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A METHODOLOGY FOR ESTIMATING EMERGENCY COMMUNICATIONS REQUIREMENTS FOR A SITUATION D EMERGENCY

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Introduction

The objective of this study is to develop a methodology for estimating the communications required to support minimum essential emergency functions during a Situation D Emergency. A Situation D Emergency includes actions taken before, during, and after a nuclear attack on the United States.

Communications is the single most critical infrastructure system required in an emergency of any kind or scope. The ability to report status, forward requests, and direct allocation of resources is fundamental to emergency management. Unless persons and offices can communicate with each other, the other functions of emergency management cannot be accomplished. It is essential to assure with a high degree of confidence that the United States will have adequate operational communications capability before, during, and after a nuclear attack.

While, the need for emergency communications has been recognized, no one really understands how much communications will be needed. The minimum requirement for communications is not very well understood.

The problem of estimating communications requirements is a very difficult one conceptually. Demand for communications always rises to match the supply. There is so much discretionary or non-essential traffic during normal times that it has not been possible to differentiate a requirement from the demand. During emergencies, demand increases and exceeds capability, leading to degradation of service. Yet, there is no way to determine in advance just how much of the demand is really necessary to perform minimum essential emergency management functions. There is no generally accepted methodology for estimating how much of that demand is essential in an actual or postulated situation.

Communicators are not very good at estimating requirements. They tend to think in terms of connectivity and concentrate on the need to have a link between two nodes. While a specified number of circuits can be considered as one kind of requirement, this approach is valid only for special networks in which point-to-point communications is established for a limited purpose and a limited number of users. Requirements derived from the connectivity approach do not help define a minimum operational capability because once the circuits are in, the demand increases to the full capacity of the system. More importantly, the number of circuits is simply not the major factor in a national communications system in which there are a large number of potential circuits and switching capacity is the constraint on communications.

On the other hand, asking the users how much communications is needed also has not worked very well. The typical user thinks of communications as a ubiquitous presence which exists to satisfy his needs without limit. The typical statement is that the user wants enough communications to be able to talk to anyone he needs to at any time -- and without any delay. In the past, therefore, user-based statements of requirements have been either irrelevant or overstated. Previous user-based requirements estimates have not been of much use to the communicators.

The Department of Command, Control, and Communications of the Naval Postgraduate School is engaged in a research program in support of the National Commmunications System (NCS). This research program is concerned with three major areas: 1) the National Emergency Telecommunications System; 2) vulnerability of the telecommunications system; and 3) requirements for emergency communications. In an effort to remedy the lack of a good way to estimate communications requirements, the Naval Postgraduate School asked Data Memory Systems to see if a good way to estimate communications requirements for a nuclear war could be found.

Concepts

General

As the work proceeded, it became evident that the derivation of a methodology for estimating emergency communications requirements would be based on some new ideas not previously applied to the communications requirements problem. These new concepts include the following:

- The difference between information and communications.
- The nature and dynamics of a Situation D Emergency.
- The Emergency Government in a Situation D Emergency.
- The National Telecommunications Network.

Information versus Communications

It is necessary to distinguish between information and communications. Information is the amount of knowledge that one user must convey to another in order to accomplish work. Comunications is the transmission of information from one user to another. Information can be quantified based on the work to be accomplished. This distinction between user-derived information and technology-derived communications makes it possible to obtain valid communications requirements for the user. The information needed in a report or directive can be derived from the user using existing social science research methods.

For this study, information has two components: amount and frequency. The amount of information to be sent is measured in bits. The frequency is the time period which can elapse before the information needs to be sent again. On this basis information is a flow, measured by bits-per-day, and represented by the symbol, "Q".

Once the information requirement is established, it can be transformed into communications requirements and stated in terms of circuits and capacities.

Situation D Emergency

The term "Situation D Emergency" is used deliberately instead of "nuclear war" in this study to emphasize the distinction between the two events. A Situation D Emergency subsumes a nuclear war, but it covers a broader time span. It includes the actions taken leading up to the nuclear war, including support of mobilization, conventional war, civil defense, and continuity of government. It includes all other lesser emergencies: local, regional, and national. It includes actions taken during and after the nuclear attack to provide for survival, response, and recovery.

