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APPENDICES A–E

SEPTEMBER 1977

PHASE I FINAL REPORT

FOR THE MODULAR SYSTEM CONTROL DEVELOPMENT MODEL (MSCDM)

for

THE DEFENSE COMMUNICATIONS AGENCY
WASHINGTON, D.C. 20305

Burroughs Corporation
Federal and Special Systems Group
Paoli, Pa. 19301

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APPENDIX A.

UTEK SYSCON Data Base Study

This appendix contains the UTEK final report and two subappendices which detail the findings based on UTEK's analysis of the reporting procedures and support networking used for monitoring and management of communications by the Defense Communications System (DCS).

MODULAR SYSTEM CONTROL

DEVELOPMENT MODEL

TASK 1 & FINAL REPORT

Prepared

By

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Overland Park, Ks. 66214

August 4, 1977

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I. INTRODUCTION AND ASSUMPTIONS

A. This study, Task I for the Modular System Control Development Model, is based on the present and near future mechanisms for direction and reporting resources to operate and manage the Defense Communications System (DCS).

This report is based on analysis and data excerpts of the material listed in Appendix VIII.

It is the goal of this report to describe the data sources and their relationships that are used for operational direction and management of the DCS.

B. Operation of the DCS includes:

1. Monitoring and maintaining the connectability of subscribers to the DCS.
2. Monitoring and maintaining the channel apertures of all DCS circuits and trunks at precribed acceptable quality.
3. Monitoring and maintaining the connectivity of all switching centers with the DCS transmission network.
4. Monitoring and maintaining the throughput and traffic volumes through DCS switching centers at adequate levels.
5. Establishing circuit, network, or system level re-route or restoral alternatives to maintain service at a reduced capability during circuit outage or switch blockage intervals.

6. Monitoring and reporting all occurances concerning traffic movement problems or network hazards.
7. Overviewing all network level problems to provide assistance and coordination during the resolution of problems.
8. Implementation of contingency plans supporting tactical situations or mobility exercises.
9. Maintaining day by day status of the DCS for the JCS.

C. Management of the DCS includes:

1. Establishing requirements for additions, upgrades or deletions to DCS/customer service.
2. Validating customer service requirement changes and, when necessary, establishing restoral priorities.
3. Establishing circuit implementation plans including, as necessary, amendments to existing restoral plans.
4. Monitoring status changes regarding use of DCS dedicated circuits and assets.
5. Monitoring the operating efficiency of the DCS and the quality of service afforded its customers.
6. Monitoring the effectiveness of DCS operational doctrine and policies and their execution.
7. Performing statistical analyses of quality and throughput data to evaluate present technical criteria and plan for future growth.

8. Participate in the planning of exercises and contingency operations which impact DCS loading or connectivity.

9. Develop long term planning for the upgrade, modernization, or re-direction of the DCS; this includes the establishment of policies and procedures for the operation and quality of the DCS.

D. Factors concerning operations and management data and its uses:

1. Data will be generated at various levels and locations within the DCS and its staff and service elemtns. Data bases exist or may be compiled to support these goals. Should additional data bases be compiled, they will be assembled from existing information for use in seasonal or cyclical/trending, or traffic analysis. These additional files will contain quantified data in sufficient amounts to permit short and long term analysis using various techniques (e.g. weighted moving average, forward bias moving average, etc.).

2. The ATEC System will be operational to provide data to the control and management network.

3. Programs are in progress, or systems are in place in the network switch facilities which functionally parallel the ability of ATEC. These systems or programs include: ACAS (AUTOVON), TDCS (AUTOVON), AUTODIN II.

4. An adequate network architecture for transmission of system control information presently exists at the middle and upper level management and control levels.
5. The DCS transmission systems are evolving from analog to digital, but customer drops and switch interfaces may still be analog.
6. Management by exception will be used. Functions will be performed at the lowest DCS level with the requisite capability using preconceived procedure. In general, only deviation reports will be submitted for operational matters. Management level data, however, will be stored and queued for transmission on a "second priority" basis.

