied or stated individual reaction or genuine warning coverage to be inadequate. Excerpts from these replies are: "We do not know what percentage of the public would take recommended defensive action as a result of hearing the siren signal." "It is anyone's guess." "It is impossible to approximate." "It is doubtful that over 50 percent of the population would recognize the signal as a warning." "Our estimate would be considerably less than 90 percent." "We think that a fairly large number of people might be slow in turning on their radios." "The present system cannot be expected to be received by, to say nothing of actually warning, 90 percent of our population." "Ninety percent of the area citizens can reliably be expected to be warned (not simply to have heard the warning) in 1 1/4 hours." "In regard to an evaluation of the capability of our warning system in terms of the percentage of the time that it can be reliably expected to warn (not simply be received by) 90 percent of our population, the answer is entirely negative."

Only nine replies showed a recognition that nighttime warning has requirements different from those of daytime warning. Night warning response is uncertain; there is no indication of any designed test or quantitative evaluation of nighttime warning.

None of the replies suggested cognizance of the predominantly indoor distribution of the population (as developed in App B).

Appendix B

STATISTICAL DISTRIBUTION OF PERSONS BY LOCATION IN WASHINGTON, D.C.

Appendix B

STATISTICAL DISTRIBUTION OF PERSONS BY LOCATION IN WASHINGTON, D.C.

DISCUSSION

The tabulations developed in this appendix are based on 1958 figures from the US Census Bureau and from the Washington Board of Trade.

The estimates in Table B1 were made by the present authors for periods of outdoor activities by various groups.

Table B1

TIME SPENT IN OUTDOOR ACTIVITIES

Group	Time, hr/week
School children	20
Indoor laborers et al.	5
Outdoor laborers, including cab and truck drivers	45
Housewives and young children	3
Nonresidents (office workers)	1

When each of these figures was multiplied by the number of persons in the respective category, the values for man-hours per week listed in the "outdoors" and "vehicles" columns of Table B2 were obtained.

Data on time spent in vehicles were developed as follows: The D. C. Transit System, Inc., indicates that its Monday to Friday daily fares number 750,000 for an average ride of an estimated 30 min. Over a 7-day week the total is about 2 million man-hours. For four-fifths of the year the vehicles operate with most windows closed, so that over the year the average weekly number of man-hours with windows closed is 1.6 million and with windows open, 0.4 million. An approximately equal number of persons ride other conveyances, */ so that the net weekly D. C. transit figures are 3.2 million man-hours with windows closed and 0.8 million man-hours with windows open. The resident D.C. labor force numbers about twice as many as the nonresident D.C. labor force, but the distances traveled by individual nonresidents average roughly twice those of individual residents. Hence the net transit man-hours are divided approximately equally for the two groups. The transit hours for D.C. residents—1.6 with windows closed and 0.4 with windows open—are not listed separately in Table B2 but are included within the D.C. residents' totals.

The indoors-asleep value of 50.2 million man-hours for D.C. residents was obtained by assuming an average 8 hr per night sleep for each individual. The 90.8 million indoors-awake figure for D.C. residents was obtained by subtracting the total of the remaining daily hours from 24 for each individual. The 12 million man-hours of the nonresident office workers corresponds to a 40-hr work week.

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*/A Washington Star survey of 5000 persons in December 1957 shows that 58 percent of Washington area persons drive private cars to work. However, the transit considerations in the present warning study involve not only workers but also school children, shoppers, and others. Of all vehicle riders, then, 50 percent in private cars would appear to be a plausible estimate.

Table B2

DISTRIBUTION OF MAN-HOURS PER WEEK IN VARIOUS WARNING CATEGORIES

Population category	No. of persons	Millions of man-hours per week					
		Indoors		Inside vehicle with closed windows	Outdoors	Inside vehicle with open windows	Total
		Awake	Asleep				
D C. residents							
School children	141,000				2.8		
Indoor laborers, retired personnel, and convalescents	493,000				2.5		
Outdoor laborers including cab and truck drivers	33,000			0.3	1.1	0.1	
Housewives and children under school age	229,000				0.7		
Subtotals	896,000	90.8	50.2	1.9	7.1	0.5	150.5
Nonresidents (predominantly office workers)	300,000	12	0	1.6	0.3	0.4	14.3
Total		102.8	50.2	3.5	7.4	0.9	164.8
Combined total		153.0		3.5	8.3		
Percent of total		93		2	5		100

Appendix C

EXPLOSIVES

Appendix C

EXPLOSIVES

DISCUSSION

A limited number of observations were made by the authors on the use of aerial fireworks as possible alerting devices. The results of these observations are regarded as inconclusive. The data obtained are presented here in case they may be of interest to anyone wishing to pursue succeeding studies.

The role of explosives in alerting is to provide an initial shock that would serve to attract attention in a dramatic manner. In connection with the technique of alerting by explosives there are two extreme possibilities of reaction. One is that persons asleep would confuse the explosions with thunder or with automobile backfire sounds and would hence ignore the alert. The other is that persons might regard the explosions as an actual enemy attack and so without any preparatory advice might pursue inadvisable courses of action. There are several problems related to explosive alerting that could be investigated. However, the present authors have confined their activity to simple physical measurements of the audible signals provided by some available classes of fireworks.

The explosives tested were aerial salutes of three types described by the manufacturer (Pottstown Banner Company) as "20 power," "30 power," and "50 power." These types are referred to here as small, medium, and large, respectively. Twenty-seven single bursts and two volleys were fired, and all functioned properly; however, data on only 23 items were recorded because of maladjustment of the measuring equipment. The measurements were made on 10 small bombs, 10 medium bombs, 1 large bomb, one volley of 3 small bombs, and one volley of 2 medium bombs. The bombs were all launched vertically, the detonations occurring at various heights above the launching site. The heights were computed by observing the angle of elevation of the explosive with a transit located at a measured distance from the launching point. The weather conditions during the test were mild: average wind speed 5 mph, average temperature 70°F, average relative humidity 65 percent.

A record of the sound pattern from a typical bomb explosion is shown in Fig. C1 as reproduced from a photograph of the face of a Tektronix Type 512 oscilloscope. The scope was fed from a General Radio Type 1551-A sound-level meter with a Model 9898 crystal microphone and a 20-kc flat amplifier. The base line on this record is biased to correspond to 100 db; two of the peaks are labeled to indicate the scale of ordinates, and the time in seconds following the initially recorded impulse is shown on the abscissa.