Requirements for emergency communications can be understood only in the broader context of the Situation D Emergency. The timing of the various stages of a Situation D Emergency is important. It is highly unlikely that a nuclear war will occur so suddenly that the telecommunications systems will have to move abruptly from normal peacetime operations to nuclear war operations. The telecommunications system will adjust to meet the different demands of actions taken to improve preparedness for nuclear war. The workload and operational configuration of the telecommunications system at the outbreak of nuclear war will be quite different than in peacetime. An understanding of this is important when obtaining estimates of information requirements from users.

Emergency Government

The form of government which will exist at the outbreak of a nuclear war is termed the Emergency Government. As the nation transitions from peacetime through preparedness, mobilization, and civil defense emergency, to population and governmental relocation and sheltering, the form and powers of governments at all levels -- local, state, and Federal -- will change. As the threat intensifies and preparedness measures are taken, the scope and authority of these governments will expand. The nation will shift from a market-based economy to a command economy in which governments will allocate resources -- including communications capacity -- for the common defense. The Emergency Government will have positive control of all resources and infrastructure systems.

The telecommunications system can operate in a Situation D Emergency only in close cooperation with the Emergency Government.

National Telecommunications Network

This is a term which encompasses the totality of communications assets in the United States. This includes the hardware, cable, switches, computers, terminals, radios, and trained personnel, which actually comprise the telecommunications capability of the nation. This comprehensive new term is needed because previous work has dealt with only subsets of total national communications capacity. It is insufficient to deal only with "government communications systems" because, with a few exceptions, governments are dependent on the common carriers for transmission of signals. Similarly, it is insufficient to deal only with the Public Switched Network, because even this large subset omits the privately owned and operated assets, which are considerable. The National Telecommunications Network (NTNS) subsumes all lesser included sets.

Distinctions based on ownership of assets or billing for service will be unimportant during a Situation D Emergency. Application of resources and priorities for use will be established by the Emergency Government based on perceptions of need for survival and recovery.

Methodology

General

The basic idea is to obtain from the users of telecommunications their own views on what they need to be able to communicate in order to get their jobs done in a Situation D Emergency. These user-based views will be used to establish estimates of information requirements, which in turn will be transformed into communications requirements.

Information requirements will be estimated for each Essential Emergency Function (EEF). The information to manage a single EEF will flow along paths which are unique to that particular EEF. These information requirements depend on the content of the EEF and are independent of the telecommunications system.

Information requirements for all EEF will be combined by adding them to the National Telecommunications Network. Nodes for each EEF will be assigned to Switches in the telecommunications network. After all EEF are added, the minimum essential information flow for each switch will be defined. The assignment of EEF nodes to switches will be accomplished by integrating the telecommunications system with the structure of the Emergency Government. The addition of all EEF, including the base flow information required to operate the telecommunications system itself, will define a minimum required information load for each switch.

The methodology involves six steps as follows.

The first step is to estimate the information required to operate and manage each Essential Emergency Function (EEF) established by the Federal Government.

The second step is to estimate the base flow of information required to operate and manage the National Telecommunications Network itself.

The third step is to establish a network systems model of the National Emergency Telecommunications System.

The fourth step is to modify the NETS Model to incorporate the Emergency Government.

The fifth step is to add the base flow information requirement and all individual EEF information requirements to the Modified NETS Model.

The sixth and final step is to compare the information flow requirements with communications capability to provide a basis for improving capability as necessary.

Step 1: Single Function Analysis

General

The first step is to estimate the information requirement for the Essential Emergency Functions (EEF) prescribed by the Federal Government.

A model of an information flow path for an EEF is shown in the figure below. Only two nodes are identified at the outset. All of the nodes are offices or organizations, and these are not connected with any particular telecommunications system or element. The National Level (NL) is the highest node and is the Federal Government office responsible for management of the EEF in a Situation D Emergency. At the lowest level is the Basic Reporting Element (BRE). BRE will vary according to the EEF, but all BRE for a single EEF will be the same kind of activity or office. The number of Intermediate Nodes (IN) depends on the particular EEF and cannot be determined in advance of the analysis.