II. FUNCTIONAL DESCRIPTION OF SYSCON STRUCTURE

A. Figure 1 depicits Levels I-V of the SYSCON Structure or DCA Operational Control Complex (DOCC). It is the basic function of this management structure to plan, engineer, operate and maintain the Defense Communication System (DCS). Two distinct but closely related aspects in managing the DCS are Systems Operational Control and Systems Management.

B. Systems Operational Control

Systems Operational Control concerns the operational direction of the resources within the DCS. Systems Operational Control is distributed throughout all levels of the management structure.

C. Each level contributes action necessary to the day-to-day health of the system. Actions are initiated from the lowest level with the requisite authority, responsibility and visibility. The actions involve:

1. Determination of the health of the system/sub-system
2. Assignment of tasks and supervision of their execution
3. Short-term re-allocation of operational facilities when necessary to support the daily mission

D. Level V is the primary DCS element in direct contact with the transmission and network systems. Level V facilities commonly contain two elements: Reporting Stations and Reported-on Stations

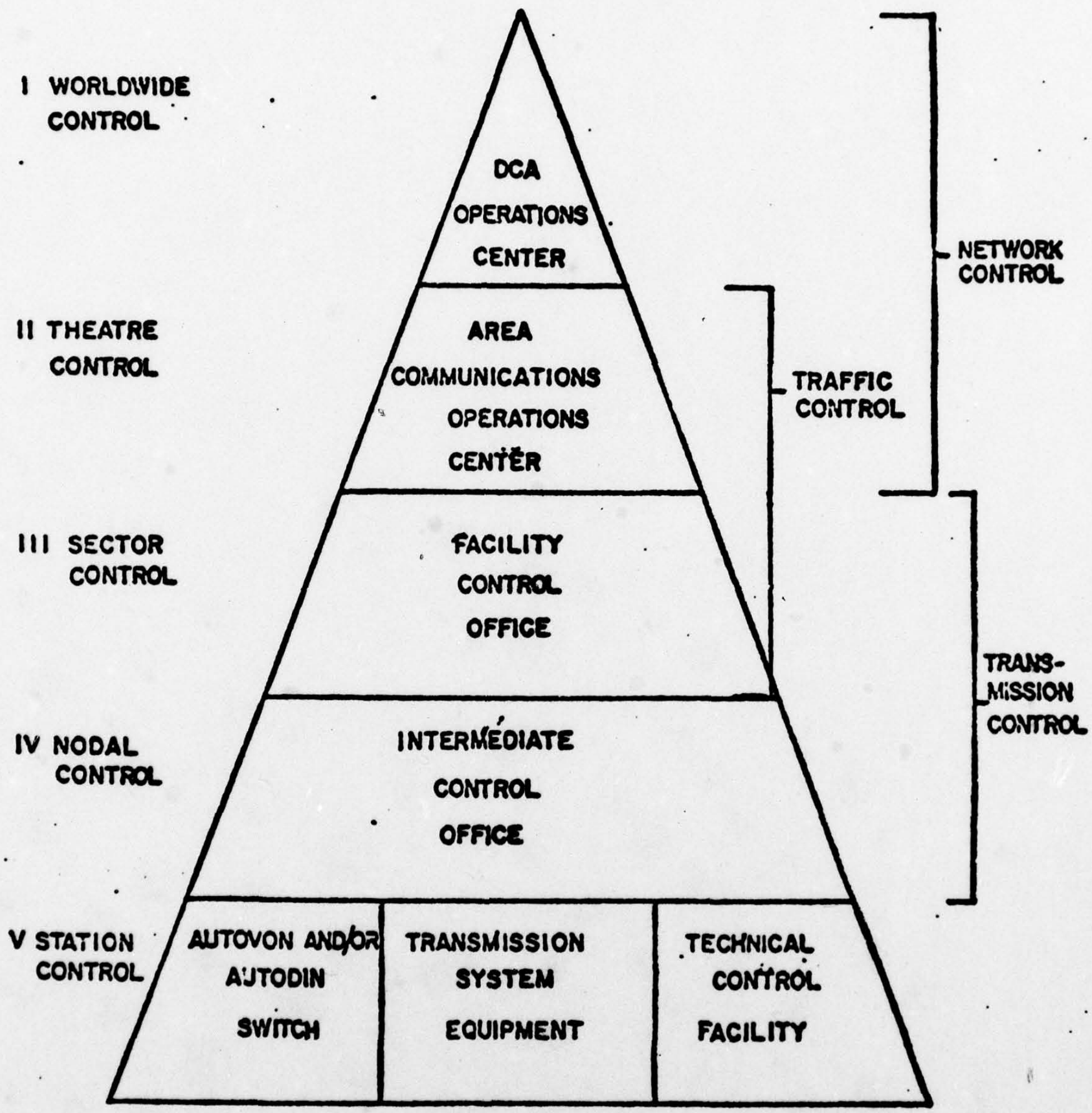


Figure 1
DCS SYSCON HIERARCHY

1. A reporting station is a facility which is optimumly positioned to sense all occurances relevant to operation of the DCS. Such facilities are generally termed technical controls. They exist at major nodal points and circuit break-out points within the transmission systems. Should the switching centers be commercially leased facilities as in the Continental U.S. (CONUS), reporting stations can be near-by transmission systems Technical Controls such as those at the European and Pacific Gateway stations.

2. Reported-on stations are small special purpose facilities which are not manned to support operational reporting or do not possess the means to sense both causes and effect of operational direction or system degradation. The reported-on station may be co-located with the reporting station or remoted. Such facilities include:

   - transmitter sites
   - receiver sites
   - radio relay sites (no multiplexing or demultiplexing equipment)
   - patch and test facilities
   - un-manned sites
   - commercially leased facilities
   - network switching centers co-located with technical controls

- other small stations

Such facilities funnel their event reporting through reporting stations, and receive operational guidance and assistance from them as necessary. Thus, they are "reported-on" by the "reporting" station.

