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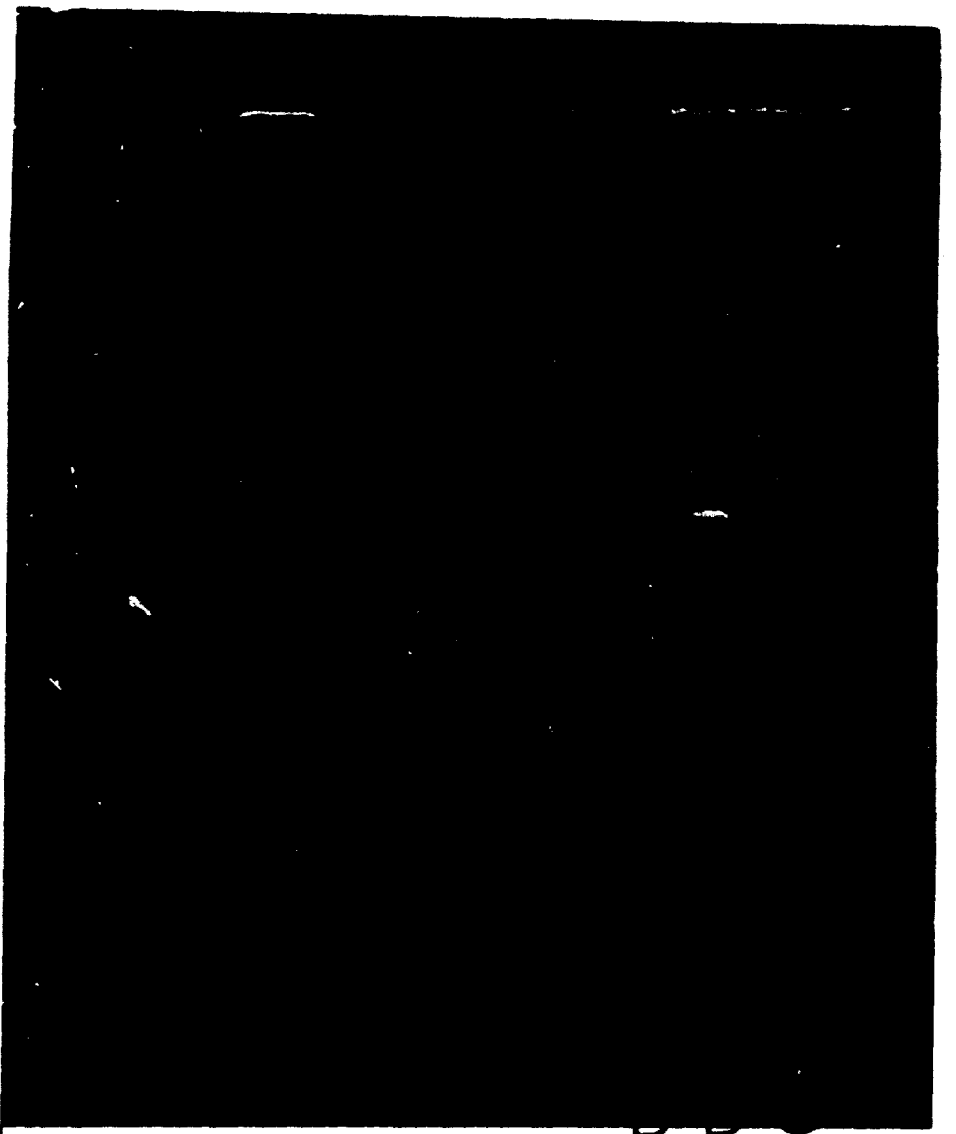

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final report

A STATISTICAL INFORMATION SYSTEM FOR ESTIMATING THE MAGNITUDE AND SCOPE OF NUCLEAR ATTACKS

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SRI Project 4949-680
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ABSTRACT

This research develops concepts, flow diagrams, and statistical methodology for an information system to estimate the magnitude and scope of nuclear attacks. The system is designed to operate in the transattack and immediate postattack period when data on the attack can be expected to be incomplete and inaccurate. The underlying principle in estimating attack size is that of statistical inference, which permits an estimate to be made of the total attack from information on only a sample of the attack. Heuristic decision rules are applied as needed to make the system operable. It is demonstrated how the target synthesis procedure thus developed may be coupled to a variety of survival estimating techniques to yield survival estimates. The research also develops statistical methodology for processing reports of nuclear detonations.

PREFACE

This research was conducted for the Office of Civil Defense as part of OCD's program to develop appropriate information systems relevant to survival estimation. The report presents information flow and processing diagrams for a statistical concept of survival estimating.

Robert M. Rodden was the principal investigator for SRI. The statistical methodology described in Section VIII of the report was developed by Charles R. Thompson, and the more detailed flow diagrams of Appendix B were devised by Frederic A. Miercort. Benjamin E. Suta and Peter B. Bjorklund assisted in development of the statistical methodology.

The study was conducted under the general guidance of Richard K. Laurino, Manager, Operations Analysis Program.

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1 INTRODUCTION

The purpose of this report is to support research directed at improving existing survival estimating systems, and to develop new systems by which civil defense can undertake a realistic postattack assessment of the extent and damge of enemy attack and the resulting surviving people and resources. Executive Order 10952, as amended, assigns civil defense responsibilities in this area as follows:

> "...develop plans and operate systems to undertake a nationwide postattack assessment of the nature and extent of the damage resulting from enemy attack and the surviving resources, including systems to monitor and report specific hazards resulting from the detonation or use of special weapons..."

In this investigation, effort is centered on postattack assessment at the national level during the transattack and immediate postattack periods. Postattack damage assessment systems at subnational levels are also considered, but detailed investigations of these systems are left for future research

The problem of estimating damage resulting from nuclear attacks on the continental United States has been the subject of continuing research for over a decade. During this time, researchers have devised numerous systems based on the use of high speed computers for determining damage to population and resources under almost any type of nuclear attack. The data produced by such systems have generally proved useful for purposes of preattack planning. On the other hand, survival estimating systems providing information for operations in a postattack environment have been studied to a much less degree. In fact, a substantial part of the concepts and methodology of the damage assessment planning systems has been carried over for use with postattack damage assessment systems that are supposed to meet the information requirement for civil defense operations. In recent years, the continuing study of the nature of the problems in the

postattack environment has made it increasingly evident that the planning system damage assessment methodology will not supply adequate information for postattack civil defense operations. This is largely due to the fact that real-time information on the magnitude and scope of the attack will be needed to apply existing damage assessment methodology, but will unfortunately not be available.

The accuracy and reliability of data available in the transattack and immediate postattack period may often be low. Attack and damage reports may be inadequate or biased. Nevertheless, the decisions that must be made during this period demand the availability of the best possible assessment of the extent of enemy attack. Accordingly, this investigation develops and describes an attack estimating system that will provide timely information needed for operational purposes and that will minimize the effects of inadequate and inaccurate information. It is further shown how the attack estimating system can be used with existing damage assessment methods.

II SUMMARY

This research develops and presents a statistical concept for making national survival estimates in the transattack and early postattack periods. Statistical methodologies are used to process reports of detonations, and the principle of statistical inference is used to estimate the magnitude and scope of the attack. Existing systems for the preparation of national survival estimates in the transattack and early postattack periods are based largely on preattack planning methods or on the tabulation of direct damage reports as they are received. Adequate and accurate data of the kind needed to produce survival estimates with these techniques will not be available in the transattack and early postattack periods.

The four principal activities of the concept developed by this research are (1) real time input processing and data preparation, (2) statistical conversion of data to information, (3) inference of attack size and target system, (4) estimation of effects on resources and population. Activities 1 and 4 above may have much in common with certain existing survival estimating systems. The main distinctions between this and other survival estimating systems are in activities 2 and 3. The concept developed by this research uses statistical inference and heuristic decision rules to estimate the magnitude of the total attack. The methodology thus devised can operate with incomplete and inaccurate information. Targets are inferred by statistical inference after appropriate grouping of target candidates into target categories and vulnerability groups.

The methodology includes: the receiving and processing of burst information and direct damage reports for use in making survival estimates; basic concepts for organizing inputs from various sources into appropriate data files; and provision for supplying measures of reporting performance to the system operator. Detonation reports and other data are converted statistically to information that is more directly applicable to survival estimating. Estimated actual ground zeros and targets for the initial

target list are determined statistically. Areas where data are incomplete or possibly inaccurate are identified, and status reports are requested to correct these deficiencies. An initial target system is developed that yields information on the target categories hit and on the severity of the attack.

The next main step is inference of the full attack size and target system. This is accomplished with the aid of the initial target list, a list of target candidates, and a knowledge of target categories and vulnerability groupings. At the completion of this step, an augmented target list that in general will be expanded considerably from the initial target list will have been developed through statistical inference. Again, status reports will be requested to cover areas of doubtful or inadequate information.

The final step of the concept is to estimate effects on resources and population by means of the synthesized target system. It is shown how a target system may be coupled with several survival estimating techniques to produce survival estimates. The survival estimating technique selected may well depend upon the requirements of the system operator at a given point in time. A summary of the system and its principal activities is given in Table 1.

Section VIII presents details of statistical methodology for estimating actual ground zeros and targets relevant to a group of detonation reports. A basic tool is the use of confidence regions and confidence intervals to determine the actual number of bursts and estimate actual ground zeros associated with a particular group of detonation reports. The selection of target candidates for the initial target list is also accomplished statistically, using a least-squares methodology. Weapon yields and heights of burst for a given group of detonation reports are derived mathematically.

Appendix A provides more detailed flow charts for some parts of the conceptual system. The basic purpose of these flow charts is to document the ideas that have been developed in the course of this research but that are not appropriate to the generalized flow charts of the main

Table 1

SYSTEM SUMMARY

Process	Activities	Data and Information: Inputs	Data and Information: Outputs
Real time input processing and data preparation	● Receive NUDET, satellite, direct damage, and requested status reports from sensors, reporting agents, operating areas, and important facilities ● Screen reports to eliminate inaccuracies and inconsistencies ● Convert reports to electronic data processing format ● Organize inputs into data files giving current facility status and reports of detonations ● Document the input system activity, numbers of facility reports, and other measures of reporting performance	Sensor NUDET Manual NUDET Satellite OCD reports a. Direct damage b. Requested status	● Current facility status ● Detonation records ▛ Reporting system activity and performance
Statistical conversion of data to information	● Analyze detonation reports to determine number of actual ground zeros and weapon characteristics ● Evaluate reports statistically to select the most likely targets ● Modify target selections to agree with direct damage reports ● Describe initial target system in terms of number of target categories hit and severity of the attack ● Document inconsistencies and apparent conflicts between target selections, direct damage reports, and detonation records	● Target candidates ● Facility status ● Detonation records	● Initial target list ▛ Exception reports 1. Detonations with no targets 2. Targets destroyed with no report of detonation
Inference of attack size and target system	● Infer attacker's priority system from initial target list and military intelligence ● Augment initial target system by addition of selected targets of high attacker priority ● Estimate total attack yield, fraction surface weapons, vulnerability group yields ● Summarize known and estimated features of the developing attack description	● Target candidates ● Initial target list	● Augmented target list ▛ Summary descriptions of initial and augmented target selections
Estimation of effects on resources and population	● Select assessment or estimating system appropriate for desired survival figures and information developments ● Calculate expected results of the attack	● Resource data base ● Initial target list ● Augmented target list ● Facility status	▛ Survival estimates and assessments

report. The flow charts of Appendix A will help provide the basis for developing the system to a point where computer programs for the system can be written. However, considerable additional work will be needed before these flow charts are adequate for that purpose.

The feasibility of inferring detonation records from direct damage reports is investigated briefly in Appendix B, which also gives a framework for such inference, using pattern recognition and hypothesis testing.

This research effort has developed methodology for estimating attack size in the transattack and early postattack periods, and has shown how this methodology can be combined with existing damage assessment methods to produce national survival estimates. More advanced survival estimating techniques, that would integrate attack size estimating and damage assessment more directly, are briefly explored. Survival estimating systems recommended for full development and implementation by the National Civil Defense Computer Facility are identified.

It was not the intention of this study to develop computer programs ready to use. The development of such programs, based on methodologies presented herein, will require much additional effort.

III FUNCTIONS AND ORGANIZATION OF CIVIL DEFENSE

The general organization of civil defense is indicated in the Federal Civil Defense Guide,* which describes functions in the national, state, and local governments. The objectives and responsibilities of civil defense are outlined in the National Plan for Emergency Preparedness.†

The principal objectives of civil defense are twofold: (1) to protect life and property by providing the means and knowledge necessary to minimize attack effects, and (2) to preserve life and property by operations and instructions necessary to reduce attack effects. Civil defense is also responsible for supporting services necessary to achieve and maintain a capability for effective and coordinated attainment of civil defense objectives. It is in this latter category that survival estimating falls.

Civil defense is the joint responsibility of federal, state, and local governments, with the federal government responsible for providing necessary coordination, guidance, and assistance. Federal government agencies, including the Office of Civil Defense and the military, advise, guide, and assist the states and their subdivisions. Figure 1 shows the major government elements likely to be involved in postattack survival estimating.

The Office of Civil Defense, under control of the Secretary of the Army, is responsible for carrying out DOD civil defense responsibilities. OCD has headquarters in the Pentagon and has eight regional offices covering the United States and its territorial possessions. The regional offices work closely with the state civil defense agencies, and through them, with local civil defense organizations. The Office of Civil Defense coordinates

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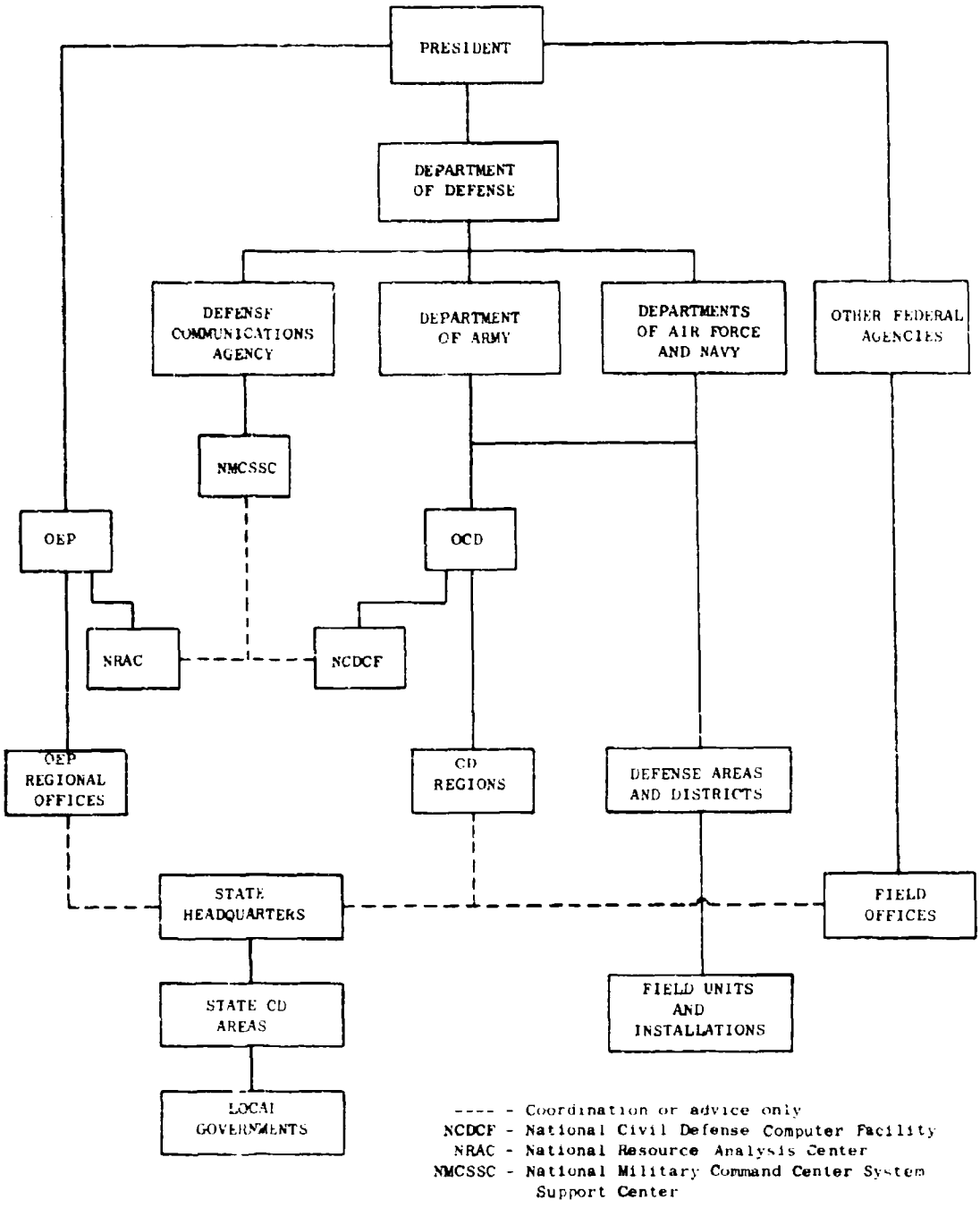
* "Federal Civil Defense Guide," Office of Civil Defense, Washington, D. C. March, 1965.

† "The National Plan for Emergency Preparedness," Office of Emergency Planning, Washington, D. C., December 1964.

Figure 1

MAJOR GOVERNMENT ELEMENTS INVOLVED
IN POSTATTACK SURVIVAL ESTIMATING



federal activities in support of situation analysis for civil defense purposes. OCD also acts as a depository for preattack and postattack resource data related to civil defense, and as an exchange point and situation analysis center for civil defense planning and operations. The National Civil Defense Computer Facility, operating under control of the Office of Civil Defense, would play an important role in postattack survival estimating.

The Office of Emergency Planning (OEP) is closely associated with the Office of the President, and is responsible for determining policy on civil defense, and for planning, directing, and coordinating the total civil defense program. OEP also determines the civil defense roles of other federal agencies and coordinates their civil defense activities with each other and with those of the states. OEP further aids in arranging mutual aid compacts among the states and in enacting legislation for civil defense purposes. The National Resource Analysis Center (NRAC), a facility operated by OEP, coordinates federal activities in support of situation analysis for purposes of continuity of government and for central programming of resources. NRAC, using its own and associated facilities, acts as a depository for preattack and postattack resource data and as an information exchange mechanism to support emergency decision making.

Other federal agencies participate in the national resource evaluation programs and provide OCD with data required for civil defense plans, programs, and operations. They also maintain the capability to assess the effects of attack on resources under their cognizance, and provide OCD with data required for plans, programs, and operations in support of situation analysis for civil defense purposes. Civil defense responsibilities of the other federal departments and agencies are presented in some detail in the Federal Civil Defense Guide. In general, each federal agency develops civil defense plans for use of its personnel, materials, and services during a civil defense emergency. Field offices of the federal agencies work closely with the states.

In the event of a national emergency resulting from a nuclear attack on the United States, the civil defense mission of the military departments is to assist civil authorities in restoring order and civil control,

by employing whatever military resources are not required for military operations. Available military support would be used to return essential facilities to operation, prevent unnecessary loss of life, alleviate suffering, and take other actions as directed to insure national survival and a capability on the part of the nation to continue the conflict. Military support would be in coordination with, and supplementary to, the capabilities of state and local governments and would be terminated as soon as possible, to conserve military resources and to avoid infringement on the responsibility and authority of civil government agencies. However, several military systems are available for civil defense purposes routinely--for example, logistic support by the Defense Supply Agency. The U.S. Army Corps of Engineers and the Naval Facilities Engineering Command provide engineering support in such civil defense activities as the shelter survey and marking program and community shelter planning, as required. A basic function of the National Military Command System Support Center, operated by the Defense Communications Agency, is damage estimation. This facility is an important part of the national damage estimation capability, and would undoubtedly contribute to postattack survival estimating for civil defense purposes.

State and local governments are responsible for civil defense operations within their jurisdictions. These governments develop the necessary plans, capabilities, and procedures to carry out civil defense activities in accordance with state law and federal policies and guidance. State and local governments collect data and prepare materials required for estimating damage and making situation reports. Local governments would report information to the state, and it in turn would report to the federal agency field offices and the OCD regional offices.

IV POSSIBLE DECISIONS REQUIRED IN POSTATTACK OPERATIONS

It would be futile to try to predict exact postattack situations in advance. There is no doubt, however, that many important decisions would be required in the very early time period following a major nuclear attack on the United States. This section will identify some of the types of decisions likely to be required and the people who may make them. This discussion is centered on decisions to be made at the national level. Decisions likely to be required at the local level will be similar in many instances, but their scope and nature may be quite different.

Some Likely Decisions

Among some of the more important decisions that are likely to be required at the national level and that will be strongly affected by damage assessment results are decisions regarding:

- Direction and coordination of state and local governments
- Provision of area warning, and public information
- Conservation and distribution of manpower
- Relocation of population to reduce direct threats to life
- Allocation of military support to civil authorities
- Maintenance or reestablishment of government control
- Formulation of plans and procedures for future actions
- Protection and restoration of essential utilities
- Allocation of resources and facilities
- Protection and relocation of essential stocks and inventories
- Reallocation or restoration of communications channels
- Maintenance or reestablishment of transportation links
- Relocation of survival resources, such as emergency hospitals and medical supplies
- Establishment of requirements for additional information

Early decisions at the lower levels will often be concerned with direct threats to life, such as fire and fallout. They will also be needed regarding protection and allocation of food, water, medical supplies, and other inventories and facilities necessary for protecting life in the immediate future.

The Decision Makers

The individuals or organizations who make the important decisions at the national level may well depend on who the survivors are. Since civil defense and national government are an extensive and highly complex network, the decisions to be made will necessarily involve a large number of individuals and organizations. Certainly the President and his staff will be closely connected with most of the important decisions, and the President may well make many of them himself. The heads of government departments will clearly be called on for many decisions. The head of the Department of Health, Education and Welfare would unquestionably be called on for decisions regarding the utilization and allocation of medical manpower and resources. The Secretary of Defense and heads of the military departments would be expected to assist the President in decisions regarding continuation of the war. The Office of Civil Defense and Office of Emergency Planning would be called on for decisions regarding: direction and coordination of state and local governments; provision of area warning and public information; emergency assistance; and many other matters.