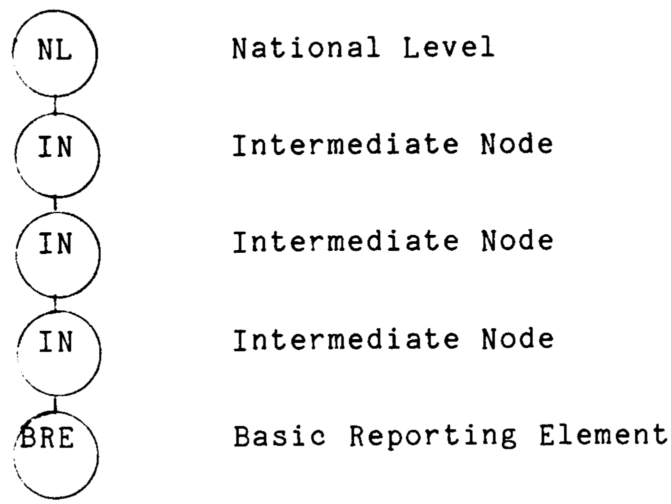


Figure 1: Conceptual EEF Information Flow Path

The analysis of a single information flow path is accomplished in four stages:

<u>Definition of Information Flow Path</u>. The first stage starts at the highest, or national, level and works down through intermediate nodes to the Basic Reporting Element (BRE). The purpose of the first stage progression from top to bottom is to define the information flow path for that particular EEF by identifying the intermediate nodes. The figure below shows a possible EEF flow path in which intermediate nodes have been identified.

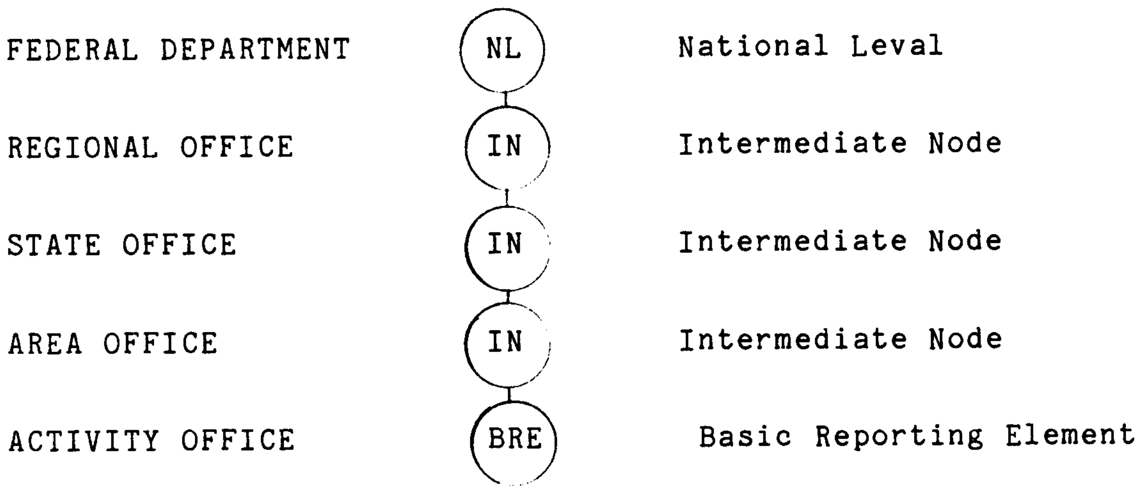


Figure 2: Possible EEF Information Flow Path

Estimation of BRE Reporting Requirements. Once the BRE is located, the second stage establishes the information needed to report the status of the functional activity or resource. Estimates of information requirements are obtained from the personnel responsible for operating the BRE. The purpose of the second stage is to estimate the information which the BRE must send upward in order to allow the EEF to be accomplished.