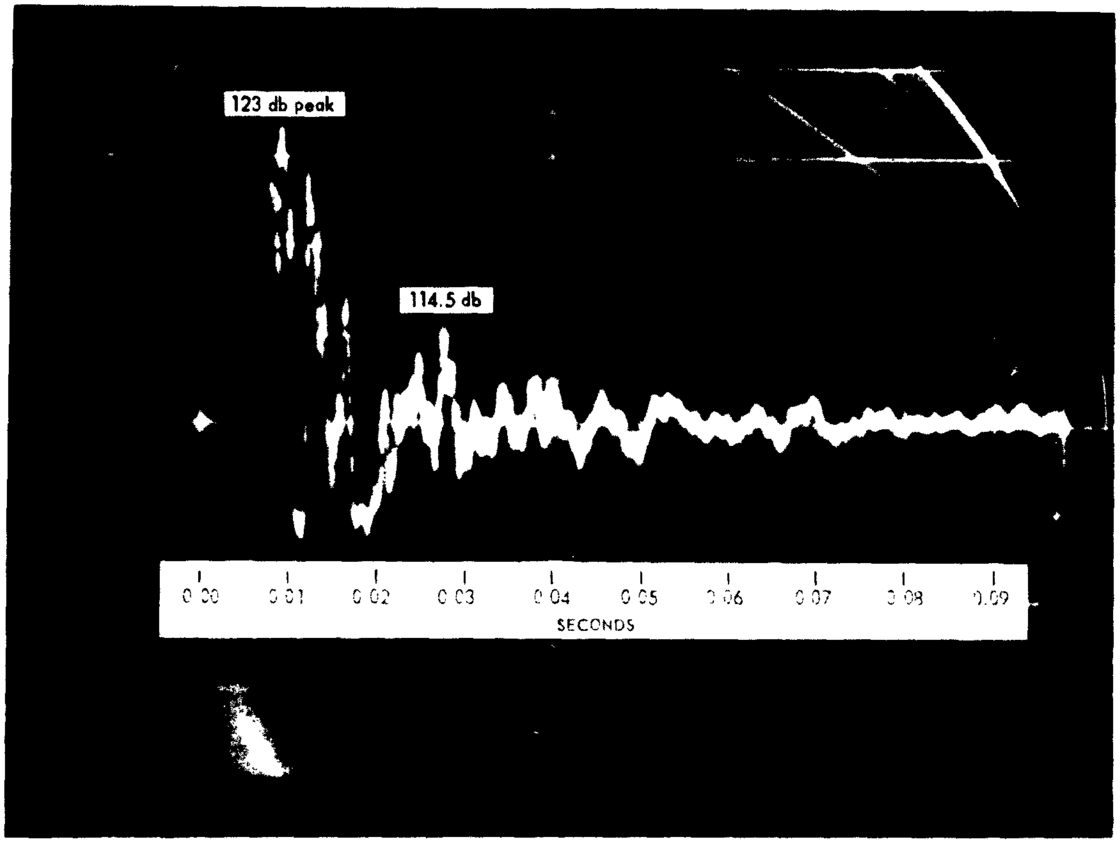

Fig. C1—Sound Pattern of Fireworks Bomb Explosion

The sounds from single-shot bursts were detected at slant ranges of from 200 to 800 ft. The peak signal intensity at 100 ft from the burst was computed from the detected value by employing the inverse square law for sound attenuation plus an estimated absorption of 2 db per 1000 ft. The average value of peak intensity at 100 ft so obtained was 131 db for the small explosives, 142 db for the medium explosives, and 147 db for the large explosive. The individual observed values are listed in Table C1.

Table C1

EXPLOSIVES DATA

Burst	Ground distance from microphone to launching site, ft	Estimated height, ft	Estimated slant range, ft	Peak level recorded on the oscilloscope, db	Standard source strength at 100 ft, db
			Small Explosives		
1	100	175	200	114	121
2	100	230	250	122	131
3	200	150	270	117	127
4	200	370	420	117	130
5	200	215	295	118	128
6	200	210	290	117	127
7	400	450	600	117	133
8	400	625	740	117	135
9	400	250	470	119	133
10	400	270	485	125	140
11 [a]	400	345	530	124	139
Mean			455	119	131
			Medium Explosives		
12	100	360	375	130	143
13	100	335	345	132	143
14	100	470	485	131	145
15	200	260	325	125	136
16	200	200	285	127	136
17	200	230	300	125	135
18	200	450	495	141	155
19	200	255	325	142	153
20	400	615	735	122	140
21	400	330	515	123	138
22 [a]	400	495	635	124	141
Mean			480	129	142
			Large Explosives		
23	100	390	405	134	147

[a] Volley.

In the volley of small salutes there was an interval of 0.6 sec between the first and second bursts, and an interval of 1.0 sec between the second and the third bursts. In the volley of medium salutes there was a 1.4-sec interval between the two bursts. These time intervals are controllable in the manufacturing to within moderate deviations from the indicated observed values.

Appendix D

AUDIBILITY POTENTIAL OF WASHINGTON, D.C., SIREN SYSTEM

FIGURES

Appendix D

AUDIBILITY POTENTIAL OF WASHINGTON, D. C., SIREN SYSTEM

PROCEDURE

The theoretical determination of the audibility potential of a target-area siren system is a complex problem. It involves, on the one hand, the physical parameter of sound exposure, which is measured by space and time distributions for both the desired signal and the background noise, and on the other hand, the psychophysiological parameter of perception within a specified time interval, which for any one person is characterized by the physical and mental state of the individual and which for a population is measured by distributions in space and in time of persons reacting appropriately.

There are at least two reasons why it is at this time of only academic interest to pursue a rigorous evaluation of audibility potential for any given siren warning system. First there are factors independent of siren audibility, as indicated in this paper, that limit the effectiveness of a siren system. Second the contribution of siren warning perception is essentially unknown at present. Nevertheless, because of a seeming existent interest in attempting to assess audibility of siren systems and because the presentation of a method might possibly serve later under more favorable circumstances, a method is developed here that could be employed in principle to determine the audibility potential of a given siren system. Although the method is illustrated by the D.C. system no attempt has been made to obtain a quantitative evaluation of the system in view of the uncertainty relative to the critical factor of perception.

Some simplifying assumptions are made in the analysis without undue concern for the implications of these simplications. The technique does admit of refinement by anyone who may be so motivated.

Specifically, limited cognizance of the directional pattern of the siren signals is taken in connection with the determination of exposure level, but no recognition is taken in connection with the factors of perception time. Also in reckoning perception time it is presumed that all sirens start simultaneously, although actually some sirens (those driven by gas engines) may require several seconds, particularly in cold weather, to reach normal operating conditions. Furthermore no attempt is made to utilize the distributions in time of persons perceiving different signal-to-noise ratios; rather only one specific signal-to-noise level is considered, i.e., that which provides perception by 90 percent of the population within 30 sec. Of the errors introduced by the four approximations indicated above, two contribute to lessen the measured audibility potential and two contribute to enhance it, so that together they tend to be mutually compensatory.