Although it will often be difficult to identify the decision maker in advance, nevertheless the decisions must and will be made, and the best possible damage assessment information is needed for such decisions.

V POSTATTACK SURVIVAL ESTIMATING PROBLEMS

The nature of the inputs available in the postattack environment would have a significant effect on the character of the survival estimating system. The postattack actuality would in some ways be more helpful than preattack assumptions, as in the case of dose rates, where direct reports would replace predictions based on assumed yield, average winds, and other factors. On the other hand, postattack data could often be quite misleading because of incompleteness and biases introduced by sensors and communications. In general, the data following attack are likely to be much more varied in content, reliability, and timing than inputs normally assumed in preattack planning.

The survival estimating system must be able to accept these varied, biased, and time-phased reports, translate them into a reasonably unbiased picture of actual damage conditions, and present findings in a form suitable for making operational decisions. Since the data will be basically inadequate, it will be necessary to make a variety of assumptions about the actual environmental conditions. Systematic rules must be applied for acceptance or rejection of these assumptions. Rules must also permit modification and repeated testing of assumptions against incoming data. Available data augmented by accepted assumptions would provide the rational basis for decision.

Differences Between Preattack and Postattack Survival Estimating

Major differences between the damage assessment problem as it is currently approached in the preattack period and the problem as it would be in an operational, postattack environment have been discussed by Spence and Moll.* Some of these differences have been expressed in terms of system input and output requirements, and are presented in Table 2.

---

* Spence, Richard H. and Kendall D. Moll, "Rapid Damage Assessment in the Postattack Environment," Stanford Research Institute, Menlo Park, Calif., February 1961.

Table 2

INPUT-OUTPUT DIFFERENCES BETWEEN PREATTACK AND POSTATTACK DAMAGE ASSESSMENT SYSTEMS

	Preattack System Assumptions	Postattack System Actualities
Input		
Weapon data	Exact yield, burst height, ground zeros	Variable quality depending on information source
Wind data	Exactly specified or assumed values	Approximate or seasonal values for given areas
Format	Fixed for individual computations	Variable
Time of receipt	One group of data from a single source	Staggered reports from varying sources
Resource locations	Fixed resources	Fixed and mobile resources
Burst time	Simultaneous bursts	Bursts at variable times
Output		
Detail	As much as is available for the analysis	As little as is necessary for the system users
Format	Selected for simplified computer output without regard to ease of interpretation	Selected for rapid analysis in an operational environment
Output grouping	Usually in single group for each set of input conditions	Output on request by users, or as damage information changes
Revisions	Not necessary	Necessary whenever new input information becomes available to the system

Source: Spence, Richard H. and Kendall D. Moll, "Rapid Damage Assessment in the Postattack Environment," Stanford Research Institute, Menlo Park, California. February 1961.

Input differences appear to be the most significant. Inputs can generally be specified exactly in the preattack system, but postattack inputs covering actual weapon strikes may be approximate, incomplete, or inaccurate. For example, postattack inputs may consist simply of reports of nuclear detonations in a general area, whereas preattack inputs provide the exact yield and location of each assumed detonation. Wind data present similar problems; such data may be exactly specified for the preattack case, but there will probably be inaccurate information and uncertainties associated with postattack wind data. For example, wind data are provided in general only at 6 hour intervals, and many changes in wind conditions are possible during such periods. Many attacks no longer assume simultaneous bursts, an improvement over the situation that existed when Table 2 was prepared.

The format for inputs to the preattack system can be standardized and fixed for individual computations. If this were done for the postattack system, however, it might well result in unacceptable consumptions of time. Thus the postattack system must be much more flexible than the preattack system. Closely related to this is the matter of burst times. Preattack systems in the past have often assumed simultaneous bursts, but in postattack systems, burst times will probably occur and be reported at varying intervals. These and other sporadic inputs must be processed as they become available, and then revised as new information is received. Staggered reports will be received from varying sources, in contrast to preattack analyses assuming a single group of data from one source.

Preattack systems are generally designed to produce the total output in a single computer run from one set of input conditions. In the postattack period, on the other hand, decisions to be made require that output be produced on request by users, or whenever damage information changes. Postattack decision makers will probably want periodic reports as well as the ability to interrogate the system on specific points of interest.

Formats for preattack systems are generally designed to minimize programming and computer computation rather than to provide ease in interpretation and analysis of output. For a postattack system, easily read formats based on rapid analysis in an operational environment are necessary.

Much of the detail generally required of preattack analyses will probably not be needed for postattack systems. Only the amount of detail that is needed for essential postattack decisions should be provided.

VI OBJECTIVES OF TRANSATTACK AND POSTATTACK SURVIVAL ESTIMATING

The traditional role of survival estimating systems is to estimate the losses of population and resources resulting from nuclear attacks. As survival estimating techniques have become better understood and developed, it has become apparent that the basic techniques can also be used to synthesize an attack during the transattack and early postattack periods. This latter capability could be very useful as the basis for warning populations and taking countermeasures.

Operational survival estimating systems are similar in many ways to preattack planning systems, but significant differences exist. For example, an operational system of survival estimating should provide for verification and correction of indirect damage assessments. The range and variety of attack parameters considered in an operational system will probably be more limited than in preattack planning systems. Furthermore, the resource base upon which the damage assessment is made should be formulated from larger groupings, i.e., the unit size of the data base can be larger, or the data base can be sampled.

The attack synthesis function of operational survival estimating performs two important functions: (1) it permits the extension of resource damage analyses into nonreporting areas, and (2) it can be used to estimate the strategy being employed by the attacker.* It is expected that the weapon data needed for damage and resource evaluation will be available from automatic and manual sensing systems, and from direct reports based on aerial and ground observations. Since portions of the sensing and intelligence gathering network are likely to be destroyed during the attacks, the nonavailability of complete information must somehow be compensated for if

* This in turn can be used to predict the development of the attack.

the damage estimates are to be complete. One way to accomplish this purpose is to employ a combination of judgment and inference from available information relying mainly on the latter. Synthesis of the attack strategy could also be useful in the early stages in estimating whether the attack is oriented toward civil population, military retaliatory forces, industrial resources, or other objectives. This type of attack-pattern projection and its ability to identify probable targets as the attack progresses could be crucial to population or other resource warning systems.

VII A STATISTICAL CONCEPT OF SURVIVAL ESTIMATING

General

The requirements to be placed on an operational survival estimating system, together with the probability of limited available information, suggest a statistical rather than deterministic approach. Concepts and some details for a statistical approach are presented in this section. The presentation of this section is largely in terms of generalized flow diagrams with accompanying descriptive material. More detailed flow diagrams are given in Appendix A.

The system described is intended to operate with incomplete and perhaps inaccurate data. The underlying principle is that of statistical inference, i.e., the definition of an entire attack design from an early and probably small sample of attack reports. The statistical inference techniques devised are then coupled with heuristic reasoning to provide the information required to implement the survival estimation procedure.

Unique features associated with the survival estimating system presented include:

1. The system operates with incomplete and inaccurate data, i.e., only a sample of the data describing the attack is needed to produce preliminary survival estimates. The approach in this respect is therefore somewhat similar to that followed by the major radio and television networks on election nights in which the networks attempt to estimate the final vote from preliminary, and other scanty, information.

2. The system makes extensive use of direct damage reports. Direct damage reports are used to infer NUDET-type information and to verify other reports.

3. The system identifies requirements for status reports that are needed to upgrade system results; that is, the system is designed

to automatically generate requests for data where there are gaps in the data, or where necessary data have not been provided.

4. The conceptual system described by this report is a real time system in that input data are continuously processed and handled statistically to infer attack size and target system. Production of survival estimates, the next step, can be essentially real time if the parametric survival estimating method is used. However, generation of survival estimates using large data bases would require appreciable time periods, thus falling outside the usual definition of real time. Also, it should be realized that detonation and direct damage reports will in most cases not be received as soon as detonations occur; there will be some delay before this input data enters the system.

5. The system may also identify certain target areas in advance of their being attacked, based upon the attack pattern produced from the sample of attack data.

6. The synthesized target design can be coupled with a variety of survival estimating techniques depending upon the needs and desires of the system operator.

Statistical Damage Assessment

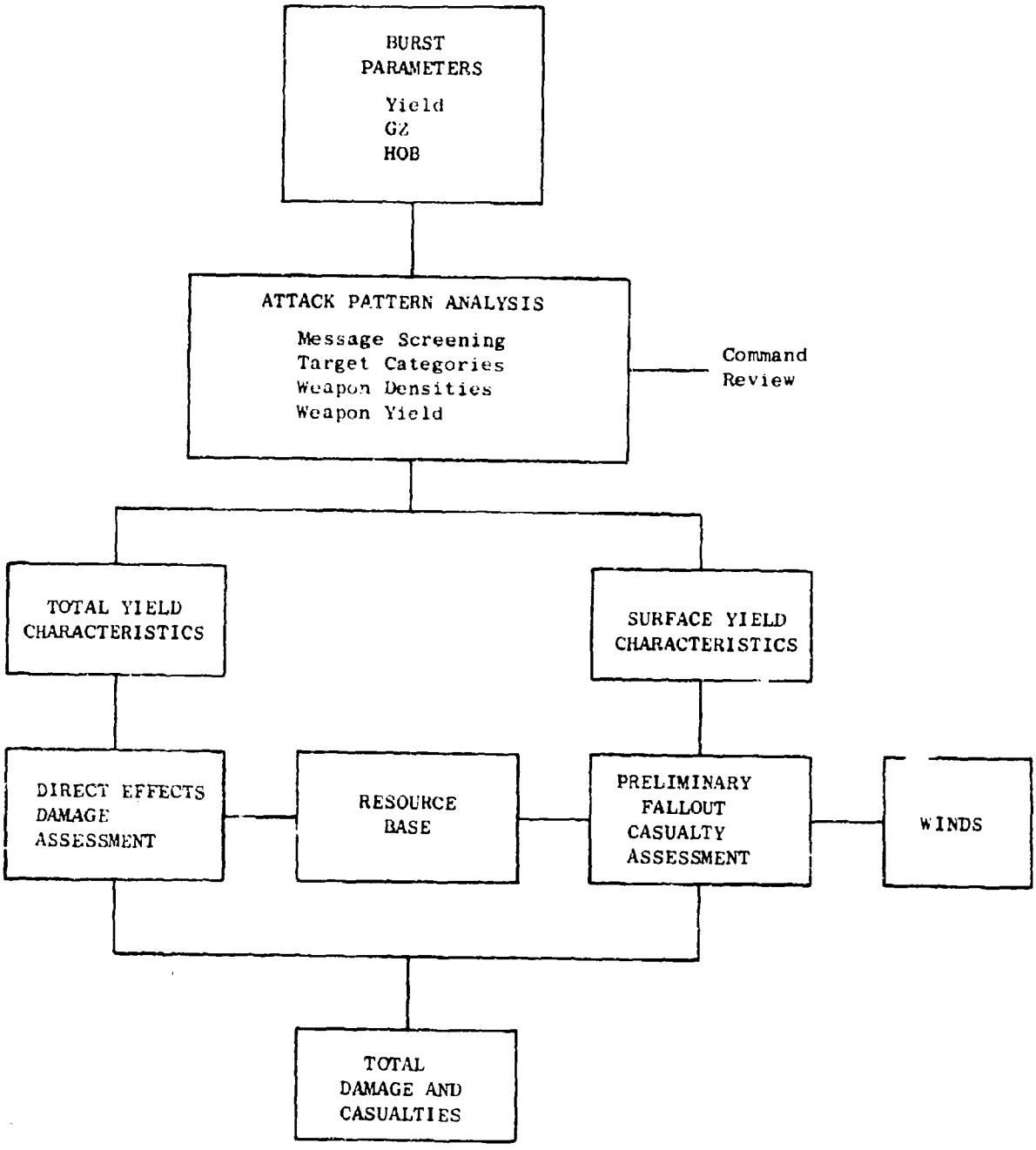
A highly relevant statistical method of estimating damage from nuclear attacks was devised and presented by Laurino.* The general logic of the overall damage assessment procedure presented by Laurino has been summarized by Bothun and is shown in Figure 2. The system logic as presented by Laurino consisted of seven distinct phases.

1. Screening of incoming reports
2. Definition of the target system
3. Determination of average yields per target
4. Determination of fraction surface yield

* Laurino, Richard, David Goodrich, and Donald Doane, "Statistical Methods of Estimating Damage from Nuclear Attacks on CONUS (U)," Stanford Research Institute, Menlo Park, California, 1962. (SECRET)

Figure 2

SUMMARIZED LOGIC OF DAMAGE ASSESSMENT PROCEDURES



Source: Bothun, R. B., "Uses of Radiological Fallout Information in Operational Postattack Damage Assessment Systems (U)," Stanford Research Institute, Menlo Park, California, January 1965 (CONFIDENTIAL)

5. Augmentation of target system
6. Determination of attack parameters
7. Determination of damage estimates

The procedures presented by Laurino provided gross estimates of population casualties and resource damage within the limitations of the data base and the approximating procedures used. The procedures provided only for survival estimates derived from precalculated survival functions of yield versus damage. In the event of computer malfunction, and where precise location of damage is not required, this system makes possible quite rapid manual calculations that take into account the pattern and weight of attack. This feature is carried over as a capability of the system presented by this study. Laurino's system is based on a minimum number of independent parameters, and the submodels of the system are as simple as possible, consistent with the general requirements for accuracy and flexibility.

Many of the statistical concepts presented by Laurino are employed in the overall system devised in this study. Where Laurino's original concepts have been adopted, they have been further developed and extended. However, several major differences exist between this and the Laurino study, including: (1) provision is made for extensive use of direct damage reports; (2) the system identifies and generates requirements for status reports; (3) the system is designed to operate on a real time basis; (4) techniques are presented coupling the basic target identification system with several survival estimating techniques rather than one; and (5) the statistical methodology and techniques have been modified and improved.

Attack Synthesis Coupling with Survival Estimating Systems

A brief description of various survival estimating and damage assessment systems will be presented before proceeding to the specific subsystem considered in this study. The purpose of this discussion is to summarize the various survival estimating and damage assessment systems that might be employed with the statistical target synthesis concept of this report.

The statistical target design system produces NUDET-type information for each actual ground zero determined. This information includes weapon

yield, height of burst, ground zero, and time of burst. The data may be summarized for use with parametric systems (based on preattack planning calculations) or may be used with individual ground zeros for more accurate survival estimating systems.

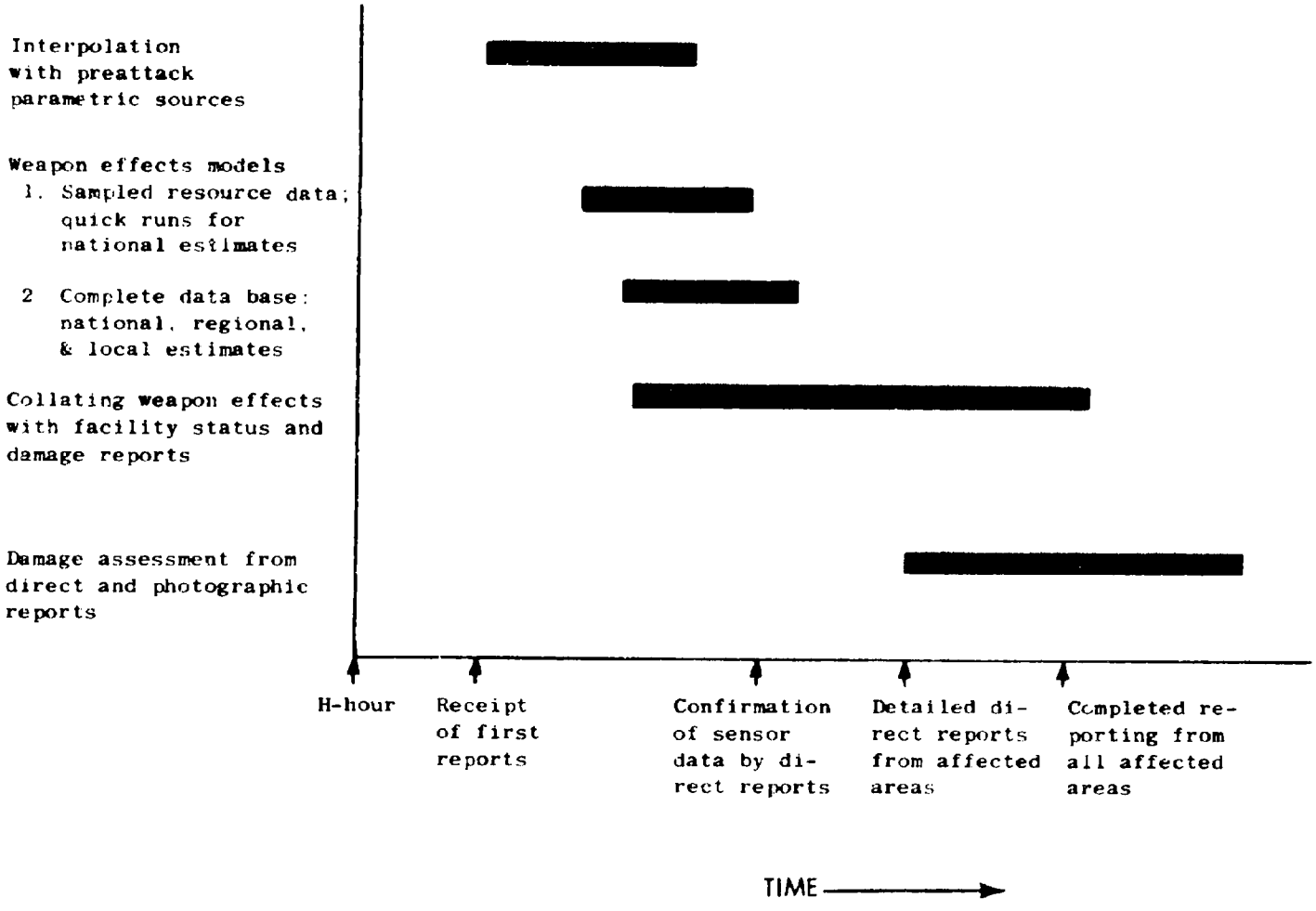
Some of the survival estimating and damage estimating systems that might be employed are shown as a function of time in Figure 3. The time axis of this figure is not intended to be exact, but only somewhat representative. The time period shown ranges from H-hour (considered to be the time of the first detonation), to the time when reporting is completed, or essentially completed, from all affected areas.

The first system indicated in Figure 3 is that which employs preattack calculated damage functions. The principal advantage of the parametric system is that it is very rapid and can easily be accomplished manually if necessary. The principal disadvantage of this system lies in the uncertainty regarding its accuracy. Unfortunately, the attack designs selected for the precalculated damage functions may not closely resemble the actual attack. The achievement of surprise is a fundamental military principle, and history is replete with examples in which surprise has been achieved. Thus, an actual attack on this country may not compare well with assumptions made for any of the preattack calculated damage functions.

The second major category of survival estimating and damage assessment systems that might be employed is based on a combination of weapons effects scaling models and resource data bases. Two such systems are illustrated in Figure 3--those based on SRI SAMPRO and DASTAP programs. These systems are currently used for preattack planning studies, but they may easily be adapted for survival estimating in transattack and postattack periods. DASTAP employs a rather complete data base of some 44,000 resource points. The SAMPRO program employs only a small fraction of DASTAP's resource points--about 4,000. Thus the SAMPRO program may be run with much less computer time than the complete data base DASTAP program. The running of a SAMPRO program may require about 5 minutes or less, whereas the running of a DASTAP program may require an hour or more. Although SAMPRO runs are less accurate than DASTAP runs, SAMPRO is accurate enough to be suitable for quick runs concerning national estimates.

Figure 3

SURVIVAL ESTIMATING AND DAMAGE ASSESSMENT SYSTEMS



SAMPRO thus appears to be eminently suited for use with statistical systems, when the sample is relatively small. The principal disadvantage of the SAMPRO system as compared with the parametric system is that SAMPRO requires a computer, and the parametric system may be operated manually. However, this advantage may be more theoretical than actual, because incoming reports from affected areas are likely to be so numerous, particularly those concerning radiological hazard conditions, that a computer will be needed for processing the quantity of incoming data in any case.

The next survival estimating system depicted in Figure 3 is one based on a combination of weapons effects scaling and reports from the field. This system would employ the statistical target synthesis method presented by this report, together with weapons effects scaling models in the very early transattack and postattack periods. In this respect, it would be like the SAMPRO and DASTAP based survival estimating models described above, but would also differ from them by using direct reports from affected areas to correct and update quick survival estimates made in the very early periods with SAMPRO or DASTAP. That is, direct damage and status reports from the various resource points in the field will be used to provide new survival probabilities at each resource point and replace earlier survival probabilities derived from weapons effects scaling models. Thus, in this particular model, survival probabilities at a given resource point will initially be based only upon the statistical target identification system and weapons effects scaling. These survival probabilities will all be replaced as direct damage reports and status reports are received from the operating areas. A transition period would exist, in which the total survival estimate would be partly based on weapons effects scaling and partly on direct reports. This system has the advantage that it can provide a continuous total national survival estimate using the best available data at all times. This model has not been developed, and considerable additional research will be required to complete it.

The remaining survival estimating system indicated in Figure 3 is one based on direct reports only. The obvious disadvantage of this system is that it provides no national survival estimate in the transattack and early postattack periods. Such a system is clearly not suited for meeting

civil defense objectives. Furthermore, it has no advantage over the system described in the paragraph above.

The preceding discussion has described how a statistical target synthesis system might be used with various survival estimating and damage assessment systems. In general, it appears that the capability for carrying out a combination of these systems is desirable. The parametric system may be useful for making flash estimates in the very early periods. If the parametric system is used, it should be followed closely by the SAMPRO system which can provide improved estimates in very short times. The most accurate and useful system in the later periods will be a system like that described above which incorporates the best features of weapons effects scaling models and direct report models. All of these systems should be useful at the national level.