The reporting requirement for a single BRE is shown by the formula below:

$$Q_R = N_R \cdot F_R$$

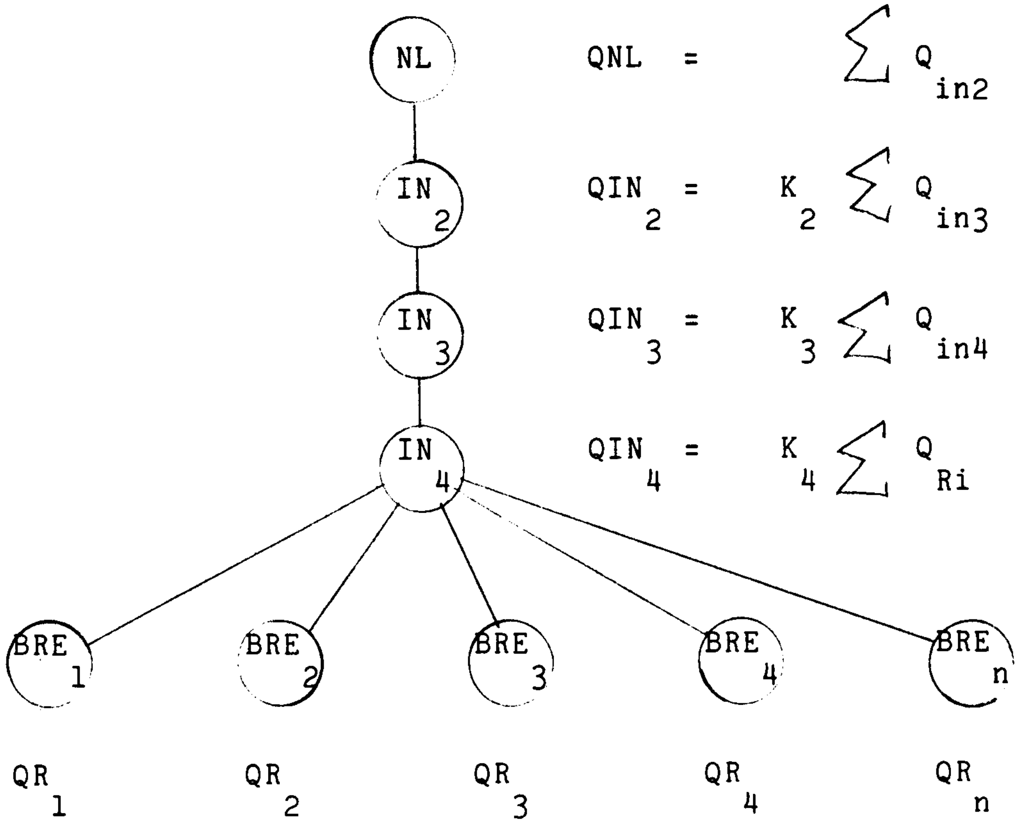
Where N = number of bits of information in the report
F = number of reports per day.

The quantity of information in the report is the number of bits needed to describe sufficiently the status and activity of the BRE. The amount of information for a single status report can be determined by direct interaction with the persons responsible to make the report. This will be accomplished initially by an interview and subsequently by questionnaires.

The frequency is the least time period between successive reports needed to assure that the information in the report is current. Frequency of reporting will depend to a great extent on the activity level and operating tempo of the BRE. Frequency will depend also on the decision cycle of higher level nodes in the EEF information flow path. The frequency of reporting may be different at the BRE level than at higher nodes. This will depend to a certain extent on whether the information flows upward automatically in response to a prearranged "push" system or waits at intermediate nodes until there is a "query." The timing of reporting is likely to be different for each EEF particularly if reporting frequency is not specified in emergency operating instructions.

Determination of Report Consolidation Factors. The third stage retraces the information flow path for the EEF from bottom-to-top to estimate the consolidation of reporting information. Reports will be processed and consolidated at each intermediate level node in the upward path, so the amount of status information leaving a node will be less than the amount of status information coming into the node. The extent to which report consolidation can occur at each intermediate node is a very important factor because the number of nodes decreases significantly at each higher level. The figure below shows an EEF information path and the information flow at each intermediate node after application of the consolidation factors. The

Intermediate Nodes are numbered in sequence from top to bottom, and the symbol "k" is the consolidation factor for each Intermediate Node.



$$QNL = \sum Q_{in2}$$

$$QIN_2 = K_2 \sum Q_{in3}$$

$$QIN_3 = K_3 \sum Q_{in4}$$

$$QIN_4 = K_4 \sum Q_{Ri}$$

Figure 3: EEF Reporting Path

<u>Additional Information Requirements</u>. Up to this point we have considered only status reporting from the BRE to the National Level. However, status reporting upward is just one part of the information flow for a single EEF. In addition to reporting, there are requesting, directing, and lateral coordination. Reporting conveys the status of resources for a

particular EEF. Requesting conveys claims on those resources. Directing conveys orders for disposition of those resources.