The general approach employed here is as follows: A probability of exposure, designated as x, is computed from considerations of sound-transmission phenomena, for persons distributed in space and in time throughout the city. (Major time and space divisions are handled separately from one another—night and day, indoors and outdoors.) The probability x measures the likelihood of a person's being exposed to sound of such physical characteristics in relation to background that statistically this type of sound, if sustained, would be perceived because of psychophysiological characteristics by a percentage p of persons in a typical population sample within a specified time interval Δt. Then for a single subject the audibility potential of the system under investigation is taken to be the product of that subject's exposure x and the probability of his perception p. A value corresponding to x is determined for the integrated population; when this is multiplied by p it gives the audibility potential for the entire D.C. area.

The procedure involves fixing p at 90 percent and Δt at 30 sec in view of the basic warning stipulations proposed earlier. Then a signal-to-noise ratio K is selected from the experimental data on perception to provide approximately this "90-30" psychophysiological reaction. Following this, a statistical determination is made of the portions of D.C. in which the signal-to-noise ratio is at least equal to K. These portions of area so found are converted to corresponding man-hour values */ from census data and from time-distribution information on people as developed in App B. The man-hour values for the separate areas are added together to yield total exposed man-hours. The total number of exposed man-hours is divided by the total population-hours of D.C. to yield percentage of man-hours exposure. Finally, this last result, when multiplied by the perception probability factor of 90 percent, gives the so-called "audibility potential" for the D.C. warning system.

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*/Man-hours per average week.

For the statistical determination of areas where the signal-to-noise ratio is at least equal to K the following nomenclature is introduced:

$\lambda_1 \equiv$ frequency average noise level in decibels.

$\lambda_2 \equiv$ frequency average (beam-directed maximum) signal level in decibels.

$N(\lambda_1)d\lambda_1 \equiv$ probability of obtaining a noise level in the range from λ_1 to $\lambda_1 + d\lambda_1$.

$S(\lambda_2)d\lambda_2 \equiv$ probability of obtaining a signal level in the range from λ_2 to $\lambda_2 + d\lambda_2$.[*]

$\Delta \equiv 10 \log K$ = difference in levels of signal and noise corresponding to signal-to-noise intensity ratio of K.

For a signal level in the range of λ_2 to $\lambda_2 + d\lambda_2$ the probability of the simultaneous occurrence of any noise level λ_1 such that $\lambda_1 \leq \lambda_2 - \Delta$ is given by

$$S(\lambda_2)\,d\lambda_2 \int_{\lambda_1=0}^{\lambda_2-\Delta} N(\lambda_1)\,d\lambda_1 \,.$$

When the above function is integrated over all values of λ_2 it yields the net probability of the occurrence of a signal that is at least K times the intensity of (Δ decibels louder than) the simultaneously occurring noise:

$$\int_{\lambda_2=0}^{\infty} S(\lambda_2)\,d\lambda_2 \int_{\lambda_1=0}^{\lambda_2-\Delta} N(\lambda_1)\,d\lambda_1 \,.$$

---

[*] N and S are normalized distribution functions:

$$\int_{\lambda_1=0}^{\infty} N(\lambda_1)\,d\lambda_1 = 1 \,.$$

The expression above may then be extended in interpretation by recognizing that (a) N depends on the nature of the area involved (e.g., outdoors, heavy traffic area; or indoors, residential area) and (b) S also depends on the nature of the area (relative to sound-disturbing effects of structures and landscape) as well as on the distance of the observation point from the source. Hence, using the parameter α to characterize the local area and the symbol r to denote the distance from the source gives

$$P(r, \alpha) \equiv \int_{\lambda_2 = 0}^{\infty} S(\lambda_2, r, \alpha)\, d\lambda_2 \int_{\lambda_1 = 0}^{\lambda_2 - \Delta} N(\lambda_1, \alpha)\, d\lambda_1 \qquad \text{(D1)}$$

as a measure of the probability P of obtaining within an area α a signal-to-noise ratio of at least K within a specified distance r from a sound source. Or from another viewpoint, if P is taken as unity Eq. D1 determines the value of r for which there is assured within an area α a signal-to-noise ratio of at least K. It is the latter view that is adopted here.

For the present D.C. system the result of the calculation is essentially unaltered by neglecting the overlapping of several sirens at any one observation point. Sounds of the individual sirens are nearly independent in their contribution to response and are not simply additive. Each siren horn rotates about a vertical axis with a 30-sec period. During this rotation the time interval from half-maximum intensity, through maximum, to half-maximum intensity on the other side covers only 3 sec of the 30 sec at any specific observation point (see Fig. D1).[34] Hence it is quite unlikely that more than one siren should consistently reinforce at any particular location. In addition the possibility of constructive interference is further lessened by the fact that the important take-cover signal varies in frequency, and this adds another dimension—signal phase—to the problem of reinforcement. Accordingly Eq. D1 serves in any practical case, where r may be regarded as the distance from the point of observation to the loudest siren heard at that point.

The problem now resolves to determining in the D.C. area (a) the function N, i.e., the background noise level in various locations, and (b) the characteristics of sound propagation and attenuation that contribute to the available warning signal level S that is received at these locations.