3. For each DCS station comprising Level V, its system visibility and particularly its authority is limited primarily to that DCS station and its communication connectivity. None-the-less, pursuant to higher direction, Level V performs most of the daily system measurements and adjustments, coordinaties with the system users, and initiates most of the status reports that reflect on the health of the system. Thus Level V operates primarily in response to pre-established instructions with near-real-time supplementary directions from higher echelons (via Orderwires).

E. Level IV is generally co-located with a Level V operational DCS station at a major hub node of the transmission network. It is concerned only with the transmission media systems within their jurisdiction and lateral coordination with adjacent levels. It is a collection point for transmission system related information, establishing multipoint visibility over transmission system elements within its authority.

Level IV can therefore direct, coordinate and monitor tasks assigned to subordinate levels stations and consolidate subordinate reports for higher level consumption. Pursuant to pre-established instructions and higher level direction, they initiate actions and directives necessary for the day-to-day maintenance of the system. Level IV duties are often assigned to Level V operating station personnel at co-located facilities.

Level V AUTOVON, AUTOSEVOCOM and AUTODIN switches processes transmission media events through Level IV but bypasses it for events solely concerned with the switch matrix, its software, and support circuitry. These events are directly reported to Level II.

F. Level III responsibility is geographically oriented at the regional level. At present, there are nine such regions within the DCS. Operations responsibility is primarily and O and M function delegated to a respective military department. A small DCA staff support element may be assigned for management functions, although circumstances may dictate their participation in operational matters. Such circumstances generally occur in the case of contingency operations in the region, or when a more real-time presence of area operations control is required (i.e. The Far East and South East Asia Regions are separated from the Pacific ACOC by 16 hours).

1. Level III Control is dual functioned. It is the upper level of control for transmission systems and the lower level of control for traffic movement. It is the hubbing point for Level IV Control Centers within the region, and is in direct contract with adjacent regions and its area control. (Area control is the hubbing station for monitoring traffic volume data handled by switching centers.) Thus it resides at the optimized position to insure the connectivity of the transmission system can support the volume requirements of the switches.