Requesting involves making claims on resources or services. Requests flow from bottom to top. Information for requesting will be estimated in the same way as for reporting, and similar consolidation factors will be defined and applied. It is assumed at the outset that reporting and requesting channels will be the same, but this may not be true for all EEF.

Directing will occur in response to requests and requires that information flow from higher to lower nodes. As information flows downward, it expands in quantity because the intermediate nodes apply judgement and separate a single directive into several directives. For each node there will be an expansion coefficient for directives, similar to the consolidation coefficient for reports and requests.

Lateral communication is important also, particularly in this situation where the survival of higher nodes is not assured. When a BRE cannot report to its "normal" next higher node, it will try to report laterally until it can find a path to move up to the next higher level, or even to the level above that. Accordingly, there is a requirement for lateral information paths as well as upward and downward.

The figure below shows the information flows for a single node. This is valid for the BRE as well as Intermediate Nodes, for the BRE also will have information flowing into them from subordinate levels.

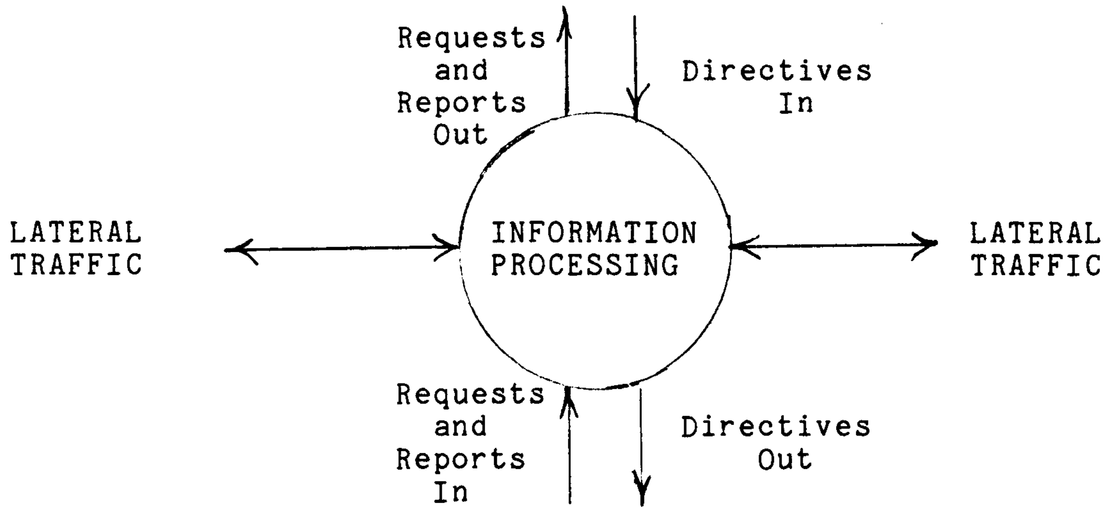


Figure 4: Information Flow for a Node

<u>Determination of Directive Expansion Factors</u>. The fourth stage is to retrace again the information flow path from top to bottom, this time to estimate the expansion of directive information. As directives flow from higher to lower level nodes, the directives will be processed, and the amount of information will tend to expand. The amount of directive information leaving a node will be more than the amount of directive information coming into the node.

<u>Estimation of EEF Information Requirements</u>. Thus far the process provides an estimate of minimum required information flow for a single BRE. The process is repeated for a significant number of BRE information flow paths, varying location and kind sufficiently to represent the population of BRE for that EEF. Once a sufficient sample of information requirements is obtained, the total national information requirement for that EEF can be estimated. This is accomplished by locating each BRE for that

EEF and defining each intermediate node. The result will be an information flow model for that EEF. The figure below illustrates an information flow model for a single EEF.