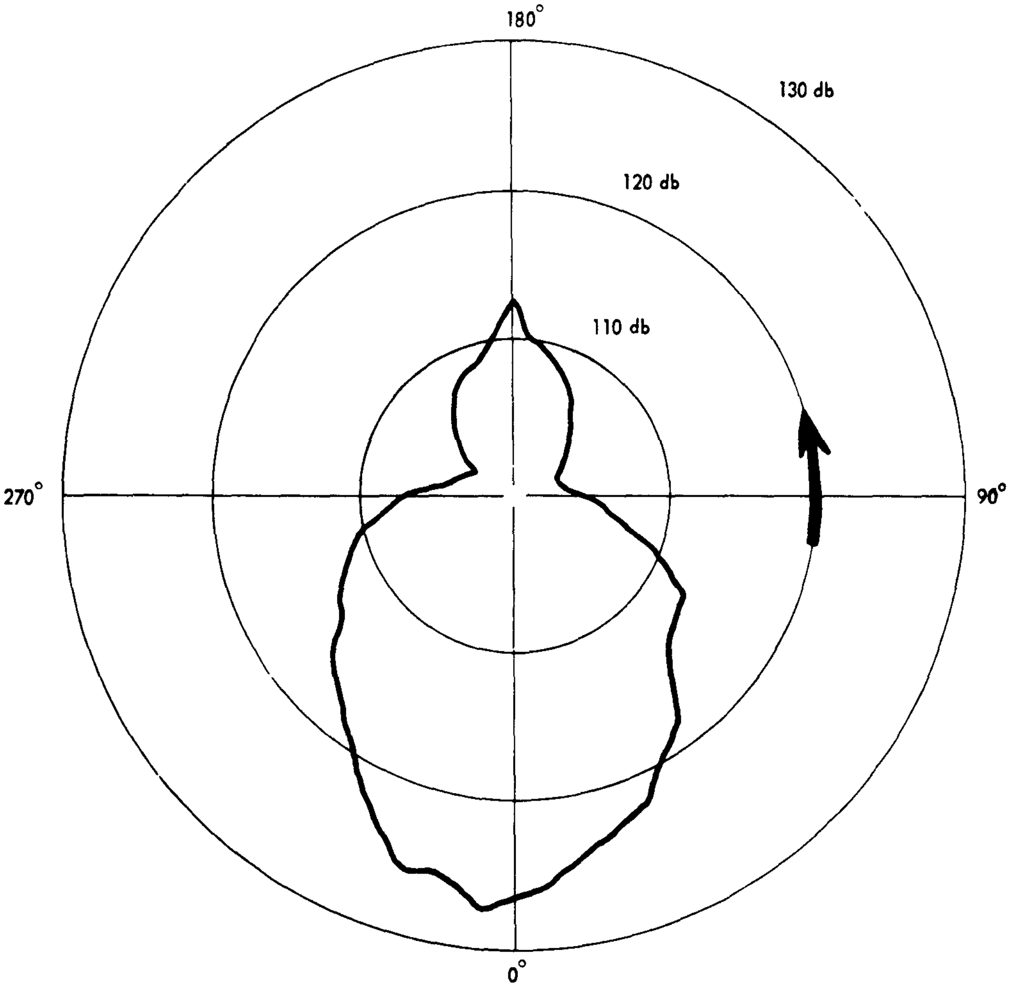

Fig. D1—Typical Directivity Pattern of Federal Siren Model 1000 TT[34]

BACKGROUND

A study of outdoor background noise was conducted by the authors to determine the correlation, if any, between outdoor ambient noise level and extent of street traffic in the Washington area Observations were made during the day on a Tuesday and on a Sunday at a total of 86 different locations within the D.C. area At each site counts of passing traffic were recorded for a 2-min period, during which time interval a total of 25 readings were taken (one each 5 sec) on a General Radio type 1551-A sound-level meter. After the original tabulations were made the data were grouped according to the associated traffic count. Thus in the range of 0 to 5 cars inclusive per 2-min interval all the observed sound-level values were collected and averaged; then in the range of 6 to 10 cars inclusive per 2-min interval, all the observed sound-level values were collected and averaged. The process was continued until all the data had been so cataloged. The average sound levels recorded are portrayed in the histogram of Fig. D2. In the course of counting traffic any vehicle such as a truck or a motorcycle that was distinctly noisier than the average passenger car was regarded as equivalent to four cars. This multiple of 4, somewhat arbitrarily selected, is not critical since the observed traffic consisted of about 10 times as many passenger cars as trucks.

The reasonably smooth envelope of the histogram indicates that the street-noise background in D.C. is closely correlated with vehicular traffic so that traffic flow from available surveys could be employed as a measure of ambient street noise. The envelope of Fig. D2 graphs as a straight line when it is plotted on a semilog coordinate system as in Fig. D3. */ This linear relation is consistent with that observed by Seacord,9/ who checked outdoor noise as a function of vehicular traffic in several cities.

Finally, in the determination of the background noise for the outdoor warning signals, reference was made to the latest available (1957) traffic-flow map of Washington, D.C., from which the traffic in vehicles per day was computed for each 1-km square of the city. Three categories of traffic flow were considered based on the number of vehicles per day, light (under 25,000), medium (25,000 to 77,000), and heavy (over 77,000).

The recorded observations of sound level as a function of traffic flow that were made at the 86 locations within D.C. were then grouped according to designated traffic-flow categories of light, medium, and heavy. The corresponding distributions are shown in the histograms of Fig D4.

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*/The plotted points are for abscissas 5, 10, 15, 20, 30, 40, and 50

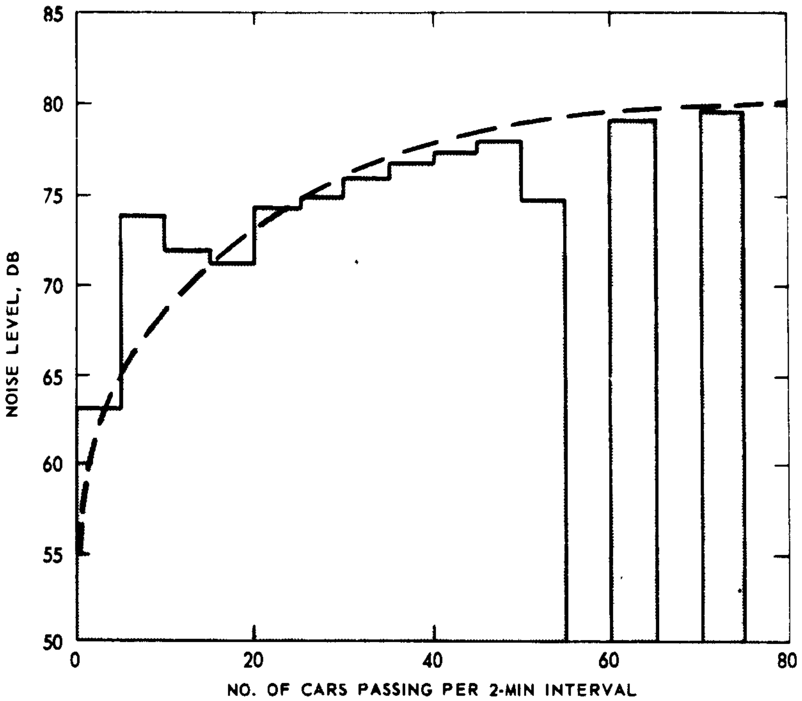

Fig. D2—Average Noise-Level Readings as a Function of Traffic Flow in D. C.

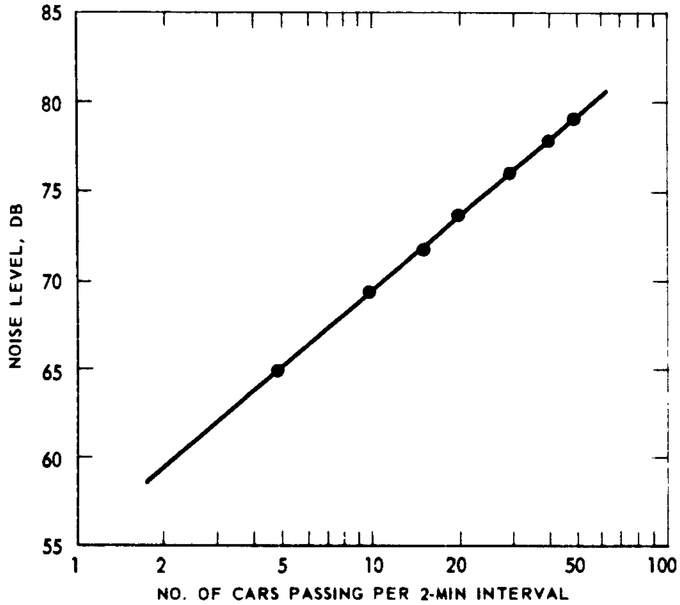

Fig. D3—Semilog Plot of Noise as a Function of Traffic in D. C.