Target Information

Certain target categorizations are desirable in the development of the statistical concept. First of all, it is assumed that the operator of the system has available to him a reasonably complete and well-defined target list. This target list will presumably be similar, or identical, to target lists currently used in preattack planning studies.

The target list will be divided into target categories, and the total target list might typically consist in some 20 to 30 target categories. For example, a target category might consist of Minuteman sites. Other examples of possible target categories include submarine bases, Strategic Air Command bases, and population centers.

For purposes of developing decision rules and estimating uncertain weapon parameters, the target list will also be broken down by vulnerability groups. The three vulnerability groups used are designated as military hard, military soft, and nonmilitary. The ways in which target categories and vulnerability groups are used will be described in following sections.

The statistical target synthesis system also uses a target priority list, by category, provided that such a list is available. The availability

of a target priority list is helpful but not essential for the system. Such a list would presumably be based in large part on strategic intelligence and pattern analysis of the early attack reports. It would also presumably be based upon the assumption of a rational enemy, but not necessarily. Use of a target priority list will be further explained later in this report.

Components of the Statistical Target Synthesis System

The statistical target synthesis system is made up from a number of subsystems. The subsystems include data input and verification, direct damage report processing, requested status report processing, detonation record maintenance, initial target selection, and final target system definition. Each of these subsystems will be described briefly below. The inputs, principal steps to be accomplished and outputs of each subsystem are shown in associated figures. A greater level of detail for some subsystems is indicated in Appendix A.

Data Input and Verification

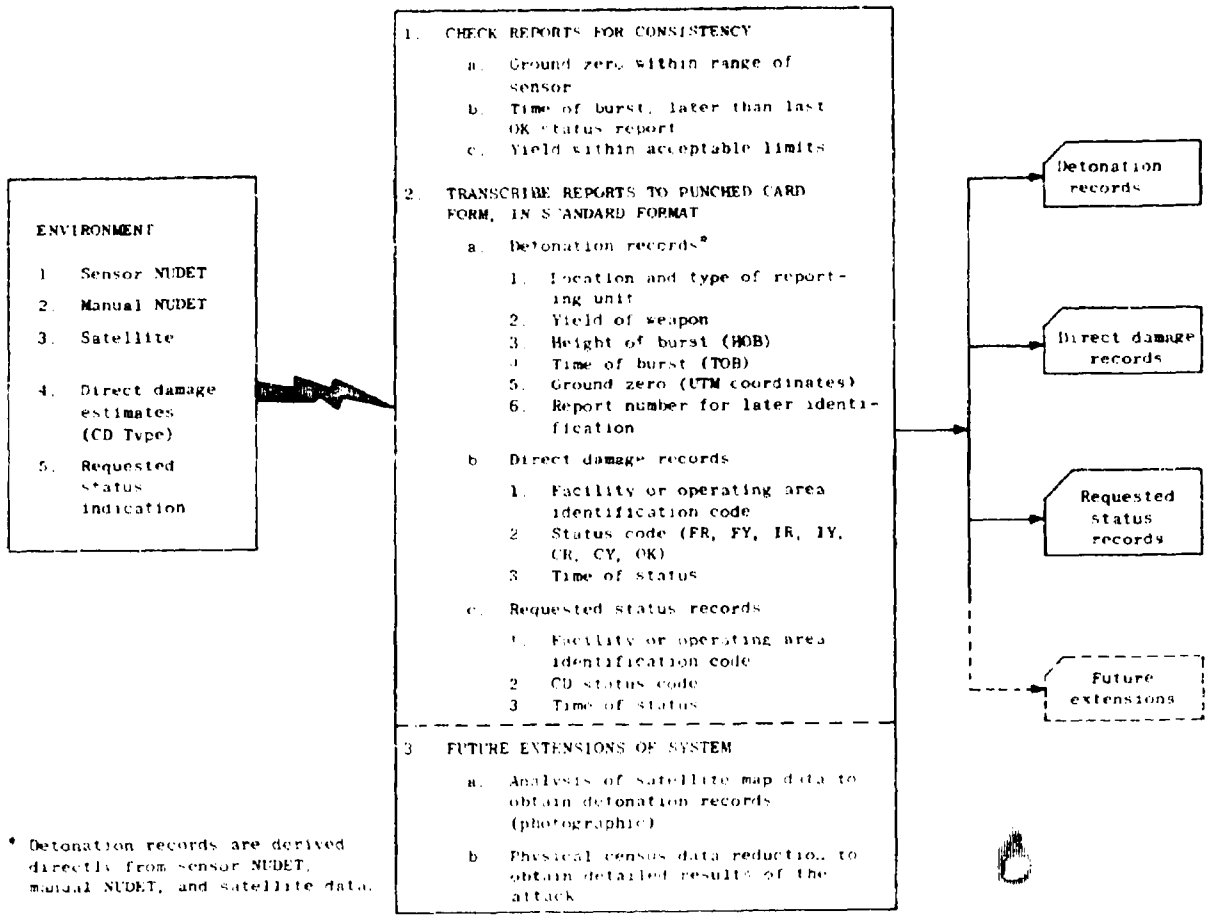
The principal elements of the data input and verification subsystem are summarized in Figure 4.

Subsystem Inputs

The subsystem is designed to receive inputs from many different sources. The principal sources are thought to be sensor NUDET, manual NUDET, satellite, direct damage reports, and requested status reports. The receipt and initial processing of this information presents many varied problems. Some of the data received will probably be accurate and some of the data will, no doubt, be highly inaccurate. The report reliability from the several sources may vary greatly. In the extremely early periods (e.g., the first detonation), there will no doubt be insufficient data for making reliable estimates. As time progresses and even in reasonably early periods, vast quantities of data may become available. There are many thousands of radiological reporting stations, and many of these

Figure 4

DATA (WEAPON AND DAMAGE REPORTS) INPUT AND VERIFICATION



* Detonation records are derived directly from sensor NUDET, manual NUDET, and satellite data.

stations will be reporting early. Dozens of manual NUDET reports covering a single detonation may be received. In this kind of situation, a system not capable of handling large quantities of data, and selecting important data while rejecting less important or trivial data, would be completely ineffective, and possibly inoperative.

The subsystem assumes the availability of electronic sensors for receiving and reporting essential NUDET data. If such a system is actually available during an attack, it presumably will provide weapon yield, height of burst, ground zero, and time of burst. The accuracy of each piece of information may vary considerably, depending on such things as distance between sensor and detonation, and other factors. Some elements of the data will probably be more accurate than others. One might expect the time of burst to be quite accurate, whereas the reported ground zero might not be very accurate if the sensor and detonation are separated by considerable distance.

Manual NUDET reports made by trained and untrained observers will probably also be received. Various techniques for estimating NUDET information manually are given in appropriate civil defense and other governmental publications. For example, weapon yield may be estimated from cloud height. The distance separating the observer and ground zero may be estimated by the time interval between the initial weapon flash and the arrival of the blast wave at the observer's location. These and other techniques may be used to estimate NUDET data manually. In general, one would expect the accuracy of manual NUDET data to be considerably less than that of Sensor NUDET data. However, the existence of one or more manual NUDET reports for a given detonation would enable one to accept with some confidence that a detonation had actually occurred. Faulty or incorrect data concerning the existence of a detonation might conceivably be received from electronic sensor systems.

A further main source of data indicated in Figure 4 is direct damage reports. These reports will be received in accordance with various civil defense directives.* Such reports may be received in the form of NUDET data, radiological contamination data, or other ways, such as a simple description of damage sustained. Direct damage reports will also presumably be received from civil defense operating areas, as in the manner described in certain current civil defense documents.† In this concept, proposed by Strope, each civil defense operating area would report its status by specified basic operating situations. The categories proposed give basic data regarding the fire and fallout condition of the operating area. This concept will be discussed further in connection with the direct damage report processing subsystem.

As indicated previously, the statistical target synthesis system will generate its own requests for operating area status when initial data are needed. Status reports would generally take the form of direct damage estimates and would be converted to a similar format when received.

The subsystem is designed to operate in the absence of one or several of the above sources of data. Presumably, direct damage reports and requested status reports could be made available in any case, but perhaps not for all operating areas. An essential point is that the subsystem is

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* "National Warning System (NAWAS) Operations Manual," Department of Defense, Office of Civil Defense, December 1966.
† "Concept of Operations Under Nuclear Attack," Office of Civil Defense, Washington, D.C., June 26, 1967. (Working Draft)

flexible enough to accept inputs from many different sources and is not dependent on any single source for its operation.

Subsystem Accomplishments

Data coming from the attack environment will first be tested for consistency. This test is intended to exclude data which are clearly inaccurate. For example, a consistency test might be one in which it is ascertained whether the reported ground zero is within range of the sensor. Another possible consistency test might be to ask whether the reported time of burst is later than the last O.K. (unaffected or undamaged) status report. Still another possible consistency test might have to do with weapon yield. Strategic intelligence should tell us what range of yields in general might be anticipated. If a weapon yield outside these limits is reported, it should be subjected to scrutiny by the system operator, and if consistency is questionable, status reports from these particular operating areas should be requested (as for other questionable cases).

After consistency tests, the next activity will be to transcribe incoming reports to punched card form in a standard format. Once this has been done, these reports are referred to as detonation records. Detonation records are initially derived only from sensor NUDET, manual NUDET, and satellite data. The elements of data that are proposed for each detonation record are as follows:

1. Location and type of reporting unit
2. Yield of weapon
3. Height of burst (HOB)
4. Time of burst (TOB)
5. Ground zero (UTM coordinates)
6. Report number for later identification

Subsystem Outputs

The outputs from the data input and verification subsystem are detonation records, direct damage records, and requested status records.

These outputs will presumably be in the form of punched cards. They will be immediately available as inputs for other subsystems.

Possible Future Extensions of the Subsystem

The subsystem activities described above are by no means intended to be a complete listing. As new sources of data become available, they should be considered for incorporation into the subsystem. For example, it has been reported that satellites will provide photographic data. These data should be used to obtain or supplement detonation records. Various information sources may also provide physical census data which can be summarized or reduced to obtain detailed specific results of an attack.

Direct Damage Report Processing Subsystem

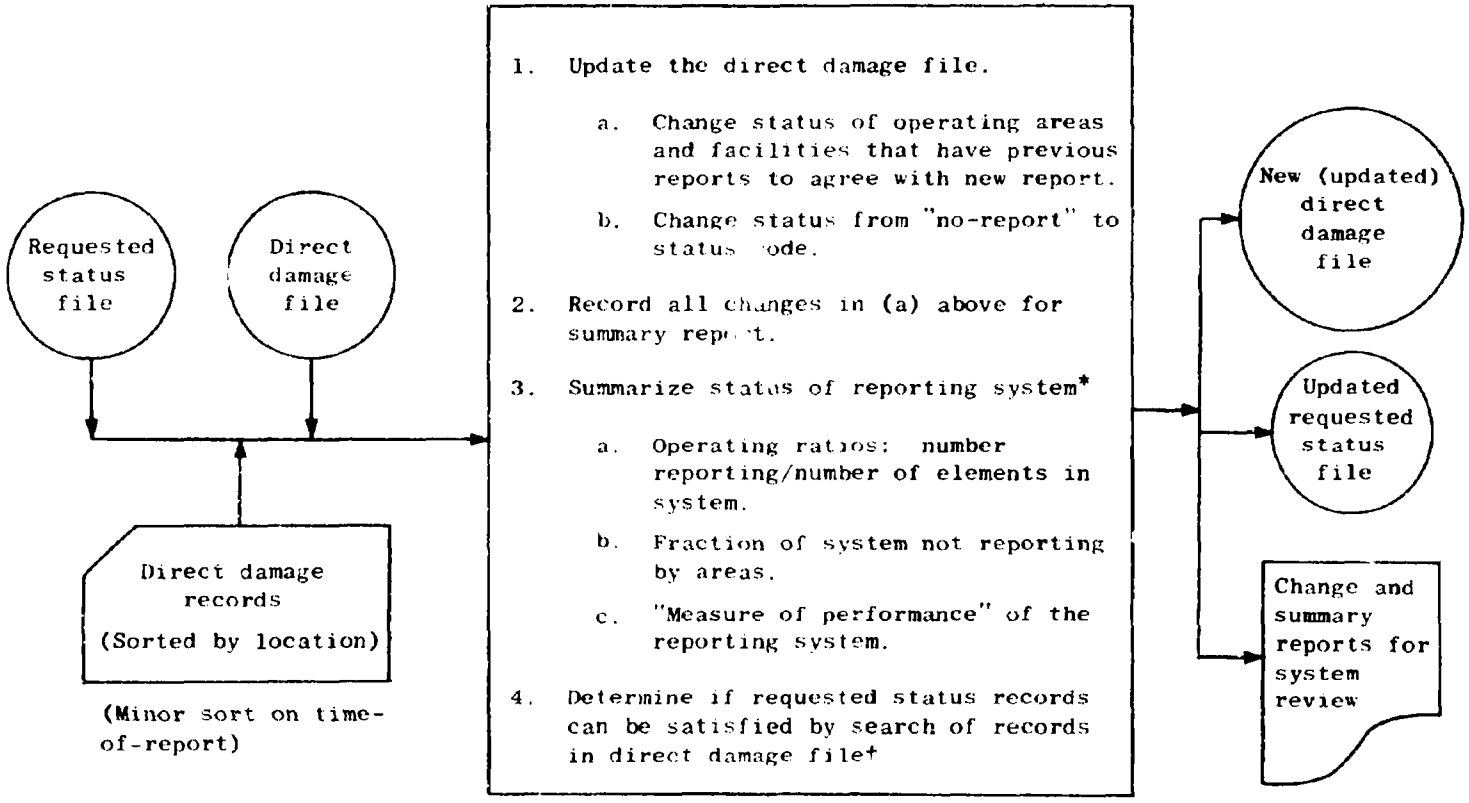
The principal inputs, accomplishments, and outputs of this subsystem are indicated in Figure 5.

Direct damage records are treated somewhat differently in the data input and verification phase since they may vary considerably and probably will not contain all of the elements of data required to produce a complete detonation record. Direct damage records should provide, as a minimum, the location of the operating area, identification code of operating area, the status code, and time of status. Various status codes might be employed but the status code considered here is that presented in "Concept of Operations Under Nuclear Attack," Office of Civil Defense, Washington, D.C. The basic operating situations and their corresponding codes are indicated in Appendix B. For example, a heavily damaged area might carry the following code designation:

Map Code	Basic Operating Situation	Situation Definition
8	LORAD-HIFIRE	Dose rate between 0.5 and 50 r/hr. Many fires beyond control capability.

Figure 5

DIRECT DAMAGE REPORT PROCESSING



* SMSAs or other geographical areas.

† Does this damage record satisfy a request for status?

This particular code will probably change as new reporting systems develop, but it is representative of possible simplified damage codes. Requested status records should indicate facility and location code, status code, and time of report.

System Inputs

The inputs for this subsystem are the direct damage file, direct damage records, and requested status file. Direct damage records are received from the data input and verification subsystem and are sorted by location. Direct damage records also receive a minor or secondary sort by time of report. The direct damage file is created upon receipt of the first direct damage record, and is maintained thereafter.

Subsystem Accomplishments

When a new direct damage record is received, the first action is to update the direct damage file. This is done by changing the status of operating areas and facilities that have previous reports so that the status agrees with the new report. If no report had previously been received from the relevant operating area or facility, the status would be changed from "no report" to the current status code.

One of the outputs of this system is a change and summary report which is presented to the system operator or other interested persons for system review. The next activity of the system, therefore, is to record all changes and operating area and facility status for the change and summary report.

A further activity of this subsystem is to provide indicators to the system operator regarding the overall status of the reporting system. Various indicators might be employed--for example, the ratio of the number of reporting operating areas to the total number of operating areas in the system would be of interest to the system operator. Another possible indicator would be the fraction of the system not reporting by areas. Such indicators should provide a measure of overall performance of the reporting system.

One of the principal uses of direct damage reports is to provide data for generation of detonation records. This is discussed in the section on detonation record maintenance and in Appendix B.

The final step in direct damage report processing is to determine if requested status records can be satisfied by a search of records in the direct damage file; that is, it should be ascertained whether the incoming direct damage record can satisfy a current status request.

Subsystem Outputs

Outputs of the direct damage reporting subsystem include an updated direct damage file, updated requested status file, and change and summary reports for system review.

Requested Status Report Processing Subsystem

Inputs, activities, and outputs of this subsystem are indicated in Figure 6. In general, the handling of requested status reports is similar to that given for direct damage reports.

System Inputs

System inputs for the requested status report processing subsystem are the requested status records themselves, the requested status file, and the direct damage file. The requested status records should be sorted by location with a minor sort by time of report.

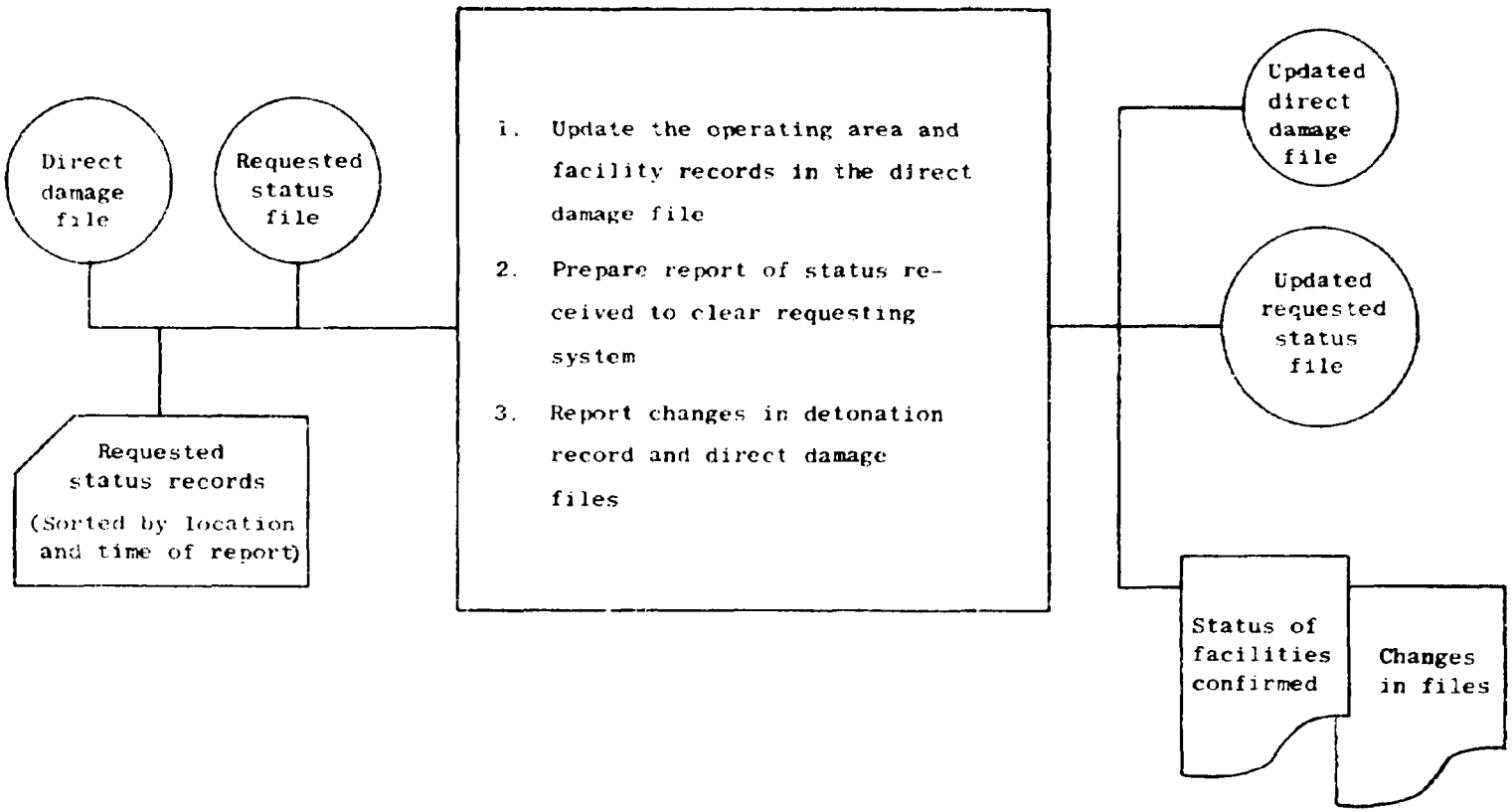
Subsystem Accomplishments

Status reports will result only in response to a specific request. Therefore, one of the first and perhaps most important actions will be to update direct damage file records for appropriate operating areas and facilities.

The requesting system should also be cleared of requests for status that have been received. Finally, reports of changes in detonation records and direct damage files should be printed out for inspection by the

Figure 6

REQUESTED STATUS REPORT PROCESSING



system operator and other interested persons. As with direct damage processing, detonation records will ultimately be inferred from requested status records as needed.

Subsystem Outputs

The principal output of this subsystem is an updated direct damage file. Other outputs are an updated requested status file, and printouts of changes in files and status of facilities confirmed by requested status records.

Detonation Record Maintenance Subsystem

Some of the statistical procedures covered in this subsystem are described in greater detail in the next chapter of this report. Several of the key points relating to the statistical basis for the survival estimating concept center around this particular subsystem. The principal components of this subsystem are indicated in Figure 7.