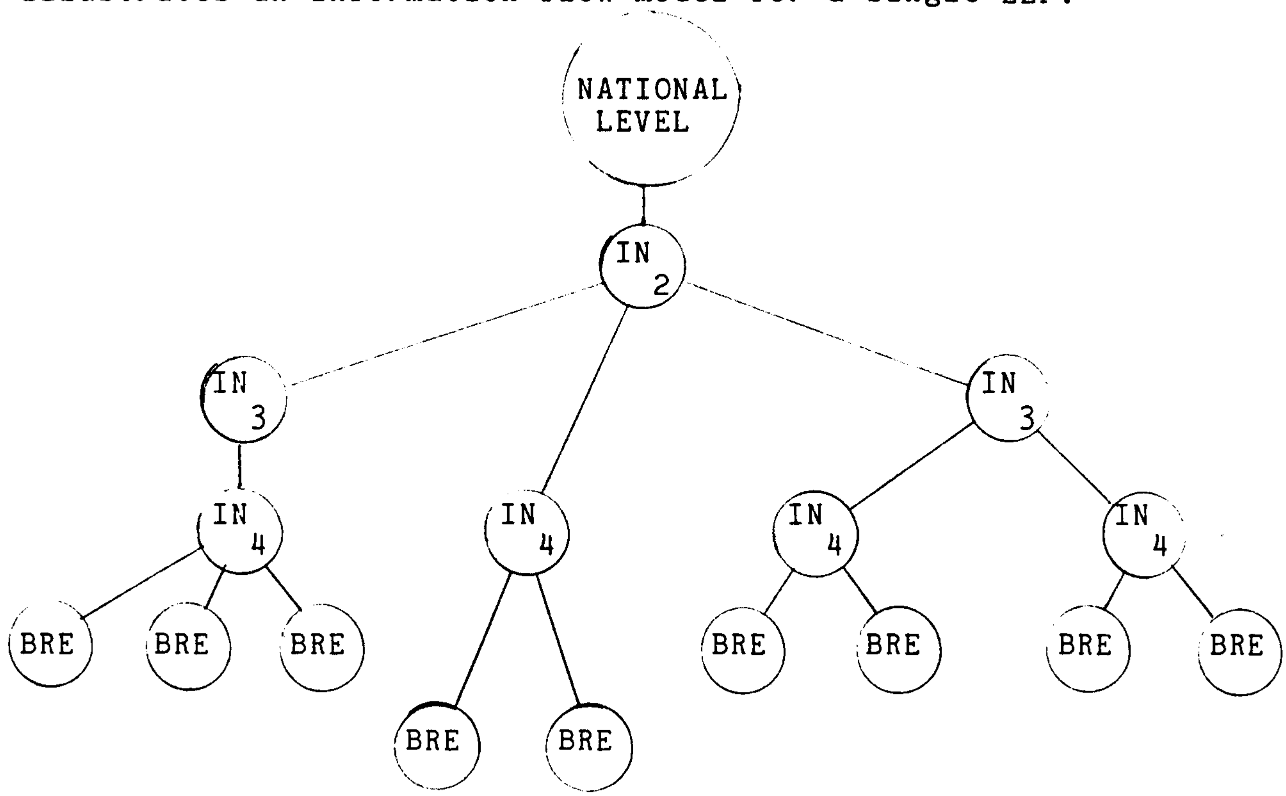


Figure 5: Information Flow Model for an EEF

Results

The single-function analysis provides an estimate of the information flow required to operate or manage a particular EEF. Appendix B is a more detailed description of how a single function analysis would be accomplished for the EEF which requires status reporting of POL stocks.

The information requirement for a single EEF will be trivial compared to the total information requirement for all EEF. It is necessary, therefore, to conduct a single-function analysis for each of the EEF specified in the emergency plan.

Once this is accomplished it will be necessary to combine the information requirements for all EEF into an overall system requirement. This will be valid to the extent that the number of specified EEF define the total requirement for conduct of emergency management.

The process and model are getting incredibly complex at this stage. There are over one hundred EEF, each with singular characteristics and different information flow paths. Combination of these many different information requirements into a coherent total requires integrating into a single model the disparate EEF information flow paths. These EEF have two properties in common: they all have to communicate using the NTS, and they all have to relate to the Emergency Government.

Step 2: Base-Flow Analysis

The second step is to estimate the information requirements to operate and manage the National Telecommunications Network itself. This kind of traffic is a base flow which is essential to the functioning of the system. Other information requirements are additive to this base flow.