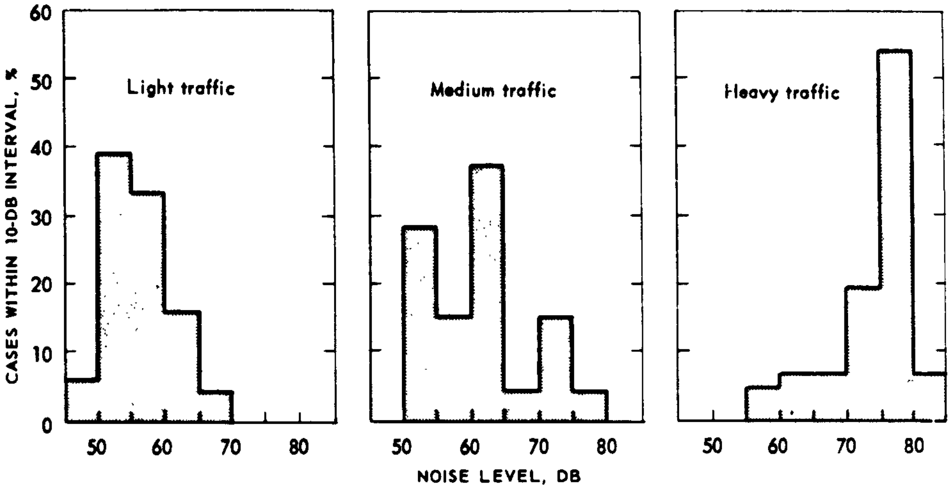

Fig. D4—Distribution of Noise-Level Readings by Traffic Volume in D. C.

For an evaluation of indoor background noise reference was made to Seacord's data of Fig. 1. Measurements of noise level were made by the present authors in a limited number of D.C. residences. The values obtained were at least consistent with Seacord's more comprehensive study.

ATTENUATION

For data on attenuation through residences reference was made to Volkmann and Graham's values shown in Table 2. In the frequency range of the take-cover signal, 285 to 465 cps, the attenuation averages about 15 db. It is estimated that the attenuation is about 20 db for a typical business establishment. The higher attenuation for business places is attributed to the greater percentage of interior space that is separated by partitions from the exterior rooms. (Within a typical residence almost every room has an outside exposure.)

SIGNAL INTENSITY

Unfortunately the scarcity of pertinent data on sound-transmission characteristics precludes a determination of the precise character of the function S of Eq. D1 and requires one to estimate simply an approximate average value S based on average attenuation values. The estimated average attenuation was determined by reference to the available literature and after consultation with several sound authorities including representatives of the Sound Section of the National Bureau of Standards. The time-average attenuation values selected are 10 db per 1000 ft for absorption and scattering effects of all kinds and 10 db for shadow effects.

To the afore-mentioned losses must be added 6 db per distance doubled (corresponding to spherical divergence of the wave front from a point source) and 15 and 20 db on passage into residences and business establishments, respectively. The resultant curves of average siren sound intensity S as a function of distance from the source are plotted in Fig. D5. The solid curve is for outdoors, and the dotted curves, 15 and 20 db below, are for the indoor residence and indoor business cases, respectively.

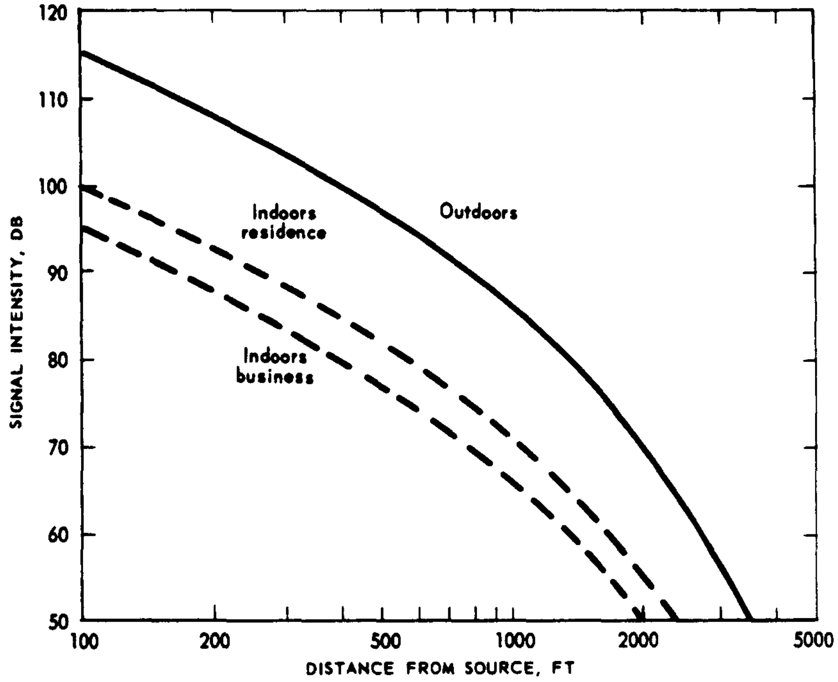

Fig. D5—Siren Signal Intensity as a Function of Distance from Source in D. C.

EVALUATION

For any given siren and for any particular category (for example, daytime outdoors) Eq. D1 may now be numerically solved with reference to the sound-transmission relations of Fig. D5 in conjunction with the appropriate background data from either Fig. 1 or Fig. D4. A specific probability of audibility can be assigned to each incremental ring surrounding the siren by noting: (a) the signal level that occurs at that position and (b) the probability of having a particular noise level at that point. A weighted probability factor is determined by multiplying the population included within that incremental ring. The procedure is repeated for each ring to yield a net weighted probability of audibility for the one siren. On adding such values for each siren and on dividing by the total population of the city, one obtains a measure of the audibility potential of the entire siren system for the one case (such as daytime outdoors).

In the event that an extension of the siren system is proposed an estimate can be made of the expected enhancement in coverage by means of the curve of Fig. D6. This curve represents a plot of cumulative percentage of population as a function of cumulative area. The area unit employed here is 1-km square. The areas are selected in order of population with the most heavily populated area listed first followed by the next most heavily populated area, etc. Thus the plot shows that the 10 most densely populated 1-km squares contain 20 percent of the total population, and the 20 most densely populated 1-km squares contain 35.4 percent of the total population. The curve then provides for extrapolation of the coverage of the siren system on the presumption that any extension of the siren system would be developed in different parts of the city in accordance with the requirements of population density.