2. Level III Control Centers are commonly co-located with Level IV/V Control Centers.

G. Level II Control is geographically oriented and solely manned by DCA personnel. There are three DCA areas: Europe, Continental U.S., and Pacific. They are both operational and managerial oriented. They are presently interconnected with the switching centers and the DCAOC by a highly interactive communications network and data processing systems termed "WWOLS" (World Wide On Line System). This system is the terminal point for the majority of all operational and management information concerning the DCS. Level operational control responsibilities include:

- Inserting all transmission system and switch status data into the WWOLS

Commercial Communications Office), it also accomplishes all circuit engineering actions supporting non-DOD users of the DCS.

H. Level I Control is maintained at the DCAOC (DCA Operations Center). The DCAOC is located at Headquarters DCA in Washington DC. Its primary mission is operational control. Management control is satellited to concerned DCA headquarters staff elements which obtain information from the WWOLS.

1. The DCAOC primary function is network control. It manifests this responsibility on a management by exception concept. This is achieved primarily through careful monitoring of WWOLS resident information which has been highlighted by the ACOC's augmented by selected information retrievals. A second function is to maintain a constant status on the configuration and support capabilities of the DCS for the JCS (Joint Chiefs of Staff).

2. The DCAOC also maintains a limited support capability for high interest contingency operations which may have short term impact on the DCS.

3. The DCAOC also maintains a special overview on the status of AUTODIN II packet data switches and earth satellite communications vehicles which support the DCS.

I. Systems Control information resources for status monitoring are the WWOLS, the subordinate level status reports, the potential resources of the AUTOVON Transmission Data Collection System (TDCS) and AUTOVON Centralized Alarm System (ACAS) at Level II (ACOC) and the AUTODIN II Nodal Control Center (NCC) at Level I (DCAOC). For events not concerning transmission media, Level V AUTODIN I, AUTOVON and AUTOSEVOCOM switches report directly and only to their respective ACOC at Level II. For transmission systems, the primary information resource will be the ATEC (Automatic Tech Control Network) or manual data inputs inserted into the WWOLS from Level III. Level V AUTODIN II packet switch nodes (PSN) report directly and only to the DCAOC (NCC), Level I. The WWOLS provides the key link between Levels I and II including data access for staff and management functions. The operational direction is effected via the automatic switched networks and orderwires to subordinant and lateral echelons.

J. System operational control can be defined and exercised in two modes which we have defined for this report. The first and preferred mode is entirely within the authority of DCA. It involves identification of DCS events/conditions which result in a short-term re-allocation of DCS resources that does

This data is available through the following reporting resources;

- WWOLS (World Wide On-Line System)
- AUTODIN I Switch Nodes
- AUTODIN II Switch Nodes
- AUTOVON Switch Nodes (CONUS and Overseas)
- ATEC
- Dedicated voice & TTY orderwires, and AUTOVON
- Historical data regarding previous exercise of pre-coordinated reroute, restoral and contingency plans

K. Systems Management

System Management involves longer term actions such as planning, engineering and analysis. It includes establishment of standards, practices, methods and procedures for the performance and operation of the systems and analysis of the system performance and operation thereby obtained. It considers future and potential requirements, system survivability, system reliability, and any operation constraints as well as data collected by the DOCC for itself and for management use. For example,

1. Traffic data is used by the operational control structure for near real-time control with procedures established by management from long term analysis of traffic flows.

2. Reroute, restoral, and contingency plans with implementing instructions and constraints are established and coordinated by management for future use but are exercised by the operational control structure when required.

3. Daily quality assessment data is collected but not used by the operational control structure. It is used by management analysis and engineering to determine the capacity reliability and serviceability of the system. Potentially it can be used by the operational control structure for trouble isolation should management establish the standards, methods, and procedures to implement the necessary programs which make use of the data.

Thus system management requires all the data needed by the operational control structure plus additional system data gathered both internally and through peripheral staff agencies involved in planning or upgrading the DCS. Management also uses on-site performance and technical evaluations to evaluate existing instructions and to confirm or revise existing policies and standards for the O and M commands.