The general approach to this step is the same as for Step 1. Base flow information requirements will be estimated by the present operators of the elements of the National Telecommunications Network, Each private company and each Government Agency which owns and operates telecommunications equipment will be asked to provide its own estimates of the amount of information required in the form of reports, requests, and directives each day to assure the proper functioning of their own systems. They will be assisted in this task by specially trained interviewers who will assist the respondents in providing estimates. Estimates will be obtained for current peacetime operations, operations in a civil defense emergency just prior to a nuclear attack, and operations just after a nuclear attack.

The process of making these estimates will provide two general kinds of information as follows:

1. Information flow paths for the National Telecommunications Network will be defined by the operators themselves. This will help to create a NTS Model.

2. Basic information flow which each node is required to be able to handle just to keep the system operational will be estimated.

Once the base flow information requirements have been estimated they will be used to help create a model of the survivable portion of the National Telecommunications Network as a basis for comparing information requirements to communications capability.

Step 3: National Emergency Telecommunications System Model

The next thing that has to be done is to create a new model (or adapt an existing model) of the National Emergency Telecommunications System (NETS).

NETS is a subset of the NTN which includes the Class 4 and 5 switches of the Public Switched Network. The composition of NETS is based on the assumption that higher level switches will not survive a nuclear attack. NETS is a useful structure for the purposes of this methodology because it is designed for a Situation D Emergency. Application of estimated information flows to

NETS is more realistic than using the entire NTN for this purpose.

Emphasis will be on telephone service during the Situation D Emergency. Special purpose radio networks, such as those employed in military units, are not useful for general emergency management purposes, although they are invaluable to serve their own special purposes. In this methodology we do not include any special purpose radio systems. As soon as someone picks up a telephone, the NETS will come into play.

The communications system is designed to transmit a message from Point A to Point B. This involves two functions: switching and transmitting. Switching is the process of routing the message from the originator through the network to the addressee. It is accomplished by switches which select at each stage a path for transmission. Once the path is selected, transmission is the process of sending the message between switches.

The links of the model will be the various transmission means. There are several means of transmitting signals: cable; microwave relays; satellite relays; and radio. The model does not make a distinction among these various transmission means.

The nodes of the NETS Model will be Class 4 and Class 5 telephone switches. Class 1, 2, and 3 switches will not be represented. Class 4 and 5 switches serve local areas. Class 1, 2, and 3 switches are designed to move calls over long distances. However, the higher level switches are unlikely to be available after a nuclear attack.

Postulated laydowns of Soviet nuclear weapons tend to destroy almost all Class 1, 2, and 3 switches, but a large number of Class 4 and 5 switches are not damaged by the direct effects of the nuclear explosions. Those surviving Class 4 and 5 switches provide the means of reconstituting the National Telecommunications Network in the immediate post-attack period. It is possible to route a call, albeit inefficiently, from one coast to the other using only Class 4 switches.

The National Emergency Telecommunications System (NETS) has been established to improve the capability to route calls through Class 4 and some Class 5 switches by adding a call forwarding capability. This will provide a means of making a limited amount of long distance calls using the remaining Class 4 and 5 switches. The figure below presents a schematic diagram of a portion of the NETS model.

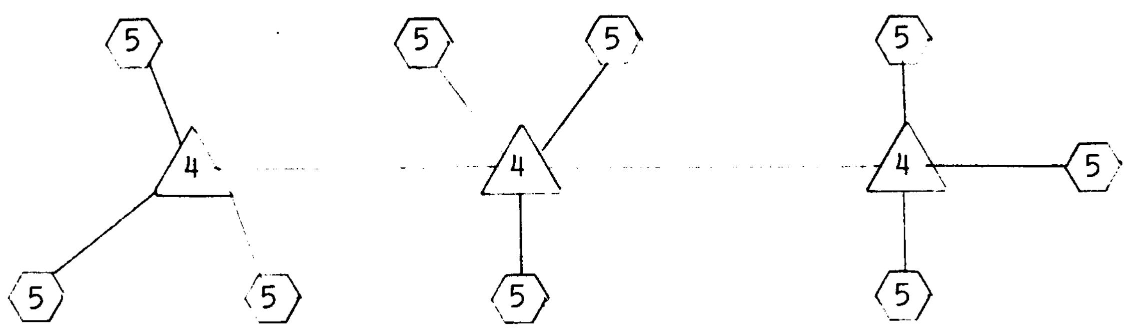


Figure 6: Schematic Model of NETS Model

<u>Step 4. Integrate the Emergency Government into the NETS Model</u>

The NETS will not operate during the emergency in isolation from the rest of society. It will in fact be the nervous system which will hold together the fabric of society. In this respect, the NETS must be associated closely with governments at all levels.