In case the system is to be increased from n to 2n sirens the increased effectiveness is approximately measured by the ratio of the ordinates corresponding to 2n and n, respectively, on the graph. For example, if n sirens provide a 50 percent audibility potential (percentage of man-hours effective) then 2n sirens would increase the value to about 75 percent.

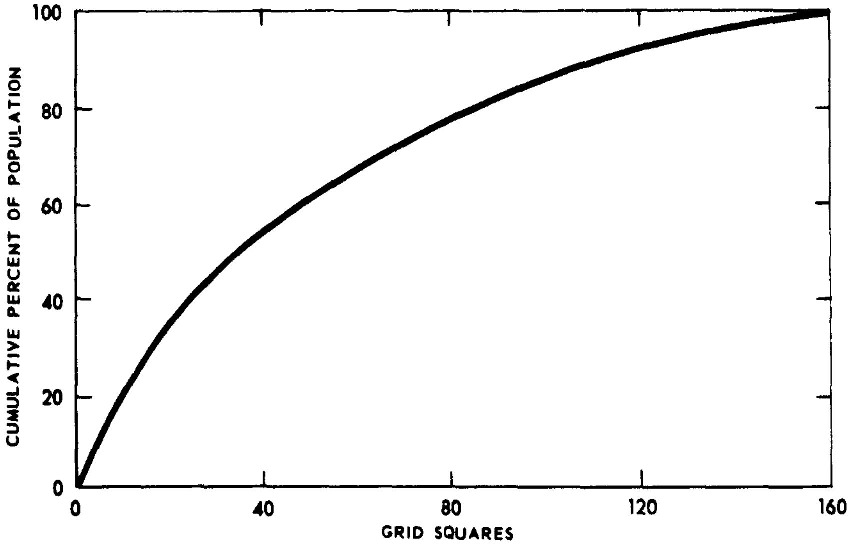

Fig. D6—Cumulative Percentage Population of D. C. by 1-km Squares

Appendix E

BASIC DESIGN CRITERIA

Appendix E

BASIC DESIGN CRITERIA

DISCUSSION

One of the fundamental parameters in the design of a warning system is time in seconds following the initiation of an attack. It is essential to establish first a time-pattern that is available for action and then to develop the system to fit within this time pattern. A possible procedure is as follows: From information provided by estimated enemy capabilities and by known US active defense capabilities, a time-distribution curve is constructed for megatons delivered on civilian targets within a specific era as a function of time in seconds following onset of an attack.

A plot indicating the general trend of such a cumulative time distribution is given by the solid curve of Fig. E1. This curve forms the basis for the over-all design of a passive defense complex: warning, shelter, and education. The dotted curves (A, B, and C) represent cumulative time-distributions of nationwide completed passive defense response to warning, wherein dollar cost is the distinguishing parameter. It may be that curve B (y percent of the population sheltered before the time of crossover with the solid curve) is selected from considerations of national policy as a proper compromise. This curve, then, forms the basis for the design of a warning system.

It is now essential to construct a system that will have the characteristics of curve B as a result of some appropriate combination of warning and reaction time. It is to be observed that warning (alert, confirmation, and judgment) has its own timewise statistical distribution that provides the input to the followup distribution of defense action. The two distributions of (a) warning and (b) action operate in sequence fashion in that over any increment of time the number of persons who begin action is that number who complete warning. Action time is controllable mainly through education; warning time is controllable mainly through physical warning facilities. The proper amount of each ingredient can be at least roughly determined so as to optimize the results relative to such variables as cost of the over-all operation or time of completion of the system.

In the absence of such an extended study there appears to be no alternative other than to make warning as fast as is reasonably attainable. This accounts for the "90-30" perception requirement selected in this study.

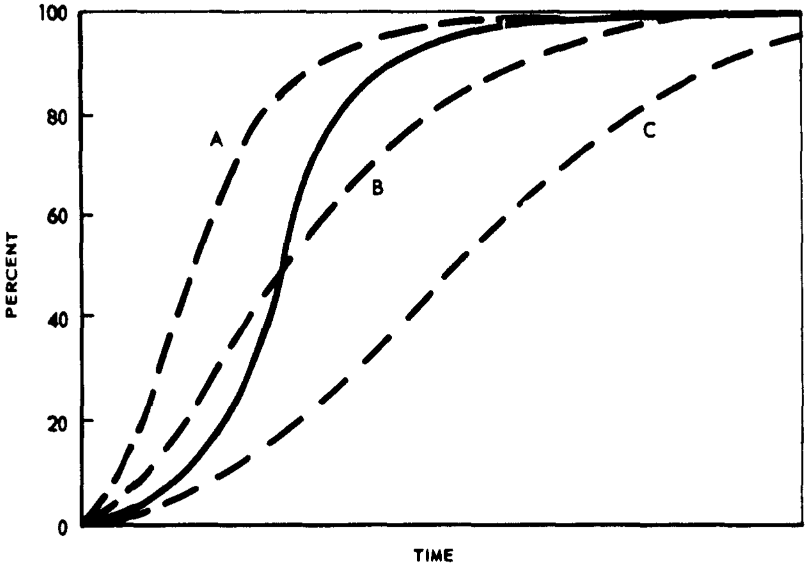

Fig. E1—Offensive–Defensive Distribution Plots

——— Percent of attack required for total casualties
— — — Percent of completed defense action

Appendix F

SIREN PERCEPTION TEST

FIGURES

Appendix F

SIREN PERCEPTION TEST

TEST DESIGN

Although some work has been done in determining the required signal-to-noise ratio for alerted subjects to respond to a variety of signals, no known work has been performed to determine the requirement to evoke a response to some unanticipated and not thoroughly conditioned warning signal. Therefore the present study was directed toward this area.

The objectives were to learn what relative signal-to-noise ratio would be required to evoke recognition and some response from unalerted persons occupied with a variety of tasks. It was also of interest to obtain some estimates of the time required for subjects to become aware of the warning signal.

With very little background data available to build on it was decided to utilize the following design for the preliminary experiment. Essentially there would be two basic groups of subjects: an "alerted" group, consisting of those who had been alerted that a siren would be sounded at intervals throughout the test and were asked to inform the experimenter as soon as they heard the signal over the background noise, and an "unalerted" group consisting of those who were not informed in any way that they were to expect a siren (or warning sound) in the background. For the background noise half the subjects were exposed to a selection of music played at a level of approximately 67 db at the position of the subjects; the other half were exposed to a recording of general noise where the basic level was set at approximately 67 db, but where the sound actually varied from periods of relatively quiet (50 to 55 db) to periods with intensities over 90 db. The noise was provided by sounds from the small ORO electronic shop (conversation plus occasional sounds of bench tools and light machines). In the recording of the general noises the level recorded at the position of the subject remained at approximately 67 db for the largest proportion of time.