Subsystem Inputs

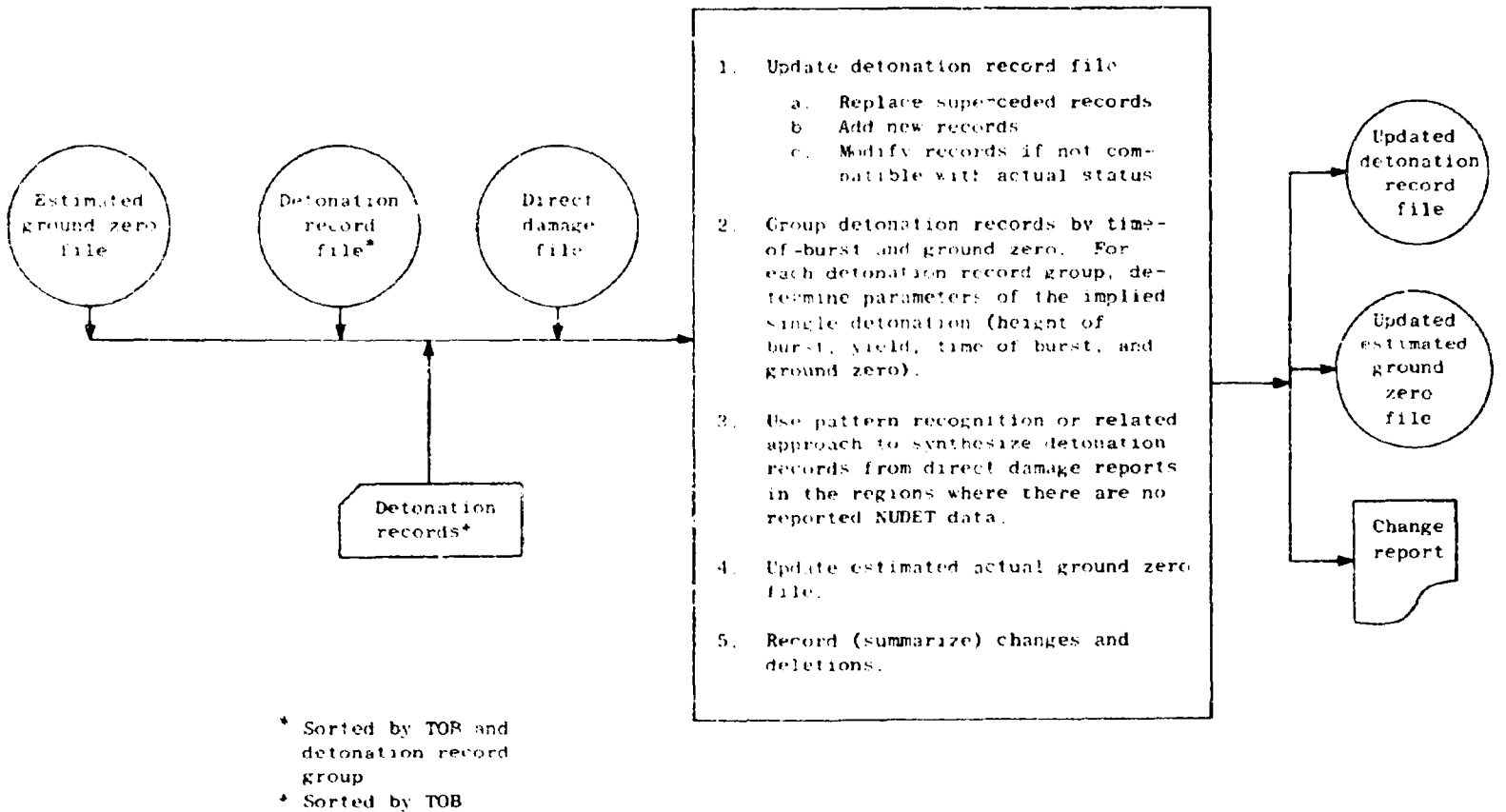
The inputs for this subsystem are detonation records, the detonation record file, the direct damage file, and the estimated actual ground zero file. Detonation records are sorted by time of burst and by geographical locations.

Subsystem Accomplishments

As new detonation records are received, they are used to update the detonation record file. Superseded records should be replaced, and new records should be added to the file. In addition, detonation records should be compared with relevant direct damage records, to determine whether they are compatible. If the detonation record is not compatible with actual status, then the detonation record should be modified to eliminate the incompatibility.

Figure 7

DETONATION RECORD MAINTENANCE



* Sorted by TOB and detonation record group

* Sorted by TOB

The number of bursts represented by the sorted detonation records and necessary weapon parameters are next determined. This is done statistically, as described in the next chapter. The number of bursts is estimated by an algorithm that separates the information inputs into groups depending on the overlaps of confidence regions associated with the reported ground zeros and times of burst. Each group generated by the algorithm represents one burst.

Detonation records are grouped by estimated actual ground zeros. These ground zeros are determined statistically from the azimuth data by a least-squares method that is described in the next chapter of this report. Standard deviations of the relevant reporting media are used in connection with determining location of reported ground zero, weapon yield, and time of burst.

The next activity of the subsystem, and a key activity for operation of the whole system, is the generation of estimated actual ground zeros and related weapon parameters from direct damage records and status reports. The generation of these data from direct damage reports and status reports is explained in greater detail in Appendix B. In general, detonations are inferred by pattern recognition techniques. A detonation could presumably be inferred from a single direct damage record, or status report, but the availability of more than one record should greatly enhance the accuracy and value of detonations inferred through pattern recognition. As time passes and more status reports are received, new estimated actual ground zeros may be generated for the same detonation. Thus, care should be taken to update the estimated actual ground zero file.

Subsystem Outputs

The principal output of this subsystem is a description of the attack size. It yields the total number of estimated actual ground zeros and related detonation record information, determined on a statistical basis. The target categories that have been attacked may be obtained if desired. Subsystem outputs also include change reports and an updated detonation record file.

Initial Target Selection Subsystem

The principal components of the initial target selection subsystem are indicated in Figure 8. The main purpose of this subsystem is to make initial target selections from the various target candidates.

Subsystem Inputs

One of the principal inputs for this subsystem is that derived from the detonation record maintenance subsystem--i.e., a file of estimated actual ground zeros together with associated weapon parameters (NUDET-type information) as well as target categories that are associated with estimated actual ground zeros. Other inputs for this subsystem include the direct damage file, detonation record file, and the target candidate file.

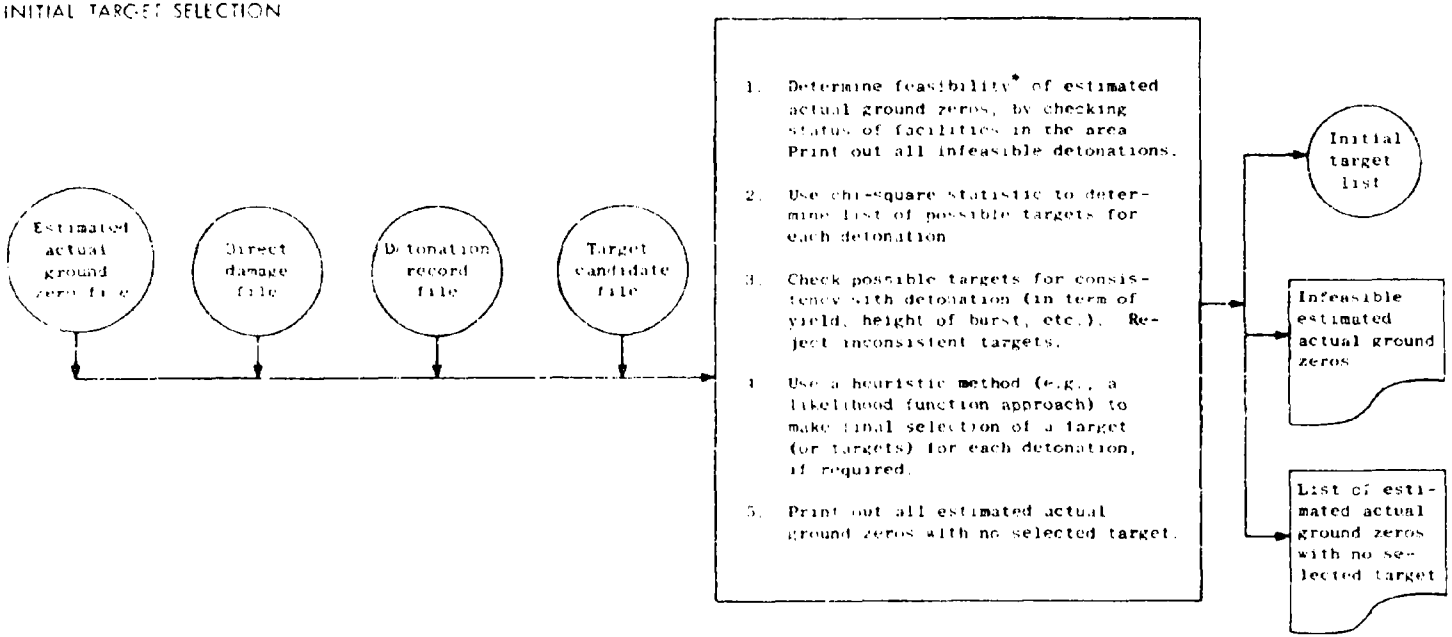
Subsystem Accomplishments

The first principal action of this subsystem is to estimate the feasibility of estimated actual ground zeros by checking the status of facilities in the area. The detonation is highly suspect and should be removed from the estimated actual ground zero file if either of two conditions are met: if there are facilities with "no hit" status reports later than the estimated time of burst; or if the reported damage is grossly incompatible with the estimated characteristics of the detonation (e.g., all facilities in the area report light blast damage and no significant fallout, while the detonation is supposed to have been a 10 MT surface burst). Also, infeasible detonations are printed out for review by the system operator.

Each detonation record group (associated with an estimated actual ground zero) is then compared against a list of target candidates. The hypothesis that a given target candidate was the target for the group is tested by using range and azimuth data to compute a variate that is distributed approximately chi-square. When the chi-square test fails to yield a possible target (i.e., a given detonation record group apparently has no feasible target), this information is printed out for the system operator.

Figure 3

INITIAL TARGET SELECTION



* Infeasible detonations include those where the reported damage is incompatible with the estimated characteristics of the detonation and those where there are facilities with "no hit" status reports later than the estimated burst time.

The next principal action is to check all possible targets for consistency with the associated detonation parameters, i.e., yield, height of burst, etc. It may turn out that there are no possible targets consistent with the associated detonation (i.e., the estimated weapon characteristics are not appropriate for use against the vulnerability group or groups of the possible targets). In this case, this information is printed out for the system operator. Heuristic methods are then used to make the final selection of a target (or targets), if more than one target candidate passes the chi-square and consistency tests.

For example, a likelihood function might be used to favor the selection of target candidates in those target categories that have a higher percentage of reported hits. The reliability levels of associated reports might also be used.

Subsystem Outputs

The principal output of this subsystem is an initial target list. The various environmental inputs of the overall system, including NUDET reports, direct damage reports, etc., have been analyzed and processed statistically to produce an initial list of targets based on a sample of the environment. The subsystem also prints out a listing of estimated actual ground zeros with no selected targets, and a list of infeasible estimated actual ground zeros.

Final Target System Definition Subsystem

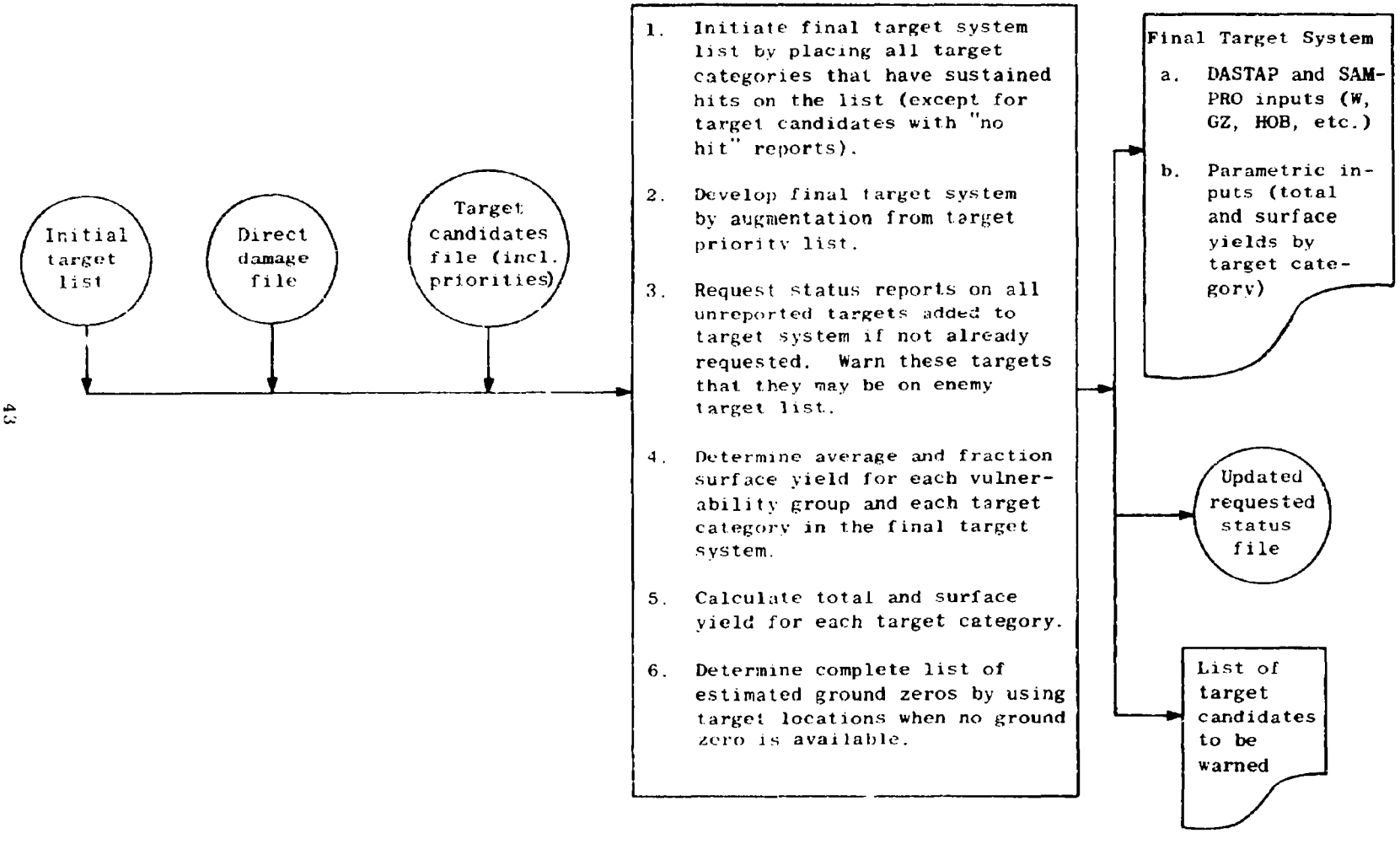
This subsystem takes the initial target list and develops an estimate of the complete target system, which in turn becomes the basis for survival estimates; that is, in this subsystem the full attack design is estimated from a sample of the targets that have presumably been attacked. The principal elements of this subsystem are indicated in Figure 9.

Subsystem Inputs

Subsystem inputs include the initial target list, the direct damage file, and the target candidate file. Priorities are assigned to the target candidates by category.

Figure 9

FINAL TARGET SYSTEM DEFINITION



Subsystem Accomplishments

The principal activity of this subsystem is to develop the full attack design. This is done by accepting as part of the final target system all of the target cagegories that have sustained hits, and by selecting additions from the target priority list. All targets in each target category that have been hit are included on the final target list unless no-hit reports have been made for that particular target candidate, with time of report later than the relevant time of burst.

Target categories are considered for inclusion in the final target system even though none of the target candidates in that category have been reported hit, provided the target category is higher on the priority list than accepted target categories with no hits, or is at the same level with them. However, decision rules are applied to target categories thus added to the list, and such categories are rejected when no other categories in the associated vulnerability group have been hit or when there are no-hit status reports for target candidates in that particular target category. Status reports are requested on all unreported targets added to the target system if status reports have not already been requested. These targets should be warned that they may be on the enemy target list.

Certain weapon yield determinations must then be made in connection with target candidates included in the final target system for which weapon yields have not been previously determined. Average weapon yields and average fraction surface yields are determined for each target category and for each vulnerability group. Appropriate decision rules are applied so that needed weapon yield information for the final target system can be determined. See Appendix A.

When no ground zero is available for a target that has been added to the target list by inference, the target location is used as the estimated ground zero.

Subsystem Outputs

The principal output of this subsystem is all of the information that is needed as input information for parametric DASTAP and SAMPRO type survival estimates. For the parametric system, the essential inputs are total and surface yields by target category. NUDET-type information is required for the DASTAP and SAMPRO systems. The subsystem also provides an updated requested status file and a list of target candidates to be warned.

Sample Target System

Before proceeding with a description of how the final target system, as described by the preceding sections, is coupled to various survival estimating systems, an illustrative example is given of how the final target system selection process operates. A simplified target system, consisting of only four target categories and up to six targets per category, is shown in Figure 10. For purposes of this example, it is considered that the target candidates can be placed in one of four classes as follows:

1. On the initial target list and having confirmed damage
2. On the initial target list, but having no confirmed damage as yet
3. Confirmed "no damage"
4. No report at all.

Other target codes, such as "damaged but not selected for the initial target list," are possible and might be included.

Target category 1 contains an example of each of these classes. Targets 1 and 3 are on the initial target list, and damage to these targets has been confirmed. Target 2 of this category is on the initial target list, but damage has not yet been confirmed. No report has been received from target 4, and a confirmed "no damage" report has been received from target 5. Target category 1 is thus selected for inclusion in the final target system, except that target 5 is deleted. Status reports will have been requested for targets 2 and 4, where no confirmed damage and no reports have been received, respectively.

Figure 10

SAMPLE TARGET SYSTEM

Target Category	Status	Remarks
1	⊠ ⊡ ⊠ • ◉	Category selected for final target system with target 5 deleted. Status reports requested on Targets 2 and 4.
2	• ⊠ ⊡ •	Category selected for final target system. Status reports requested on Targets 1, 3, and 4.
3	⊡ • ⊠ • ⊠ ◉	Category selected for final target system with Target 6 deleted. Status reports requested on Targets 1, 2, and 4.
4	• ◉ • ◉	Category not selected.
5	• • • • •	May be selected for final target system. depending on its location on the target priority list, and decision rule criteria.

Symbol	Description
⊠	Initial target list and confirmed damage
⊡	Initial target list and no confirmed damage
◉	Confirmed "No Damage"
•	No Report

Target categories 2 and 3 provide further examples similar to those given for target category 1. Target category 4 is not selected for inclusion in the final target system since no targets in that category have been placed on the initial target list. Similarly, status reports are not requested for the target candidates of target category 4 for which there are no reports, since there is no apparent activity in this target category. If target category 5 is equal to or higher than target categories 1, 2, or 3, it would also be included in the final target system. This would depend on its meeting other decision rule criteria that may be established.

The simplified example described above applies to the final target system at some specified point in time. In actual practice, the definition of the final target system, being a dynamic process, is constantly improving with time.

Parametric Survival Estimating

A parametric subsystem for survival estimating, with information provided by the final target system definition subsystem, is indicated in Figure 11. This is a highly simplified system that could be either manually or machine operated.

Subsystem Inputs

Inputs for this subsystem include total and surface yield for the attack by target category and precalculated survival functions. The survival functions will be based on preattack planning calculations for various types and weights of attack. Such survival functions are currently available for a wide range of types of attack. One example of this kind of survival function is given in Figure 12, "Expected Fatalities Versus Weapons Detonating at U.S. Cities."* Figure 12 enables one to make gross predictions of the percentage survivors as a function of total attack design. Important parameters to be considered in such functions include attack objective, height of burst, and shelter posture. The assumptions made will have important effects on the functions. Similar survival functions are available for survival estimates concerning damage to various types of industry and other resources.

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* Exemplar only, not based on actual calculations.