Before, during, and after a nuclear attack, the Emergency Government will be in charge. Local, state, and Federal governments will do what is necessary to save lives, protect property, and maintain society. Before the attack, emphasis will be on preparation for survival. During the attack, emphasis will be on survival, and activity will be minimal. After the attack, emphasis will be on recovery and facing the formidable obstacles to continued survival.

A major premise of this methodology is that all EEF, all communications, and almost all other activities will be managed by the Emergency Government.

The most immediate role, and perhaps the most important, will be played by county governments. There are 3,200 counties in the United States. About 2,400 of these will survive the direct efects of even a massive nuclear attack on military and urban-industrial targets. Another 300 counties will have significant areas which will survive the direct effects. County governments will be the prime mover in taking actions to recover from the nuclear attack.

State governments also will play a significant role. State governments have significant resources at their disposal, and Governors have broad authority to deal with emergencies. State governments will reassert control of counties in their respective states in the immediate post-attack period. The primary function of State governments will be to allocate resources among the various counties.

The figure below shows the hierarchy of the Emergency Government.

The Federal Government also has significant resources at its disposal. These will be made available to local governments in part, but the Federal Government will have concerns and missions which are not shared by state and local governments in this situation. The role of the Federal Government in the emergency will be to wage war as necessary, seek peace, and provide for the survival of the nation. This will include allocating resources among the states.

The Federal Government will operate at two levels: National and Regional. The National level of operations will include the Executive Office of the President and the headquarters of the Departments and Agencies of the Executive Branch, the Supreme Court, and the Congress and other agencies of the Legislative Branch. The Regional level will consist of existing regional offices of the Departments and Agencies, augmented to perform a major role in management of the emergency.

The figure below shows the hierarchy of the Emergency Government.

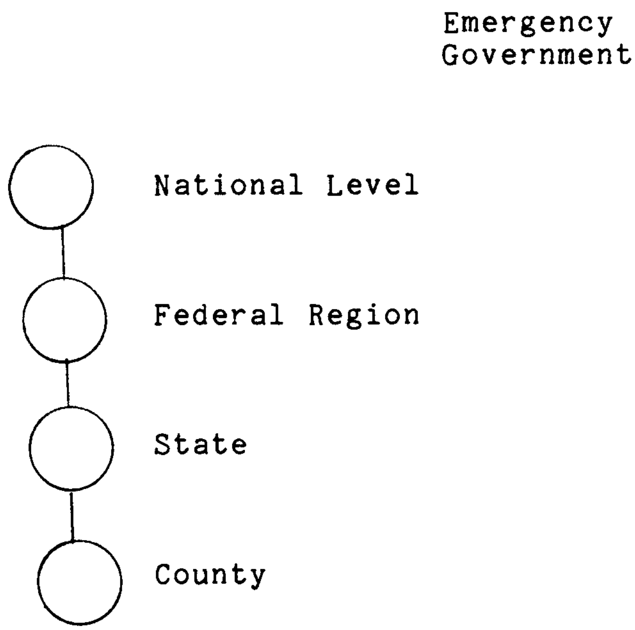


Figure 7: Emergency Government Hierarchy

Performance of the emergency functions of government requires each government to know what is available and what is needed in each locality. Upon the basis of this information, decisions can be made to reallocate resources to provide the maximum benefit to society as a whole. In order to function, there must be a link between the Emergency Government and the National Emergency Telecommunications Systems.

The most essential link will be at the county level. It is assumed that each county government will take control of communications within the local area of authority. One of the actions to obtain this control will be to take over the Class 4 or Class 5 switches which service the telephones in the county. Even if this is not preplanned action, it will occur, because local government cannot function in the emergency without controlling communications. (It is assumed that county