The task assigned to half the subjects was the block-design phase of the Wechsler-Bellevue Intelligence Test, and the signal was sounded on designs 5 and 6, beginning 12 sec after the start of each design, and lasting until just before the completion of the design.

The other half of the subjects were given a more difficult assignment. They were first presented with three cards selected from the Thematic Apperception Test (TAT) and requested to tell a story about each card (in accordance with standard TAT procedures). The signal was sounded on the second and third cards—again beginning at 12 sec after presentation of the card, and lasting for a total of 42 sec. After completing the three TAT cards the subjects were presented with a selected article from a magazine and requested to read out loud the first few paragraphs. The signal was sounded in the same manner for this reading as for the TAT tests.

It was planned to use three levels for the signal, which was a recording of a Chrysler siren,*/ reproducing the sound of the Red alert in the Washington metropolitan area. The first signal level was selected to be 67 db to correspond with the basic level of background noise used. It was then planned to select the other two levels after obtaining some information from the responses of the subjects run under this condition—information to determine whether higher or lower intensities should be used for subsequent signals.

Of course the primary interest was in the comparative performance on the two TAT cards in order that the experimental design would be evenly balanced. The additional reading aloud (and even a further reading by the unalerted subjects after alerting them to listen for a siren) was used primarily for control purposes, i.e., to have some check on the accuracy of their answers.

TEST ADMINISTRATION

The subjects were seated across a small typing table from the test administrator.

The test room was a band practice room approximately 10 by 12 ft with the top half of the walls and the ceiling covered with acoustical tile. The door to the room was also soundproofed, but the window was left in normal condition.

The background noises came from three directions so that the subjects were totally surrounded by the background sounds. The signal came from a separate speaker that was located in the window in hopes that the siren would appear to come from outside the test room (as indeed most subjects stated after the test).

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*/Recording kindly provided by R. N. Lane, President of Texas Research Associates, Austin, Tex.

The alerted groups of subjects were, of course, told of the nature of the test prior to each test session The unalerted groups were told that it was a test of ability to perform a variety of tasks with a variety of background sounds.

Unfortunately the mere fact that the unalerted subjects had to be told something concerning the fact that they were exposed to background sounds may have in some unknown way biased the results. However, it was a test situation in which most persons were trying to do their best in the performance of the task given them (i.e., working with block designs or story telling), and this too may have influenced the results in some as yet unknown way.

It was quite unexpectedly found impossible to obtain any time data at all from the unalerted groups. Unfortunately not a single subject gave any overt (or at least any recognizable) indication that he had been aware of any warning signal in the background. When questioned later all who stated that they had heard a siren in the background, with the exception of two subjects, were able to describe it correctly.

There were only two cases in which unalerted subjects stated that they had heard a siren on some task other than the correct ones, and these subjects had confused the sound of a sander being turned on in the general background noises. (The sander sound was similar to that of a vacuum cleaner.) The same mistake was also made on one occasion by a subject in the alerted groups.

RESULTS FOR ALERTED SUBJECTS

(a) When anticipating a siren warning signal (i.e., when in a psychological state of anticipation), subjects had approximately 90 percent probability of perceiving that signal when the level of the signal was 10 db below the background noise and when the subjects were engaged in a variety of tasks. (See Fig. F1, which plots the average of the perception percentages for the two backgrounds—music and noise—against the signal level.)

(b) When anticipating a siren warning signal, those who heard the signal did so very quickly—most of them well within 2 sec. The average time, however, was 3 sec because a limited number of the subjects required a considerably longer time.

(c) For alerted subjects the type of noise in the background appeared to have little or no effect on the probability that the subject would recognize the signal (see Fig F2).

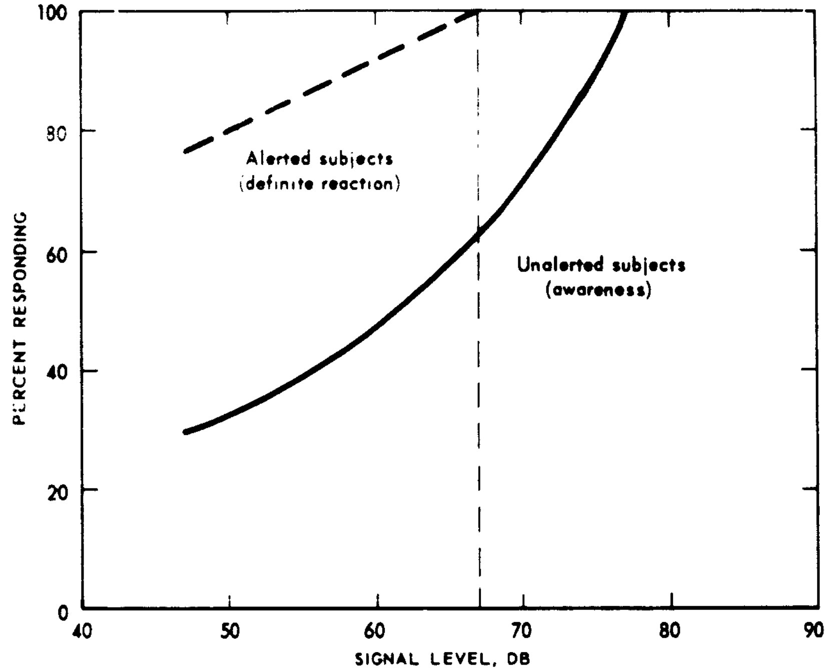

Fig. F1—Percentage of Task-Oriented Subjects Responding to Siren Signals at Various Levels with Background Noise Level at 67 Db

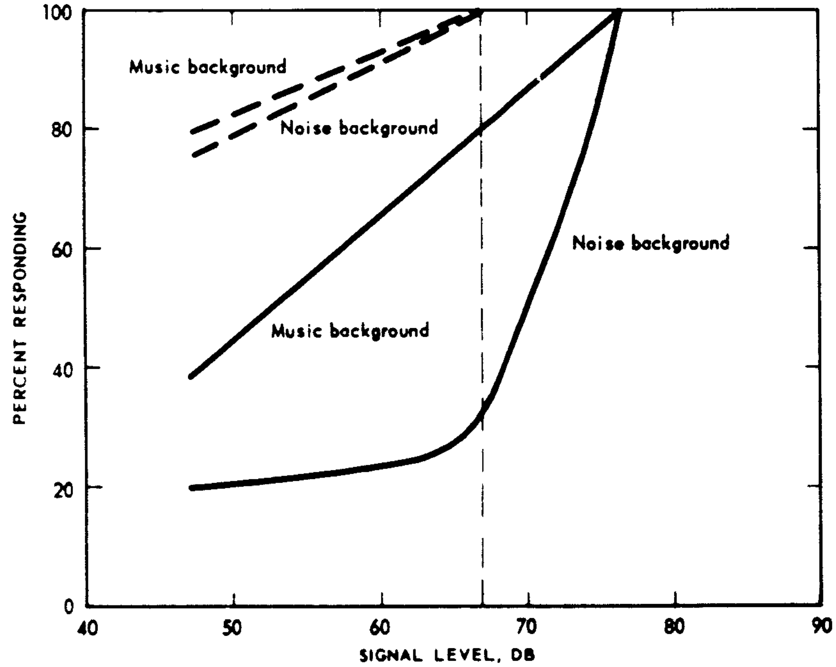

Fig. F2—Percentage of Task-Oriented Subjects Responding to Siren Signals at Various Levels with Type of Background Noise as Parameter

— — Alerted subjects; —— Unalerted subjects.