Figure 11

PARAMETRIC SURVIVAL ESTIMATING

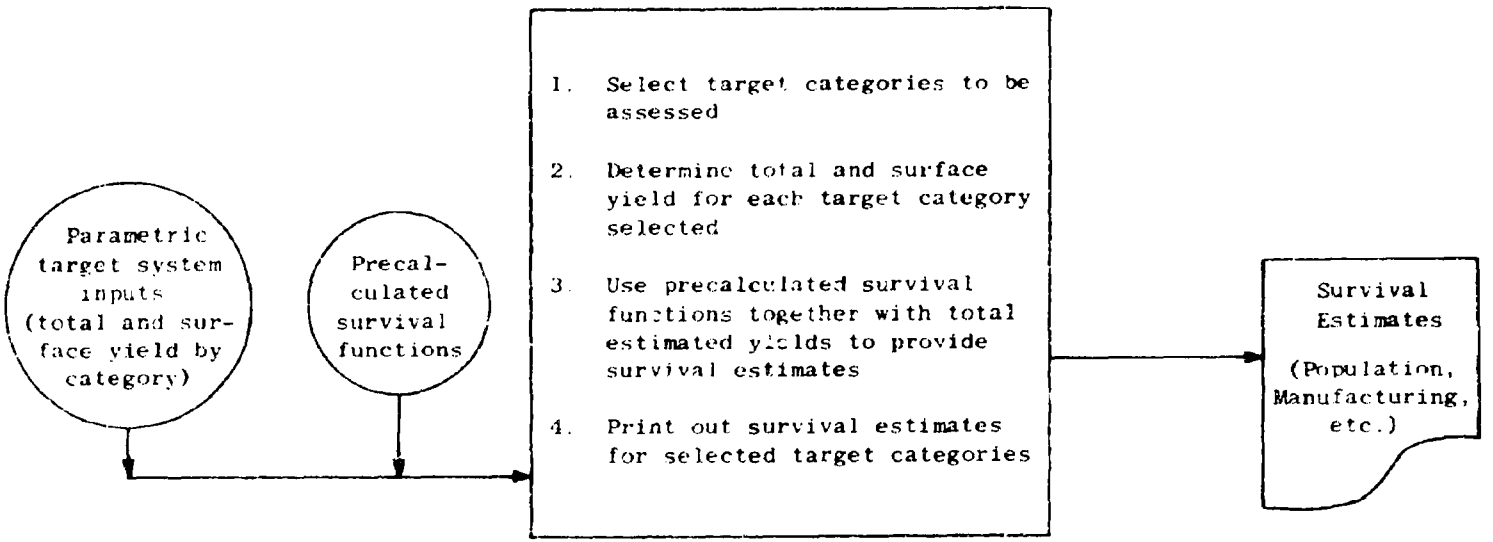
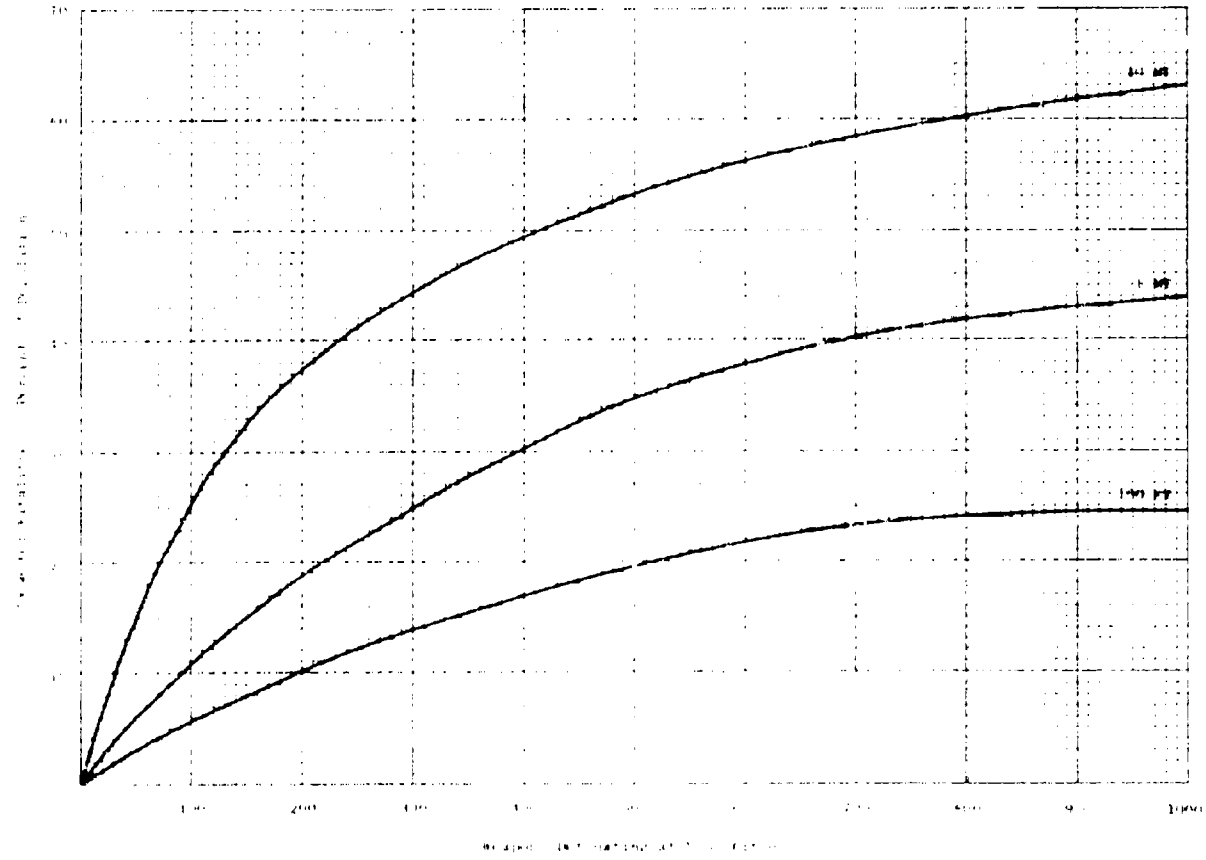


Figure 12

EXPECTED FATALITIES VERSUS WEAPONS DETONATING AT U.S. CITIES



As suggested earlier in this report, however, there is no assurance that the actual attack will closely resemble the hypothetical attacks upon which precalculated survival functions are based. This is a major limitation of parametric survival estimating based on precalculated survival functions. Such functions are clearly applicable only to national estimates. For example, the presence or absence of ballistic missile defense systems could have important implications for precalculated functions, as well as for the planning parameters mentioned above.

Subsystem Accomplishment and Output

The principal function of this subsystem is to provide quick national estimates of surviving population and other resources. Steps required to carry out this function are indicated in Figure 11.

DASTAP and SAMPRO Survival Estimating Subsystem

Survival estimating based upon the DASTAP and SAMPRO models is suitable only for machine operation. The DASTAP model calculates survival probabilities, standard intensity, and equivalent residual dose for each of some 40,000 resource points (depending on the data base used). Results of these calculations are inputs to an environment tape which, in turn, is used to develop total survival estimates. Other inputs to the environment tape include wind patterns, weapon descriptions, damage functions, mean lethal radii, and yield scaling features. Comparable survival models are in use by NRAC, RAND, and other organizations. The principal limitation of this type of model is the time required for running the program. Running times range typically from 1 to 3 hours, depending upon the type of attack and whether or not fallout is present. Attacks involving fallout require more time.

The SAMPRO model is a modification of DASTAP and employs statistical sampling techniques to reduce the number of required resource points to about one-tenth of those used by the DASTAP model. Running time is thus greatly reduced and there is very little sacrifice in accuracy for national estimates. In general, the SAMPRO model appears to be quite

suitable for use with a statistically designed target estimating system. The principal components of the DASTAP and SAMPRO survival estimating subsystems are indicated in Figure 13.

Subsystem Inputs

Inputs for the DASTAP and SAMPRO models include: (1) resource point data, (2) weapon data, (3) wind data, (4) damage functions, and (5) shelter conditions. Weapon data will be derived from the final target system definition subsystem. Wind data and shelter conditions may be assumed or otherwise obtained as desired.

Subsystem Accomplishment and Output

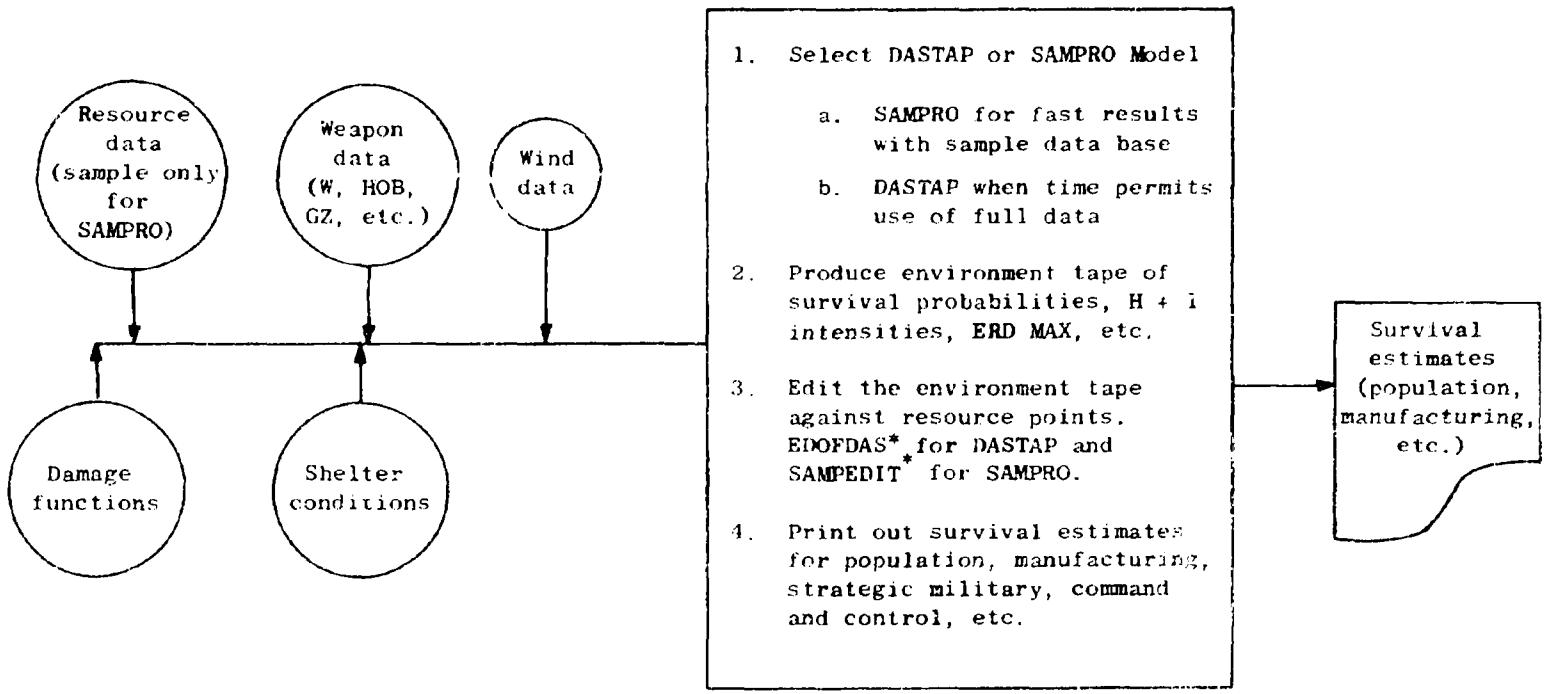
The DASTAP and SAMPRO models produce environment tapes of survival probabilities, H + 1 intensities, equivalent residual dose, and other parameters. The environment tape is then edited against resource points. This edit results in survival estimates for population and other resources.

Survival Estimating Systems

This section has presented methodology for estimating the magnitude and scope of nuclear attacks, and for combining this methodology with existing damage assessment techniques to produce national survival estimates. Thus the objectives of the study are met and exceeded, since more than one survival estimating system, each capable of coping with incomplete attack information, has been devised. In the opinion of the authors, systems based on the parametric and SAMPRO methodologies should be fully implemented for use by the National Civil Defense Computer Facility. Further, another system that should be fully developed and implemented is a survival estimating system based on the statistical methodology for estimating attack size and damage assessment techniques that collate weapons effects with facility status and damage reports. The next section gives details regarding statistical methodology for estimating attack size.

Figure 13

DASTAP AND SAMPRO SURVIVAL ESTIMATING



* Editing routines.

VIII STATISTICAL METHODOLOGY*

General

This section of the report develops and discusses statistical methods for processing nuclear attack information that have been mentioned in the preceding chapter. These methods are developed primarily in terms of a standardized report model that utilized time of burst, reporting station location, azimuth, and range between reporting station and detonation. The model develops estimates for the number of weapons used, the locations, times of burst, and heights of burst of the weapons, the weapon yields, and the targets against which the weapons were aimed.

Knowledge of ground zeros and times of burst is a prerequisite for efficient allocation of recovery resources and is also important in predicting fallout paths. Data on ground zeros (together with data on yields and fission ratios) can also be used with damage assessment techniques to provide civilian and military planners with estimates of surviving national resources. The estimates of intended targets can be used to predict the attacker's choice of targets. Such predictions might enable evacuation or movement to shelter to be carried out before a location is actually attacked.

Although manual NUDET and sensor NUDET reports may be the principal information sources for this statistical process, the method is presented in a general way that is not dependent on these systems. Thus, major changes in reporting systems will not require corresponding changes in the statistical processing. This independence is possible because the different reporting systems provide similar info mation even though the formats and methods are very different.

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* This chapter is based on the working paper "Statistical Methodology for Nuclear Attack Information Processing," TN-OAP-22, by Charles R. Thompson, Stanford Research Institute, Menlo Park, Calif., August 1967.

The Report Model

The standard report model consists of data that can be obtained or inferred from a report about an attack. In some cases, the data may be available directly from a report by a station, but this may not necessarily be the case.

The items of data in the standard model are:

ψ = azimuth of burst from reporting station
R = range of burst from reporting station
t = time of burst
k = identifier of the reporting system used
g = geographical coordinates of the reporting station
y = weapon yield
h = height of burst

Azimuth is given in degrees clockwise from true north. Range is in nautical miles. Time of burst is given in hours after H-hour (start of attack). Item k identifies the reporting system by a code such as 1 for [illegible] NUDET and 2 for sensor NUDET. The coordinates, g, of the reporting stations are given in terms of the Universal Transverse Mercator system in hundreds of meters.

The model describes the statistical properties of the report items by means of probability density functions and confidence regions. The range, azimuth, and burst time estimates will be assumed to be independent, normally distributed random variables with means at the true values and known standard deviations dependent on the reporting system.

The standard errors are in hours, degrees, or miles; they may be the same for all stations in a reporting system, or may be derived from a variance given in the original report from a station.

Confidence Intervals

The confidence interval for the burst time of a weapon reported by a station is obtained from tables of the normal distribution. A number, b, is obtained from the tables so that

$$\Pr\{-b \geq Z \leq b\} = 1 - \alpha$$

where

Z is the standardized normal variable

α is the probability of a variable exceeding the confidence bound.

The confidence interval for the true burst time, t', of the reported burst is

$$t - b\sigma \leq t' \leq t + b\sigma$$

where

σ is the standard deviation of the station report of burst time, and

t is the reported time of burst.

If the confidence level were 90 percent, then

$$t - 1.645\sigma \leq t' \leq t + 1.645\sigma$$

would be the confidence interval. For a large group of attack information inputs, 90 percent of the intervals constructed in this manner will contain the time of burst.

Confidence Regions

The confidence region for the station-reported location of the ground zero (θ, r) can also be developed. One region can be defined by

$$\hat{\theta} - a\sigma_1 \leq \theta \leq \hat{\theta} + a\sigma_1$$

$$R - b\sigma_2 \leq r \leq R + b\sigma_2$$

σ_1 = standard deviation of azimuth

σ_2 = standard deviation of range

a, b = constants

This region is a sector of a circle about the line-of-sight determined by the reported azimuth. The constants, a and b, are obtained from tables of the normal distribution, so that

$$P_r \left\{ -a \leq Z \leq a \right\} \times P_r \left\{ -b \leq Z \leq b \right\} = 1 - \alpha$$

If the confidence level is 90 percent, then a = b = 1.960 will provide a suitable confidence region for (θ, r), the true position of the ground zero relative to the reporting station. For a large group of reports, 90 percent of the intervals constructed in this way will cover the true ground zero.

Figure 14 illustrates 90 percent confidence regions for the location of an actual ground zero by two different reporting stations. The confidence regions for the two station reports overlap, indicating that a single burst may have elicited both reports. Note that a confidence region is associated with each report.

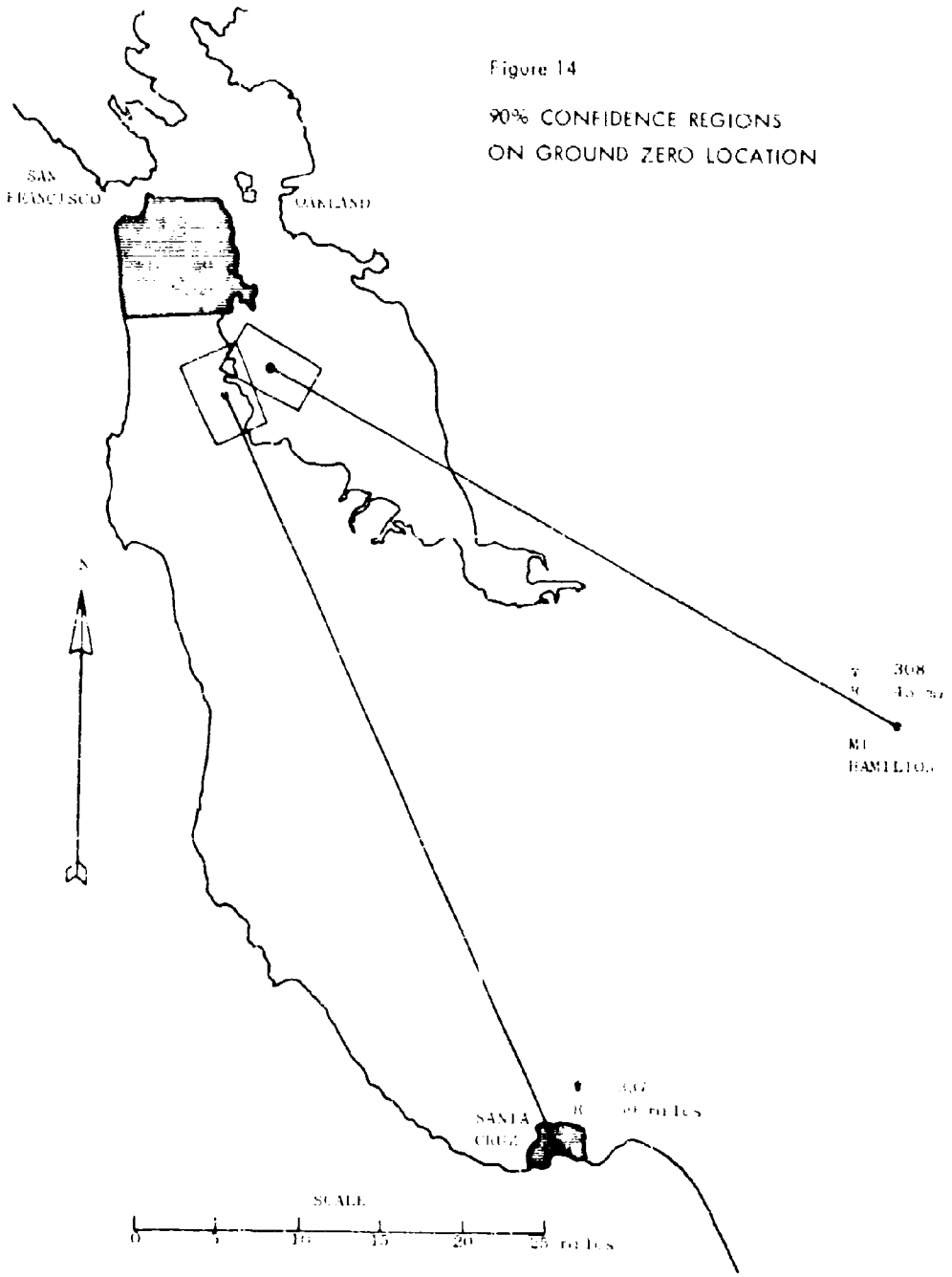
The confidence regions may be approximated by rectangles because the estimated ranges, R, of the bursts will be large with respect to the range standard deviation, and small variances in angles are to be expected. The rectangular representation will allow manual processing of station reports by graphical techniques, as a back-up for a computer processing system.

Associating Standardized Station Reports with Bursts

The standardized station reports are the basic data for determining weapon characteristics. Each report gives data for a particular burst. Moreover, the same burst may have been reported by many stations. The more stations reporting a given burst, the more data available to develop information on weapon characteristics. In order to develop this information, the reports must be separated into groups corresponding to separate bursts. Because of the statistical nature of the separation, it will be impossible to tell exactly which burst a station reported, thus causing some reports to be associated with more than one burst.

Figure 14

90% CONFIDENCE REGIONS
ON GROUND ZERO LOCATION



The confidence regions and times of burst associated with the station reports can serve as classifications of reports into groups pertaining to a single burst or clusters of bursts. The basic ideas used in this classification are: (1) the same confidence region for several reports indicates a single burst for all; (2) different confidence regions for two or more reports indicates different bursts; and (3) overlapping of confidence regions indicates that the reports may be for the same burst. The time of burst intervals may then be used as a check on the categories set up by confidence regions. For example, if confidence regions overlap for two reports, then overlapping of the confidence intervals for their burst times would indicate that the two reports pertain to a given single burst, and they would be placed in that group. Figure 14 shows the overlapping case.

Detonation Record Grouping

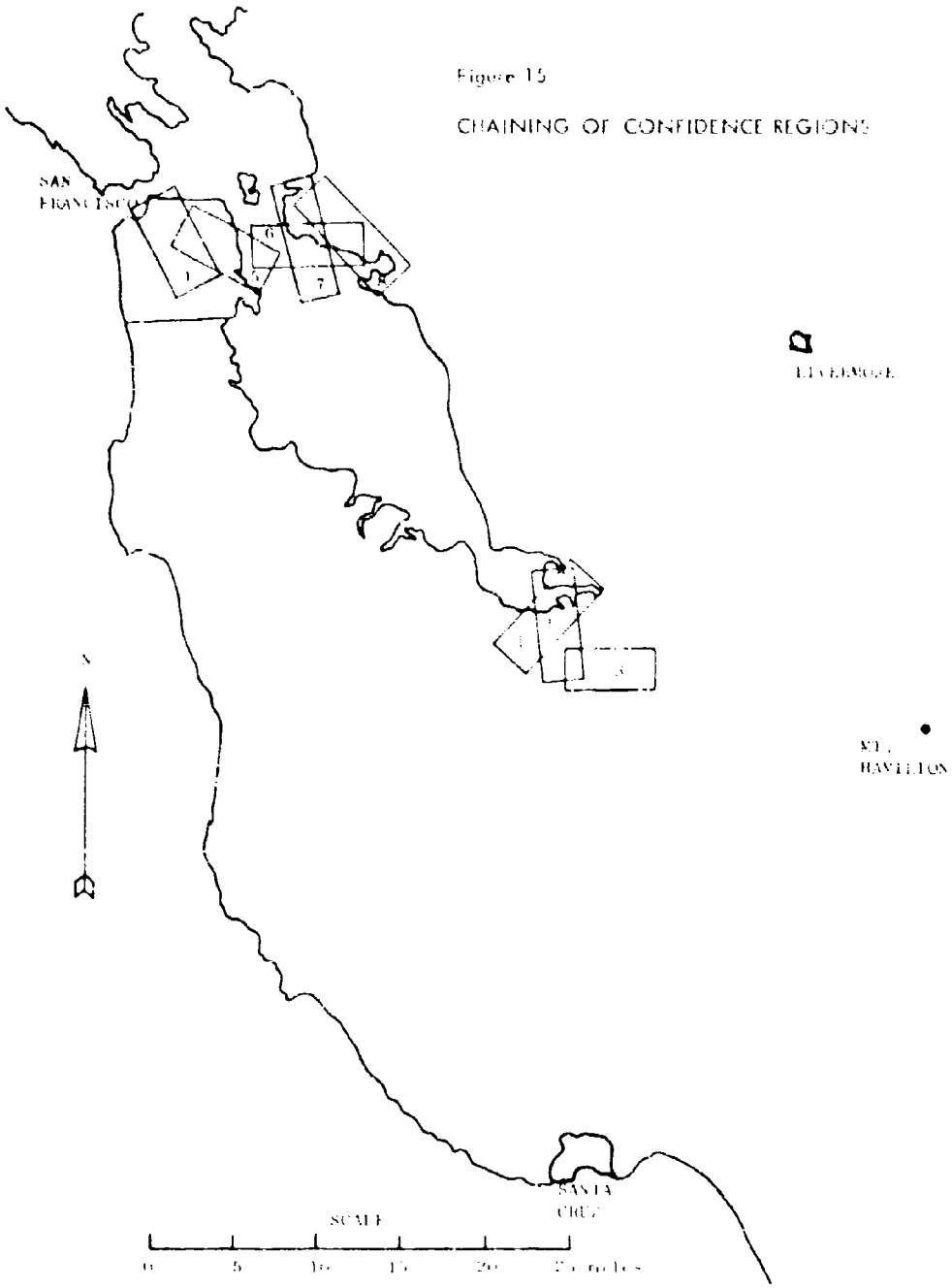
The simple rule stated above is complicated by the "chaining" of confidence regions. Figure 15 gives an illustration of this characteristic; reports 1 and 3 are separate, but they are chained together by report 2. There may be a single burst in region 2 or bursts in regions 1 and 3. Since it is undesirable to overestimate the number of bursts, a single group containing records 1, 2, and 3 is made, subject to separation by times of burst. Similarly, records 4 to 8 also form a single group.

Burst Time Discrimination

The records grouped by position may be separated further on the basis of times of burst. In some cases, the times may differ widely and hence allow a simple discrimination. For example, if report 6 of Figure 15 has a burst time of 6 hours later than the other records in the group, and the standard deviation is 1 hour, then record 6 must represent a distinct burst. After the removal of record 6 from the group, a check indicates that two position groups are now present. In the absence of further time discrimination, three burst groups are formed from the original group of five records. They are (6), (4, 5), and (7, 8); each represents a distinct burst.

Figure 15

CHAINING OF CONFIDENCE REGIONS



In many cases, the times of burst intervals will overlap, but discrimination can still be performed by constructing frequency plots of the time data. The modes of these plots can be used as estimated burst times, and the records that have confidence intervals containing these estimates are grouped together.

The plots are obtained by sorting the upper and lower bounds of the confidence intervals by time and assigning frequency values from the lowest time to the highest. If the sorted values are numbered by $i = 1, 2, \ldots, n$, and if f_i is the frequency of the ith value, then

$$f_1 = 1$$

$$f_i = f_{i-1} + 1 \text{ if } i \text{ is a lower bound}$$

$$= f_{i-1} - 1 \text{ if } i \text{ is an upper bound}$$

It should be clear that $f_n = 0$ because there are equal numbers of upper and lower bounds.

An example will clarify this process and also illustrate the reduction of position groups by time of burst. Table 3 gives the estimated burst times from station reports 1 to 8 (Figure 15). If a 90 percent confidence

Table 3

REPORTED TIMES OF BURST FOR RECORDS OF FIGURE 15

Record	Time of Burst (hours after H hour)	Standard Deviation (hours)
1	3.0	1.2
2	3.5	1.2
3	10.1	1.2
4	8.2	1.2
5	10.1	1.2
6	13.1	1.2
7	6.3	1.2
8	7.1	1.2

level is required, then the confidence interval about each reported time is ± 2.0 hours. The sorting of record group (1, 2, 3,) will produce (1, 1.5, 5, 5.5, 8.1, 12.1); the frequency plot from this sorting is given in Figure 16. Note that the frequency goes to zero before the records are completely plotted. This indicates that the records should be separated into two groups: (1, 2) and (3).

Figure 16 also shows a plot of records 4 to 8. This plot does not provide the high confidence separation that the plot of records 1 to 3 provides, but it does have two modes. The modes at 12 and 8 hours indicate that two groupings should be formed. They are (4, 5, 7, 8) and (5, 6). The first group can be further subdivided on a location basis into (4, 5) and (7, 8). This illustration also shows the use of a single record, 5, in two different burst groups.

Burst Time Discrimination with More Than One Reporting System

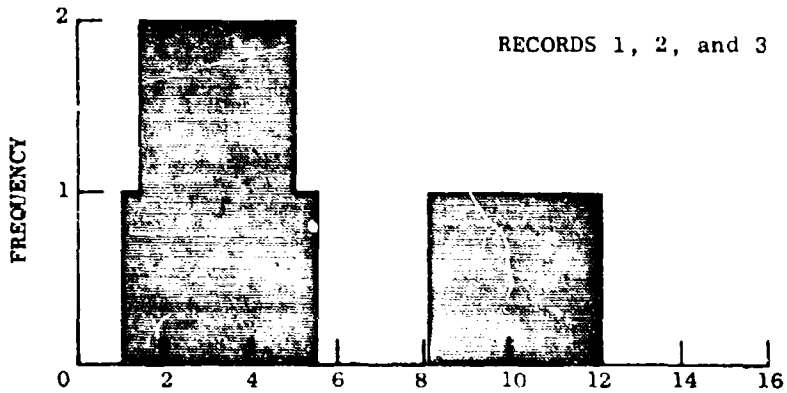
The records represented in the above examples (Table 3 and Figures 15 and 16) are a simplified case since all records came from the same reporting system (standard deviation 1.2 hours). In practice, at least two reporting systems (two different standard deviations) will be in use; any set of records will be a mixture of records from various systems. Figure 17 illustrates this general situation for two reporting systems.

The rules for separating these records into groups are similar to those for the simple case. The smaller confidence areas are grouped without reference to the larger areas. Any larger areas overlapping the small area groups are added to these groups. After this operation, any larger areas not yet processed are grouped, and these larger areas that overlap these groups are placed therein. For Figure 17, the following groups are derived:

Group	Records
1	9, 1, 2
2	10, 4, 5
3	11, 12, 13, 8
4	3, 2, 4
5	6, 7, 8

Figure 16

FREQUENCY DIAGRAMS FOR REPORTED TIMES OF BURST



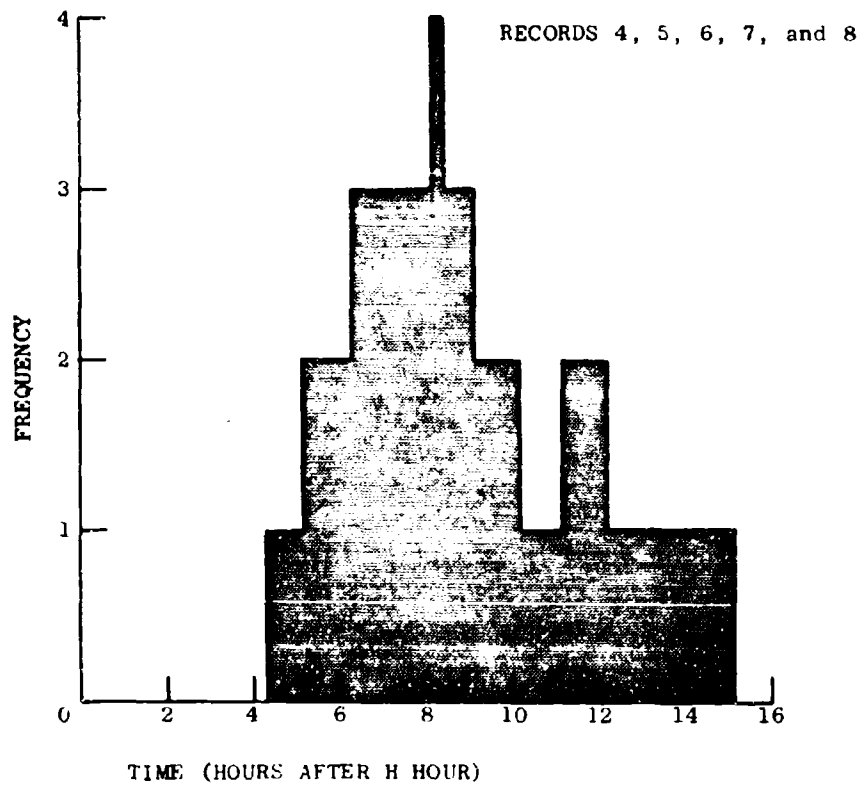
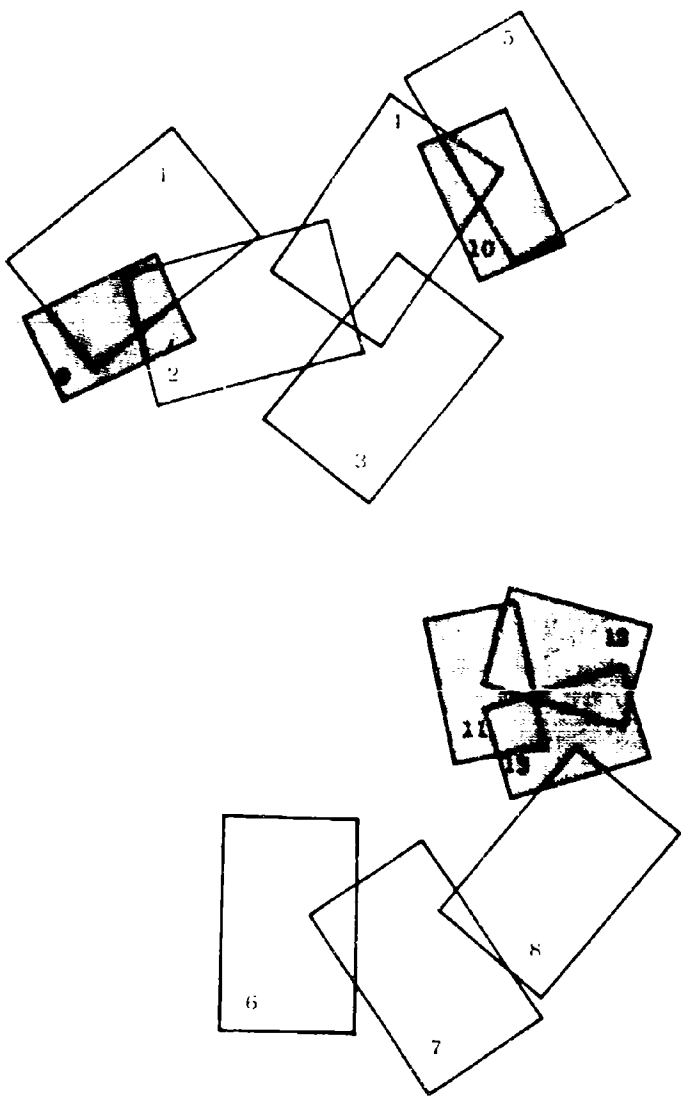


Figure 17

REPORTS FROM TWO SYSTEMS WITH DIFFERENT STANDARD DEVIATIONS



Some of the records appear in more than one group because of the uncertainty of an exact placement or grouping.

The position groups are tested for time of burst discrimination by the method of frequency distributions. The confidence intervals are of different sizes when different standard deviations are involved. The frequency function is modified to account for this by weighting the f_i inversely to the standard deviation. The modified rules are:

$$f_1 = 1\sigma_1$$

$$f_i = f_i + 1/\sigma_i \text{ if } i \text{ is a lower bound}$$

$$= f_i - 1/\sigma_i \text{ if } i \text{ is an upper bound}$$

The bounds have been arranged in order of reported times and i-numbered by $i = 1, 2, \ldots, n$.

Estimating Actual Ground Zero

Each group is considered to represent a single ground zero. The coordinates of the ground zero are unknown, but may be estimated by statistical methods using the azimuth data from the standard report. Range data are not used because they are generally less accurate than azimuth data. If a burst group contains a single report, then the range and azimuth given in the report determine the estimated ground zero.

A method for determining the position of an object from several azimuth measurements has been developed and presented.* This method can be used to determine an estimated ground zero which minimizes the sum

$$\delta = \sum_{i=1}^{n} \left(\frac{\psi_i - \bar{\psi}_i}{\sigma_i} \right)^2 ,$$

* John, Floyd F., "Statistical Problems in Position-Fixing," WP-63-5, Office of Research Analysis, Office of Aerospace Research, Holloman Air Force Base, New Mexico, May 1963.

where

ϕ_i = reported azimuth of the i^{th} report

$\bar{\phi}_i$ = azimuth of the estimated ground zero from the i^{th} reporting station

σ_i = standard deviation of reported azimuth for the i^{th} reporting station

n = number of reports in the report group

Figure 18 illustrates the general idea behind the method.

In order to apply the method, a rectangular coordinate system must be established. Let (X_i, Y_i) be the coordinate of the i^{th} reporting station in this coordinate system. The lines of sight from the i^{th} reporting station to the burst are written in terms of this system as

$$Y \cos \theta_i - X \sin \theta_i = P_i$$

where

$$\theta_i = \frac{5\pi}{2} - \phi_i$$

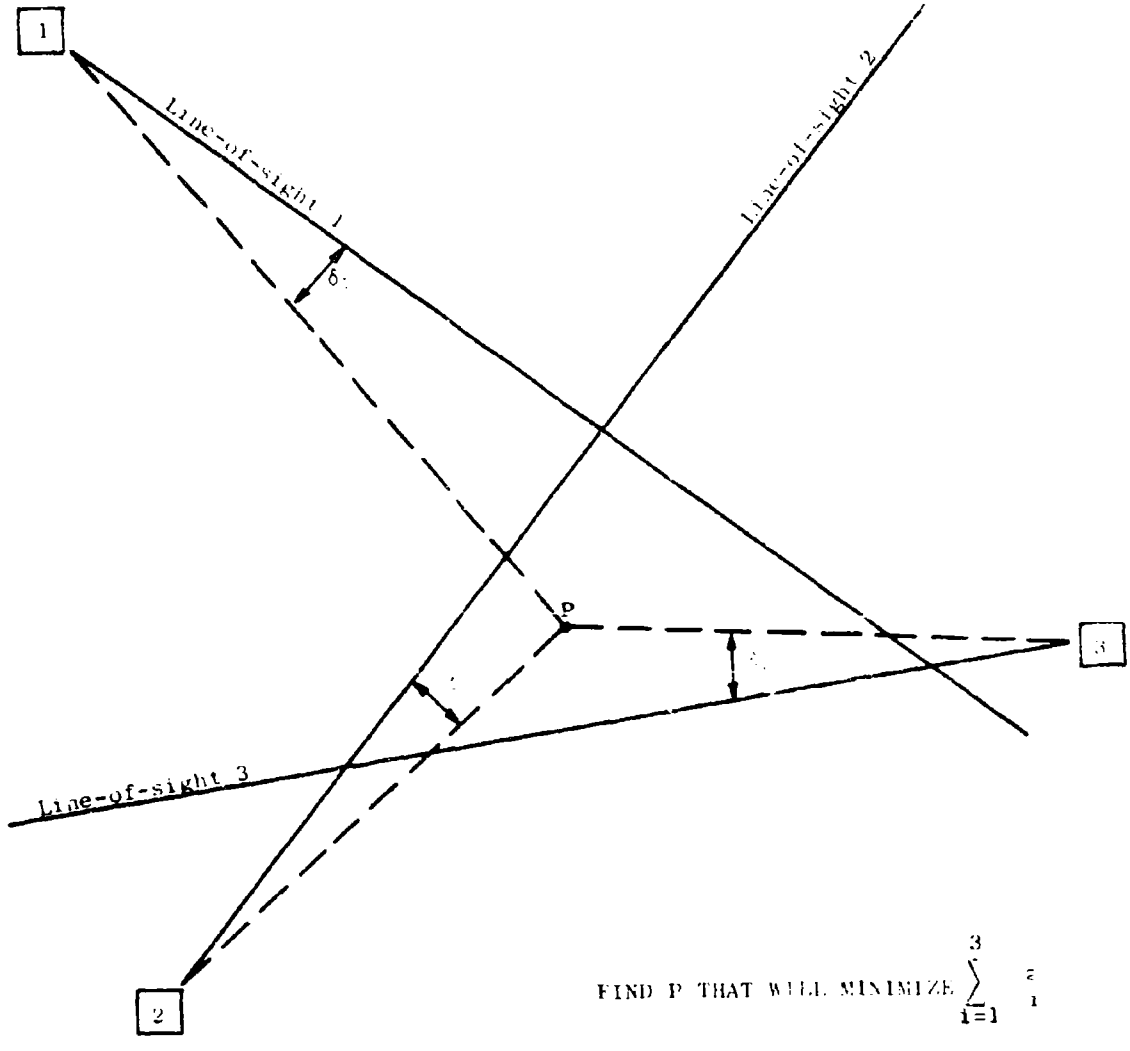
(X, Y) = coordinates of an arbitrary point on the line of sight

$$P_i = Y_i \cos \theta_i - X_i \sin \theta_i$$

The appropriate transformation for establishing this system is a gnomonic centered near the reported ground zeros. The earth coordinates of the station and reported ground zeros are moved by this transformation to a plane tangent to the earth at the center of the transformation. The projection is along a radius of the earth. The important feature of the

Figure 18

ESTIMATING THE ACTUAL GROUND ZERO - 3 REPORTING STATIONS



FIND P THAT WILL MINIMIZE $\sum_{i=1}^{3}$

Estimating the Target

At the time of launch or release, every weapon has an intended target. The standard reports can be used to provide information regarding the target to be associated with each burst group.

Let the important resources that would be considered as targets be identified by $T_1, T_2, \ldots T_m$. For each of these target candidates, the coordinates must be known in order to calculate azimuths and ranges with respect to the reporting stations. Targets with large areas for which no one set of coordinates is satisfactory must be considered separately.

The burst groups and target candidates are related by the statistic

$$S_j = \sum_{i=1}^{n} \left\{ \left(\frac{\theta_i - \phi_{ij}}{\sigma_i} \right)^2 + \left(\frac{R_i - r_{ij}}{\alpha_i} \right)^2 \right\}$$

where

n = number of station reports in group

θ_i, R_i = station reported azimuth and range to estimated ground zero

ϕ_{ij}, r_{ij} = calculated azimuth and range to target j from reporting station

σ_i, α_i = azimuth and range standard deviations

under the hypothesis that the intended target was T_j, the statistic S_j is distributed as a chi-square variable with 2 degrees of freedom because the parameters are estimated from sample values. The hypothesis can be accepted or rejected by reference to the distribution tables of the chi-square variable.

In some cases, all target candidates will be rejected--considered as not being associated with a burst group. This leads to three possibilities:

1. There was no burst for the burst group
2. The target candidate list is incomplete
3. The weapon missed its target by a large distance

Heuristics may be developed to resolve these questions in operating systems.

A further possibility is that the target was a resource area of large size, such as an urban area or oil field. The reported ground zeros of the record group can be tested against the area targets. An area may be accepted as a target for a burst group if a high fraction of the reports in the group indicate a ground zero in the area.

It may also occur that two targets are accepted for a single burst group. This may mean that there is more than one burst represented by the group, but it may also mean that the data are not good enough to discriminate targets in all cases. A useful heuristic that can be used in this case is to weight the two targets by strategic importance and resolve ambiguity by selecting the more important target. Many variants of this weighting system can be developed. One such development has been presented by Laurino* as a likelihood function, and provision for such functions is made in the subsystem of Figure 8, Initial Target Selection.

Until heuristics or more advanced statistical models are developed, however, a rule that uses the statistics $S_j (j = 1,2,\ldots,m)$ is used to estimate the targets of an attack. The rule is to select every resource, T_i, for which S_i is significant at the 10 percent confidence level. The selected T_i are the estimated targets of the attack.

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* Laurino, Richard, David Goodrich, and Donald Doane, "Statistical Methods of Estimating Damage from Nuclear Attacks on CONUS (U)," Stanford Research Institute, Menlo Park, California, December 1962 (SRI 2-1506, SECRET).

Appendix A

STATISTICAL SURVIVAL ESTIMATING CONCEPT FLOW CHARTS (DETAILED)

In Section VII of this report, the various subsystems comprising the statistical survival estimating concept are described, and flow charts are presented which outline the steps in each subsystem activity. This appendix contains more detailed flow charts for some of the subsystems. These more detailed flow charts were devised during development of the basic methodologies presented by this report; as such, they are considered to be over and above the basic objective of this study. They represent a first step in implementing the basic methodologies for computer use, and they are documented here so that the effort expended will not be lost. Figures A-1, A-2, A-3, and A-4 present flow charts for the following activities:

1. Data Input and Verification
2. Definition of the Initial Target System
3. Definition of the Final Target System
4. Parametric Survival Estimating

These flow charts do not follow the same sequence as the subsystem activities described in Section VII. For example, the activity outlined in Figure A-1, Data Input and Verification, includes most of the activities described in Section VII under the headings: data input and verification, direct damage report processing, requested status report processing, and detonation record maintenance. Also, the level of detail is not uniform throughout the flow charts. This reflects the fact that at present, certain activities within the proposed statistical survival estimating concept have received more study, and are more specifically defined, than other activities.

The concept presented in Figure A-4, Parametric Survival Estimating, represents a somewhat different approach to parametric survival estimating from that given in Section VII. In general, it is considered by the

authors to be more cumbersome and probably no more accurate than the parametric survival estimating procedure of Section VII. It is included here only for possible further evaluation when the basic methodologies of this study are implemented.

In spite of their incompleteness, the following flow charts should be useful because they represent a first attempt at defining the logic and interrelationships of certain essential activities of the statistical survival estimating concept in a more detailed manner. With additional work, they could be extended to provide the basis for a computerized system implementing the proposed survival estimating concept.

Appendix B

INFERENCE OF DETONATION RECORDS FROM DIRECT DAMAGE REPORTS

Earlier sections of this report have stated that detonation records may be inferred from direct damage reports and from status reports. The principal data that must be inferred include weapon yield, height of burst, and ground zero. It is hoped that direct damage reports and status reports will contain time of burst information. If not, however, time of burst must also be inferred, and in this case the time that the report was made would probably become the principal basis for inferring time of burst. Radiological fallout information might also be useful for this purpose.