RESULTS FOR UNALERTED SUBJECTS

(a) At no time in the study, with siren signals up to 20 db in excess of background, did a single unalerted subject give any evidence of special concern.

(b) The strongest observable reaction to the siren signal could be described as "vague awareness." By "vague awareness" is meant that when questioned a subject was able to recall reliably the particular task that he had been performing when the siren sounded but he in no way indicated that he connected the siren with any type of warning signal. Many subjects indicated that they thought either an ambulance or fire engine had passed close by, and two stated that they "heard something that sounded like an air raid alert." One of them added, "You hear things like that all the time." There was at no time during the study a single recognizable response (such as a questioning look, pause in the task, or an extra eye blink) that would indicate to the experimenter that a subject had perceived the signal when it was sounded. Vague awareness was exhibited by 90 percent of the unalerted subjects for a signal level of 8 db above background.

(c) With the unalerted subjects the type of background had considerable effect on the number of subjects who became vaguely aware of the warning signal when it was equal to or less than the level of background noise. A larger percentage of subjects became aware of the signal with music in the background than with general noises (see Fig. F2).

CONCLUSION

The experience obtained to date indicates that an air raid alert siren must exceed the background level by more than 20 db—there are no data to indicate by just how much more—in order for any significant percentage of occupied persons acting independently to be stimulated to defense behavior within a half minute with the present level of public awareness (or apathy).

Appendix G

CASE STUDIES OF RESPONSE TO SIREN SOUNDINGS

Appendix G

CASE STUDIES OF RESPONSE TO SIREN SOUNDINGS

A number of instances of unexpected siren soundings are now on record. Observations on a few of these cases are presented herewith. Some of the surveys cited are informal and inconclusive. Nevertheless, collectively they present a human-interest portrayal of existing reaction to sirens and a suggestion of probable reaction to a genuine siren alert.

CASE I

A false alarm that occurred in Oakland, Calif., on 5 May 55 was reported by the Survey Research Center of the University of Michigan, whose workers interviewed 146 Oakland residents after the event.35/ The alarm was occasioned by the presence of unidentified aircraft in the vicinity, and it operated for over 5 min. Nearly all those who heard the alarm interpreted the signals correctly as coming from the air raid sirens. However, only 10 percent tried to protect themselves. Most persons hearing the sirens regarded the signals as either a mistake or a test; and to quote the Michigan report: "Over three quarters of those interviewed say that if it happened again, they would still not take it seriously, or at least would not behave in terms of self-protection."

CASE II

In the District of Columbia on 25 Nov 58 several sirens in the downtown area and one in a residential area sounded for approximately 4 min as a result of a technical fault. The sirens were accompanied by bells and klaxons in some government buildings, and many but not all of these buildings were evacuated into areas of dubious safety in the streets. A few days following this false alarm ORO interviewed 15 individuals at random from those who had heard the siren in the residential area involved. In no case was a person found who undertook any sort of defensive action.

Three teachers at Western High School, where the defecting residential siren was located, reported hearing the school's siren clearly, deciding it was a test, and doing nothing further about it. (The incident occurred after school hours, and there were only a few persons in the building at the time.) One woman who heard the siren while she was standing on a street corner indicated that at first who wondered what to do, but that when she saw a policeman across the street who was obviously unconcerned she forgot about the siren. One individual, who was thoroughly cognizant of the threat, reported that although he recognized the sound of an air raid siren he was completely unaffected by it. He did not turn on a nearby radio receiver; he simply felt no compunction to do so. He listened to the siren for some time and then continued with his work. Four women who had been playing bridge heard the siren blowing for several minutes. Since it blew so steadily they decided that "war must have been declared," and realizing that there was nothing they could do about it they returned to their bridge game.

It was originally believed that more than one residential area siren had sounded, and accordingly over a hundred persons were interviewed in various parts of the city. It was later learned, partly on the basis of an excessive number of completely negative responses to inquiries of residents in the neighborhood of certain allegedly defecting sirens that only the residential siren at Western High School had been activated. After eliminating the meaningless negative responses received from areas where no siren had sounded, the residual data amounted to only 15 cases from the immediate vicinity of Western High School.

From statistical arguments based on the binomial distribution (see, for example, Snedecor 36/) it can be stated at 99 percent confidence level that the finding of no defense response in a sampling of 15 cases indicates that fewer than 30 percent of the whole population responded with defensive action.

CASE III

At 5 min before 1:00 A.M. on the morning of Saturday, 13 June 59, a single siren operated accidentally in a suburban community on the outskirts of Washington, D.C. The siren sounded continuously for about 15 min, and then after a 5-min lull it sounded again for about 10 min. On the following Monday ORO interviewed 36 families in the area served by the siren. In each of 32 of these families at least one person heard the siren distinctly. In 11 of the families who heard the siren no defense action of any kind was undertaken, nor was any attempt made even to check on the siren signal. Of these 11 families who undertook no action whatsoever in spite of 25 min of siren sounding four interpreted the signal as an accidental discharge or as a prank; three said they just didn't know what it meant; two said they thought it was a vehicular siren or a fire station siren; the other two simply accepted it as an actual air raid warning and then returned to bed. In the 21 families who did at least obtain some confirmation of the siren signal several cases were reported of persons watching television at the time who interpreted the obviously routine character of the broadcasts, particularly the news features, as implying that the siren sound was a false alarm. In many cases besides those covered by the interviews, persons used the telephone to call for further information from police and fire stations, newspaper offices, radio and television broadcast stations, civil defense officials, and friends and relatives. Accordingly several public switchboards were saturated for a period of well over an hour.

MISCELLANEOUS

The Washington Post on 11 Jan 59 on the occasion of a siren test that evidently had not been thoroughly publicized in advance stated:

> A brief test of Washington area civil defense sirens found most of them working well yesterday, but a sampling of downtown pedestrians showed that many people didn't know or care why the sirens were wailing.
>
> Said one woman: "Am I supposed to know? It's none of my business."
>
> Said a man as the sirens went off on schedule at 11:55 A.M.: "They sound them every Saturday at noon." The last test in the District was held Nov 8.
>
> Another man explained: "I'm not from Washington, so I wouldn't know."
>
> Several thought fire engines were passing.

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