Various techniques and methods are available for inferring the weapon yield, height of burst, and ground zero data. A method for estimating these essential data from radiological fallout reports has been devised and presented by Bothun.* Other possible methods include pattern recognition, hypothesis testing, statistical applications, and heuristic decision rules.

A system based mainly on pattern recognition has been suggested by the Office of Civil Defense.† With this system, emergency operating centers will first receive estimates of operating situations from subordinate operating areas and plot this information on a map to establish the general situation within that region. The basic operating situations corresponding to the suggested map codes (1 through 9) are shown in Figure B-1.

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* Bothun, K. B., "Uses of Radiological Fallout Information in Operational Postattack Damage Assessment Systems (U)," Stanford Research Institute, Menlo Park, California, January 1965 (CONFIDENTIAL).

† "Concept of Operations under Nuclear Attack," Office of Civil Defense, Washington, D.C., June 26, 1967. (Working Draft)

Figure B-1

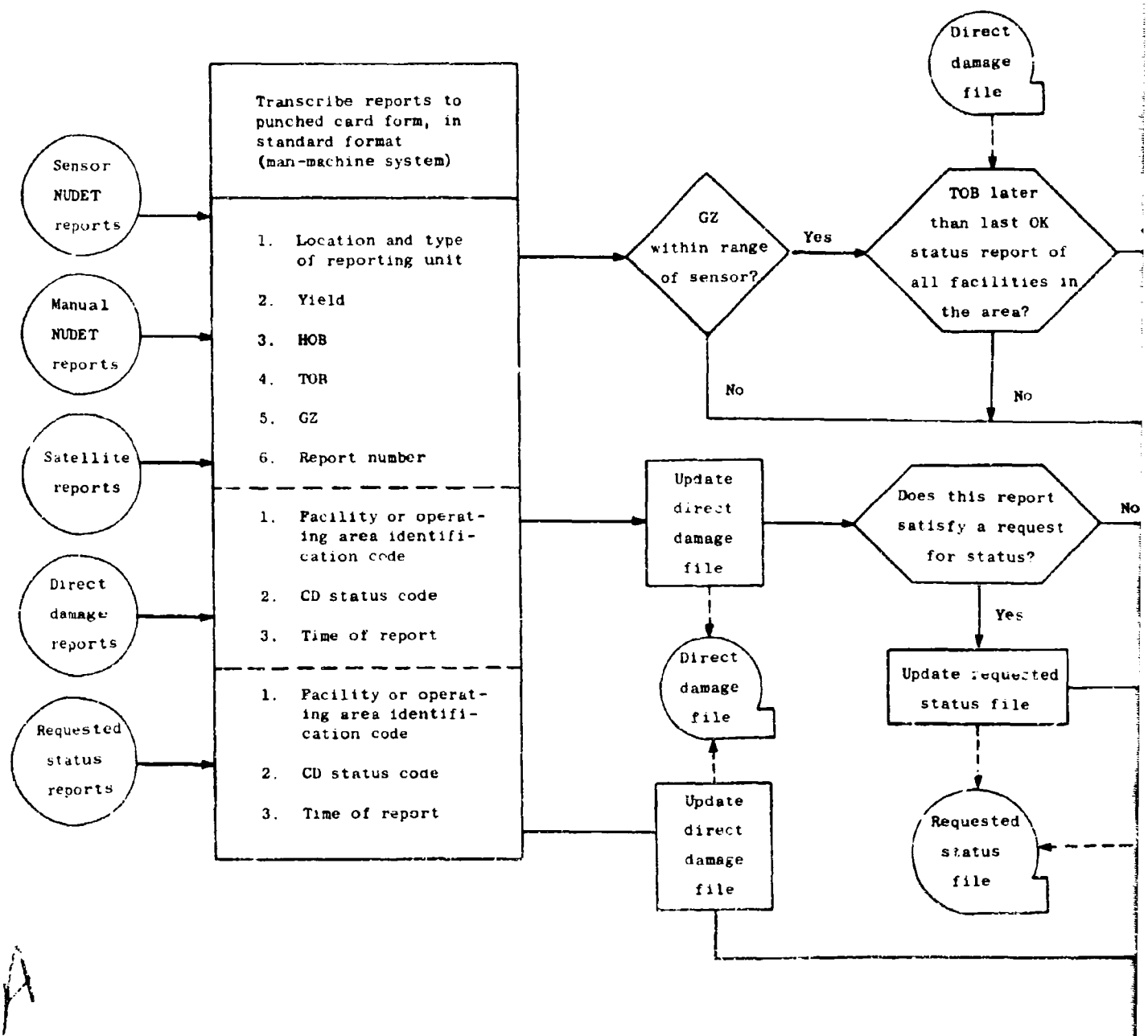
NINE BASIC OPERATING SITUATIONS

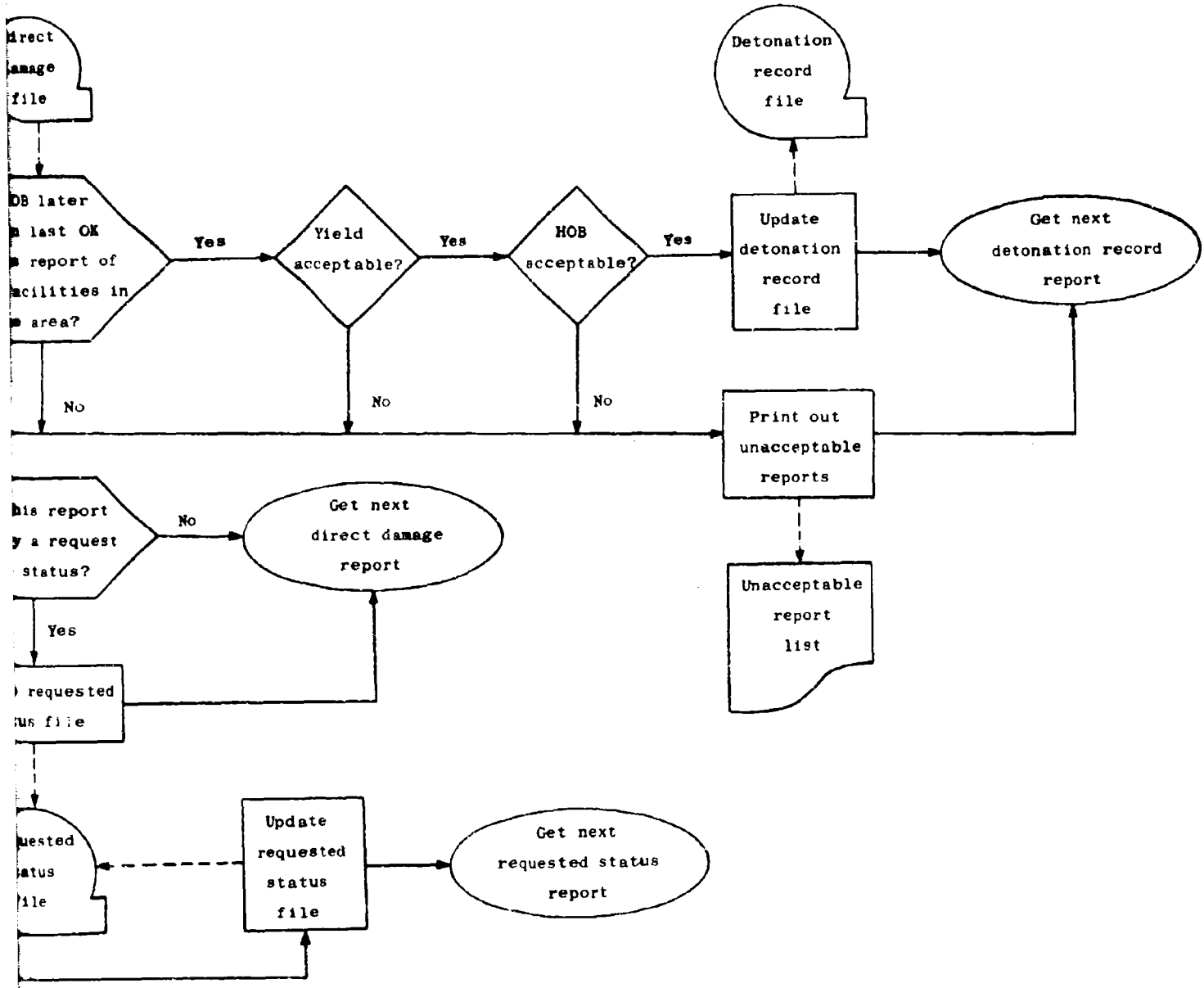
	NEGLIGIBLE FIRE	CONTROLLABLE FIRE	UNCONTROL-LABLE FIRE
NEGLIGIBLE FALLOUT	1 NEGRAD NEGFIRE	4 NEGRAD LOFIRE	7 NEGRAD HIFIRE
MODERATE FALLOUT	2 LORAD NEGFIRE	5 LORAD LOFIRE	8 LORAD HIFIRE
SEVERE FALLOUT	3 HIRAD NEGFIRE	6 HIRAD LOFIRE	9 HIRAD HIFIRE

Source: "Concept of Operations under Nuclear Attack," Office of Civil Defense, Washington, D.C., June 26, 1967 (Working Draft)

Figure A-1

DATA INPUT AND VERIFICATION

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amage
file
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record
file
DB later
n last OK
report of
acilities in
area?
Yes
Yield
acceptable?
Yes
HOB
acceptable?
Yes
Update
detonation
record
file
Get next
detonation record
report
No
No
No
Print out
unacceptable
reports
his report
y a request
status?
No
Get next
direct damage
report
Yes
Unacceptable
report
list
requested
tus file
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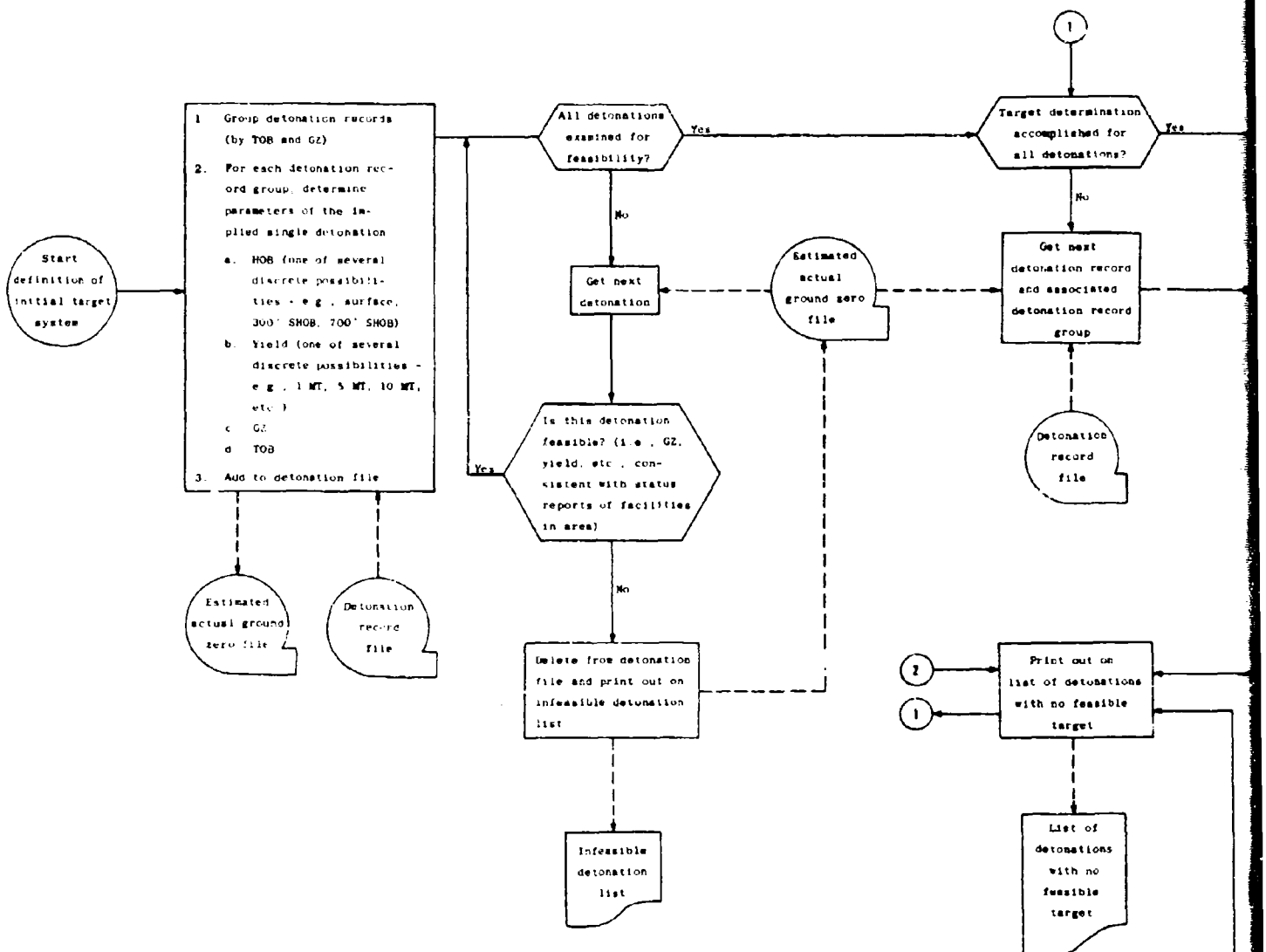
atus
ile
Update
requested
status
file
Get next
requested status
report

B

Figure A-2

DEFINITION OF THE INITIAL TARGET SYSTEM



A

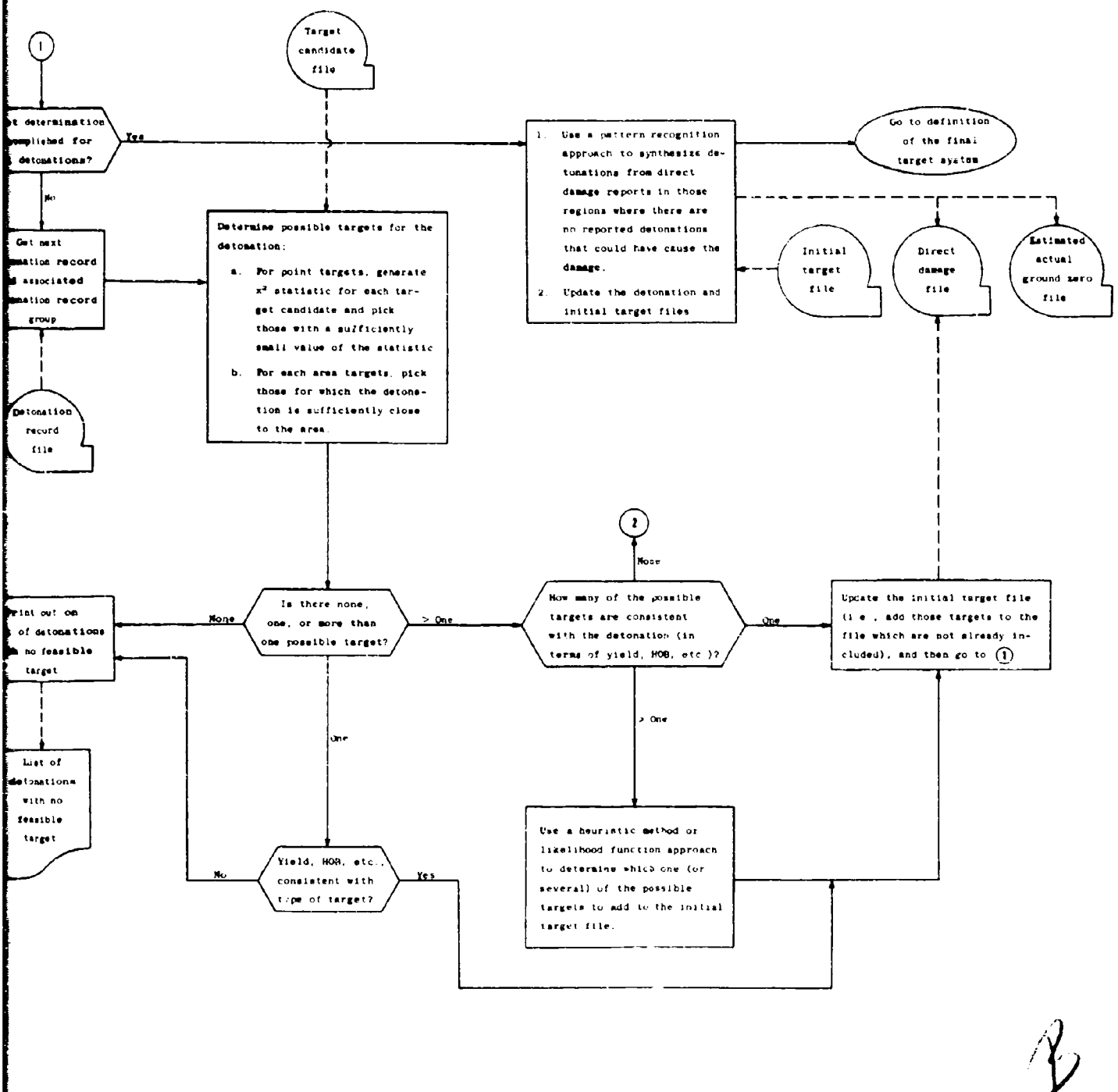
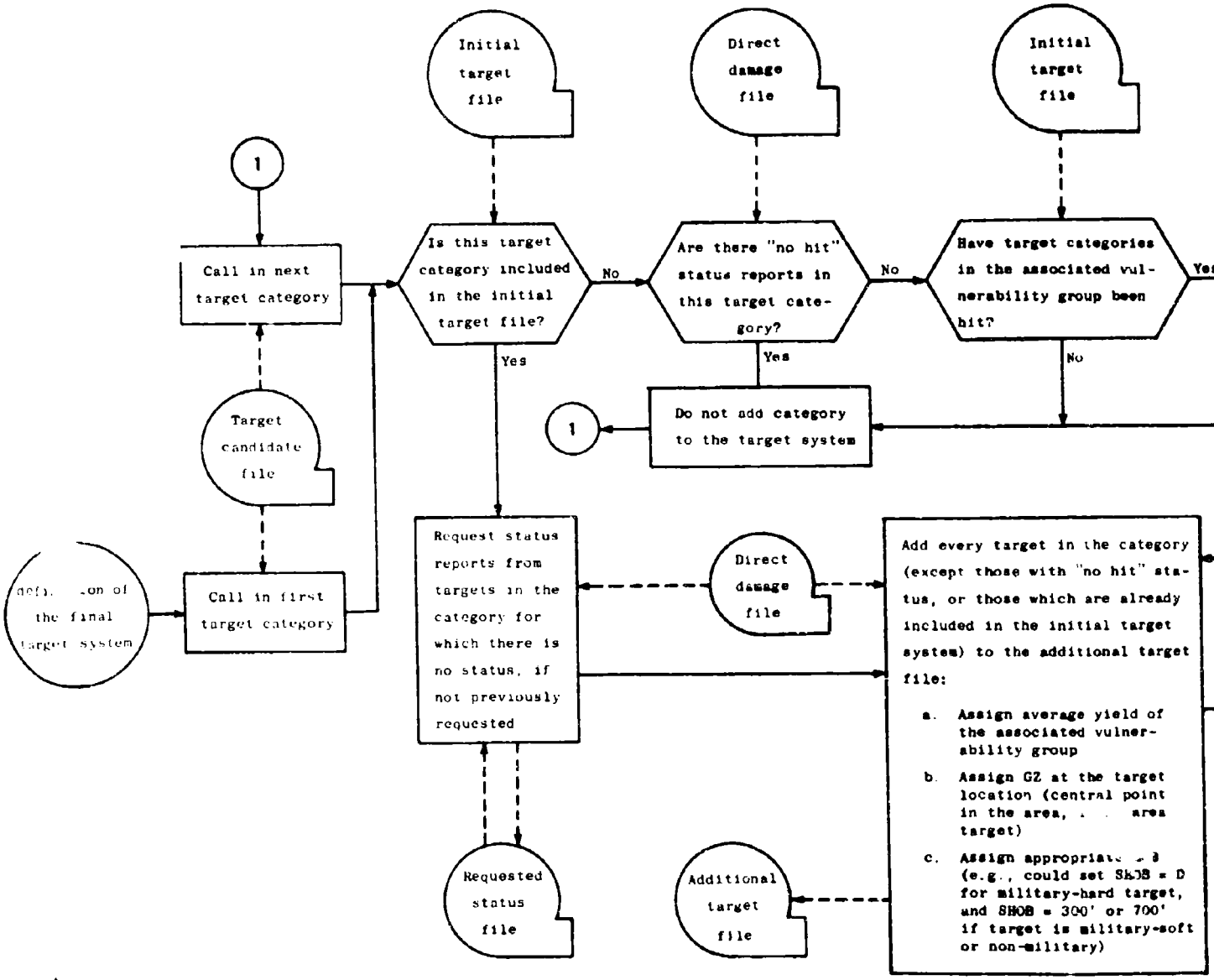

1
Target candidate file
t determination mplished for detonations?
Yes
No
Get next mation record associated mation record group
Detonation record file
Determine possible targets for the detonation:
a. For point targets, generate x^2 statistic for each target candidate and pick those with a sufficiently small value of the statistic
b. For each area targets, pick those for which the detonation is sufficiently close to the area.
1. Use a pattern recognition approach to synthesize detonations from direct damage reports in those regions where there are no reported detonations that could have cause the damage.
2. Update the detonation and initial target files
Go to definition of the final target system
Initial target file
Direct damage file
Estimated actual ground zero file
2
More
How many of the possible targets are consistent with the detonation (in terms of yield, HOB, etc)?
One
> One
Update the initial target file (i e , add those targets to the file which are not already included), and then go to 1
Is there none, one, or more than one possible target?
None
> One
One
rint out on of detonations h no feasible target
List of detonations with no feasible target
Yield, HOB, etc., consistent with type of target?
No
Yes
Use a heuristic method or likelihood function approach to determine which one (or several) of the possible targets to add to the initial target file.

Figure A-3

DEFINITION OF THE FINAL TARGET SYSTEM



A

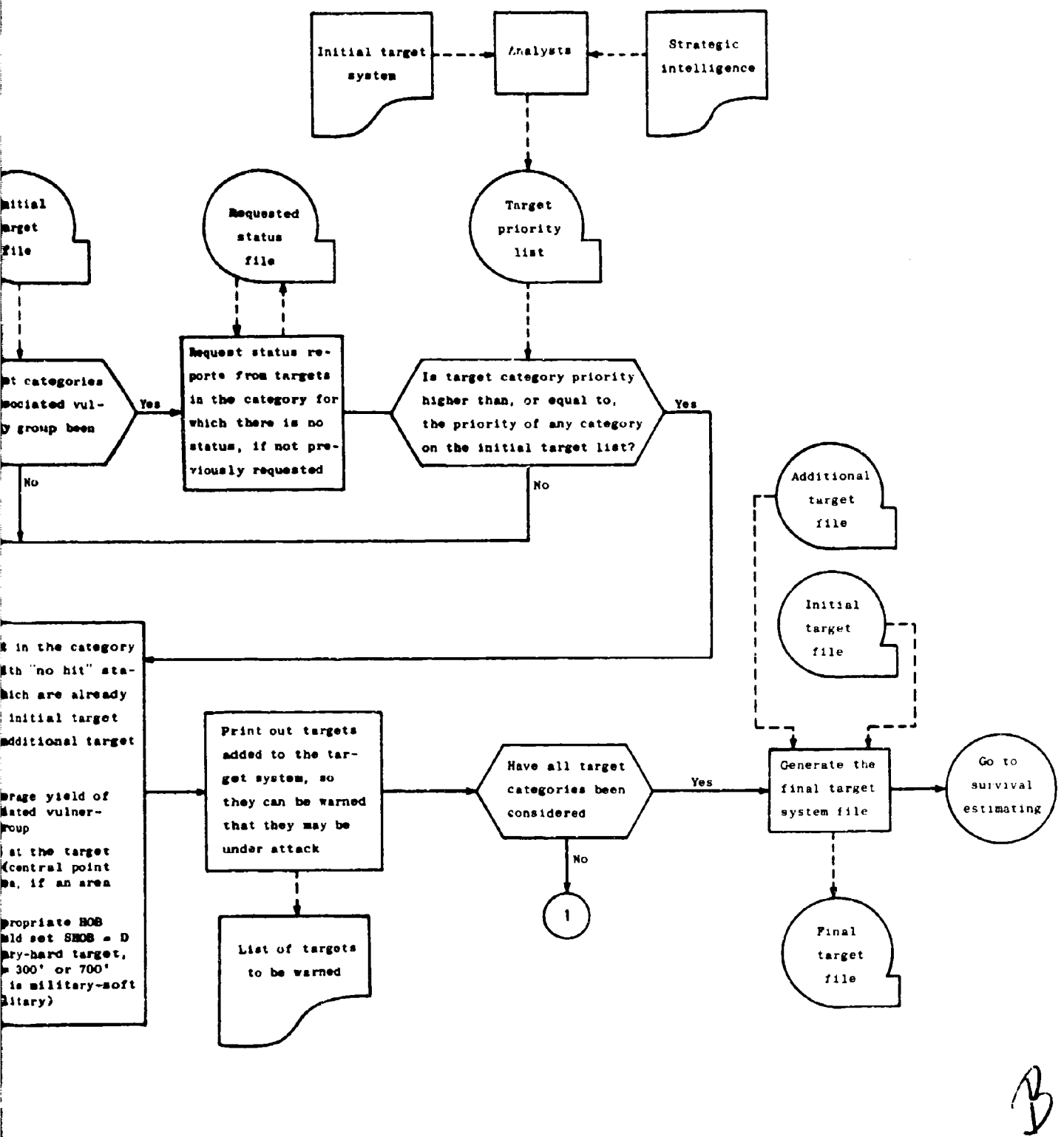
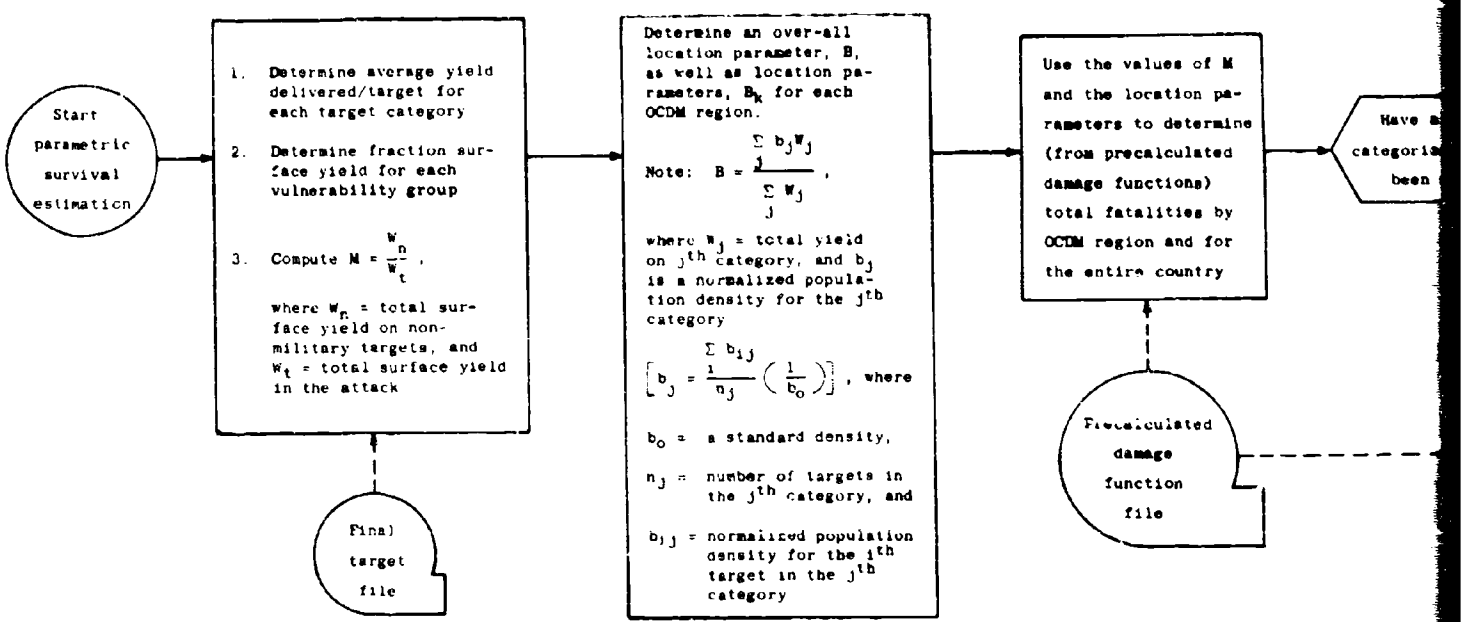
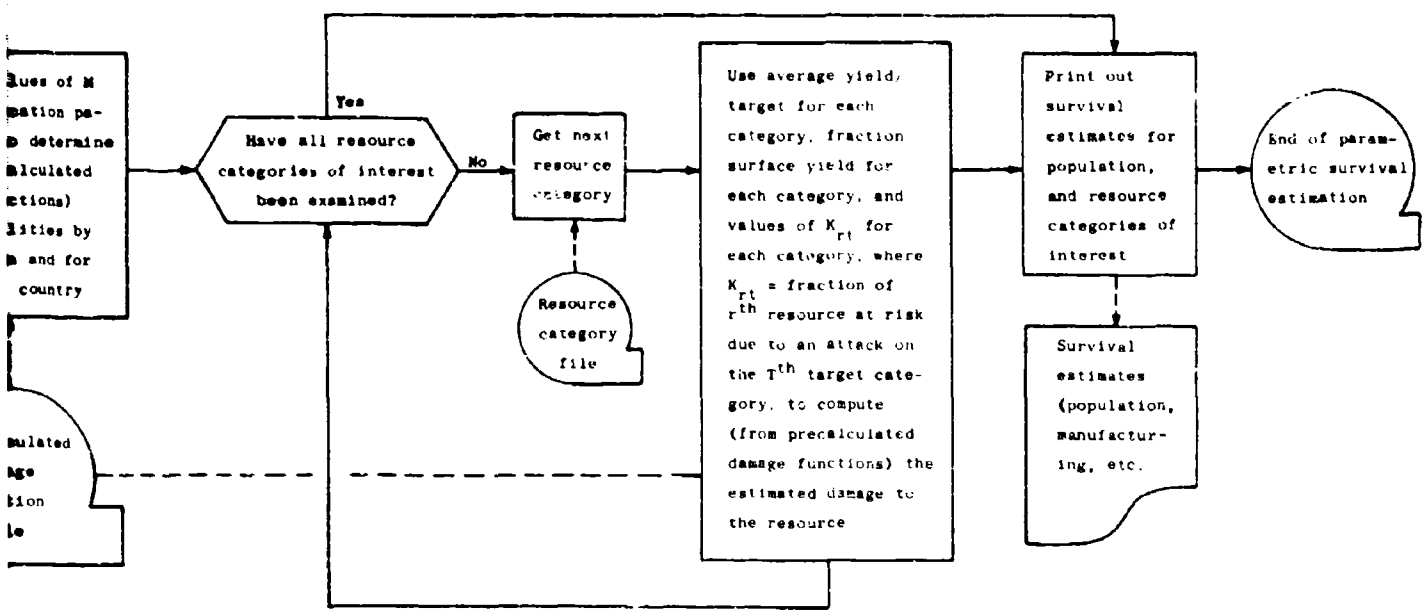

Initial target system
Analysts
Strategic intelligence
Requested status file
Target priority list
Request status reports from targets in the category for which there is no status, if not previously requested
Is target category priority higher than, or equal to, the priority of any category on the initial target list?
Yes
No
Additional target file
Initial target file
Print out targets added to the target system, so they can be warned that they may be under attack
List of targets to be warned
Have all target categories been considered
Yes
No
1
Generate the final target system file
Final target file
Go to survival estimating

Figure A-4

PARAMETRIC SURVIVAL ESTIMATING




lues of M
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determine
lculated
ctions)
ities by
and for
country
ulated
ge
tion
le
Yes
Have all resource categories of interest been examined?
No
Get next resource category
Resource category file
Use average yield/target for each category, fraction surface yield for each category, and values of K_{rt} for each category, where K_{rt} = fraction of r^{th} resource at risk due to an attack on the T^{th} target category, to compute (from precalculated damage functions) the estimated damage to the resource
Print out survival estimates for population, and resource categories of interest
Survival estimates (population, manufacturing, etc.
End of parametric survival estimation

B

It is suggested that early reports from LOFIRE and adjacent NEGFIRE zones in the vicinity of a nuclear explosion could then be used to establish the location and approximate yield of the detonation by measurement of the diameter of the LOFIRE area and comparison with a curve or table showing the anticipated diameter as a function of yield. An alternative procedure would be to apply templates of predicted LOFIRE areas for weapon yields to a map showing operating area situation reports to estimate location and yield of detonations. The later procedure is illustrated in Figure B-2. In this illustration, the LOFIRE region extends to approximately the 1 psi range, which is in agreement with generally accepted estimates for scattered fires.

A statistical approach to the estimation of weapon yield is also possible. One possibility is to make use of small sample theory techniques such as use of the noncentral "student's" t distribution, which tests the hypothesis that the mean perimeter operating area radius is equal to a specified value. In this distribution, the statistic t is defined as:

$$t = \frac{\bar{X} - \mu}{s} \sqrt{N - 1}$$

where

N = number of sample points, or perimeter operating areas.

μ = hypothesized mean radius between ground zero and centers of perimeter operating areas, i.e., for 1 MT, 5 MT, 10 MT, or 20 MT.

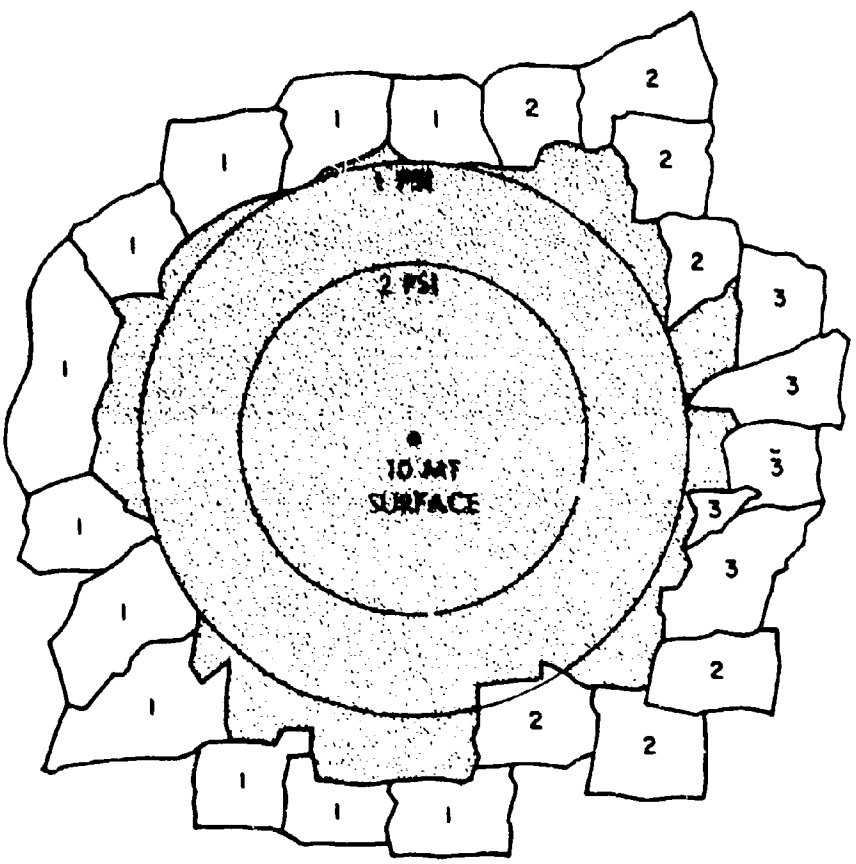
$\bar{X}$ = mean of sample radii between ground zero and centers of perimeter operating areas.

s = standard deviation of sample radii.

This system might be used in such a way that μ for the weapon yield is tested for various hypothesized values of perhaps 1, 5, 10, and 20 megatons. The use of a statistical approach has the important advantage that confidence intervals may be set which supply the system operators with information as to how much confidence might be placed upon a given weapon yield selection.

Figure B - 2

NUDET ESTIMATE



Contains Zones with Basic Op Situations Higher Than 3.

Source: "Concept of Operations under Nuclear Attack"
Office of Civil Defense, Washington, D.C.
June 26, 1967 (Working Draft)

The statistical approach might also be used in estimating ground zero; for example, a circular area of weapon effects may be derived through pattern recognition for two or more of the weapon effects such as observable blast damage and scattered fires. A comparative analysis of these two circles for the purpose of estimating ground zero is possible that would have a more quantitative basis than simple pattern recognition. In actual practice, however, it may well be that simple pattern recognition is adequate for estimating ground zero.

The above discussion has illustrated that in many cases, a combination of pattern recognition, heuristic decision rules, and statistical analytical techniques can be used to estimate essential NUDET data from extremely elementary direct damage reports. Yet because of the obvious uncertainties involved, sensor and manual NUDET reports should be used when available. An obvious difficulty with the inference of detonation reports from direct damage reports is that direct damage reports probably will not have been received from all operating areas, particularly in the early time periods. When insufficient direct damage reports are available for estimation purposes or when additional direct damage reports are desired, status reports should be requested for the appropriate operating areas.

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A STATISTICAL INFORMATION SYSTEM FOR ESTIMATING THE MAGNITUDE AND SCOPE OF NUCLEAR ATTACKS

By Robert M. Rodden
Stanford Research Institute

February 1968

OCD Work Unit 4615A

DETACHABLE SUMMARY

This research develops and presents a statistical concept for making national survival estimates in the transattack and early postattack periods. Statistical methodologies are used to process reports of detonations, and the principle of statistical inference is used to estimate the magnitude and scope of the attack. Existing systems for the preparation of national survival estimates in the transattack and early postattack periods are based largely on preattack planning methods or on the tabulation of direct damage reports as they are received. Adequate and accurate data of the kind needed to produce survival estimates with these techniques will not be available in the transattack and early postattack periods.

The four principal activities of the concept developed by this research are (1) real time input processing and data preparation, (2) statistical conversion of data to information, (3) inference of attack size and target system, (4) estimation of effects on resources and population. Activities 1 and 4 above may have much in common with certain existing survival estimating systems. The main distinctions between this and other survival estimating systems are in activities 2 and 3. The concept developed by this research uses statistical inference and heuristic decision rules to estimate the magnitude of the total attack. The methodology thus devised can operate with incomplete and inaccurate information. Targets are inferred by statistical inference after appropriate grouping of target candidates into target categories and vulnerability groups.

The methodology includes: the receiving and processing of burst information and direct damage reports for use in making survival estimates; basic concepts for organizing inputs from various sources into appropriate data files; and provision for supplying measures of reporting performance

to the system operator. Detonation reports and other data are converted statistically to information that is more directly applicable to survival estimating. Estimated actual ground zeros and targets for the initial target list are determined statistically. Areas where data are incomplete or possibly inaccurate are identified, and status reports are requested to correct these deficiencies. An initial target system is developed that yields information on the target categories hit and on the severity of the attack.

The next main step is inference of the full attack size and target system. This is accomplished with the aid of the initial target list, a list of target candidates, and a knowledge of target categories and vulnerability groupings. At the completion of this step, an augmented target list that in general will be expanded considerably from the initial target list will have been developed through statistical inference. Again, status reports will be requested to cover areas of doubtful or inadequate information.

The final step of the concept is to estimate effects on resources and population by means of the synthesized target system. It is shown how a target system may be coupled with several survival estimating techniques to produce survival estimates. The survival estimating technique selected may well depend upon the requirements of the system operator at a given point in time. A summary of the system and its principal activities is given in Table 1.

Section VIII presents details of statistical methodology for estimating actual ground zeros and targets relevant to a group of detonation reports. A basic tool is the use of confidence regions and confidence intervals to determine the actual number of bursts and estimate actual ground zeros associated with a particular group of detonation reports. The selection of target candidates for the initial target list is also accomplished statistically, using a least-squares methodology. Weapon yields and heights of burst for a given group of detonation reports are derived mathematically.

Appendix A provides more detailed flow charts for some parts of the conceptual system. The basic purpose of these flow charts is to document

Table 1

SYSTEM SUMMARY

Process	Activities	Data and Information: Inputs	Data and Information: Outputs
Real time input processing and data preparation	● Receive NUDET, satellite, direct damage, and requested status reports from sensors, reporting agents, operating areas and important facilities ● Screen reports to eliminate inaccuracies and inconsistencies ● Convert reports to electronic data processing format ● Organize inputs into data files giving current facility status and reports of detonations ● Document the input system activity, numbers of facility reports, and other measures of reporting performance	Sensor NUDET Manual NUDET Satellite OCD reports a. Direct damage b. Requested status	● Current facility status ● Detonation records ● Reporting system Activity and performance
Statistical conversion of data to information	● Analyze detonation reports to determine number of actual ground zeros and weapon characteristics ● Evaluate reports statistically to select the most likely targets ● Modify target selections to agree with direct damage reports ● Describe initial target system in terms of number of target categories hit and severity of the attack ● Document inconsistencies and apparent conflicts between target selections, direct damage reports, and detonation records	● Target candidates ● Facility status ● Detonation records	● Initial target list ● Exception reports 1. Detonations with no targets 2. Targets destroyed with no report of detonation
Inference of attack size and target system	● Infer attacker's priority system from initial target list and military intelligence ● Augment initial target system by addition of selected targets of high attacker priority ● Estimate total attack yield, fraction surface weapons, vulnerability group yields ● Summarize known and estimated features of the developing attack description	● Target candidates ● Initial target list	● Augmented target list ● Summary descriptions of initial and augmented target selections
Estimation of effects on resources and population	● Select assessment or estimating system appropriate for desired survival figures and information developments ● Calculate expected results of the attack	● Resource data base ● Initial target list ● Augmented target list ● Facility status	● Survival estimates and assessments

the ideas that have been developed in the course of this research but that are not appropriate to the generalized flow charts of the main report. The flow charts of Appendix A will help provide the basis for developing the system to a point where computer programs for the system can be written. However, considerable additional work will be needed before these flow charts are adequate for that purpose.

The feasibility of inferring detonation records from direct damage reports is investigated briefly in Appendix B, which also gives a framework for such inference, using pattern recognition and hypothesis testing.

This research effort has developed methodology for estimating attack size in the transattack and early postattack periods, and has shown how this methodology can be combined with existing damage assessment methods to produce national survival estimates. More advanced survival estimating techniques, that would integrate attack size estimating and damage assessment more directly, are briefly explored. Survival estimating systems recommended for full development and implementation by the National Civil Defense Computer Facility are identified.

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13 ABSTRACT

This research develops concepts, flow diagrams, and statistical methodology for an information system to estimate the magnitude and scope of nuclear attacks. The system is designed to operate in the transattack and immediate postattack periods when data on the attack can be expected to be incomplete and inaccurate. The underlying principle in estimating attack size is that of statistical inference, which permits an estimate to be made of the total attack from information on a sample of the attack only. Heuristic decision rules are applied as needed to make the system operable. It is demonstrated how the target synthesis procedure thus developed may be coupled to a variety of survival estimating techniques to yield survival estimates. The research also develops statistical methodology for processing reports of nuclear detonations.

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	ROLE	WT	ROLE	WT	ROLE	WT
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Information System						
Nuclear attacks						
Transattack						
Postattack						
Statistical inference						
Heuristic decision rules						
Target synthesis						
Survival estimating						
NUDET						
Damage assessment						

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