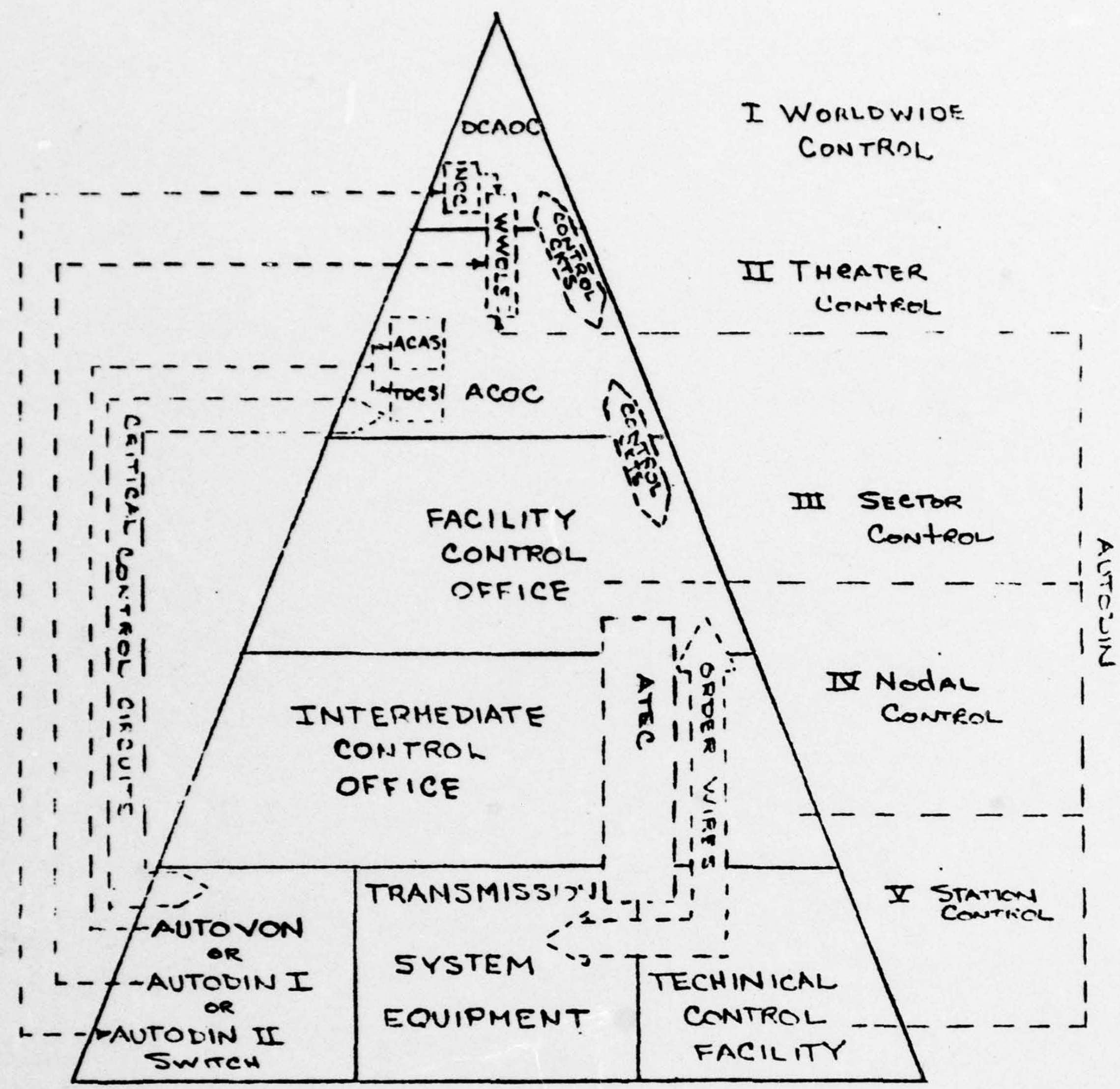


Fig 2 SYSCON Management Structure

B. World Wide On-Line System (WWOLS)

The pivitol element in the DCS information/data gathering system for operational direction and management of the DCS is the World Wide On-Line System (WWOLS). Refer to Appendix I for a detail description of the WWOLS. Fig. 3 highlights the connectivity of the WWOLS between Levels I and II of the management structure. The WWOLS sites can operate independently in a stand-alone mode but normally work together as a system using AUTODIN for inter-connection of sites. The data bases use the TOTAL management information system to provide outputs for the DCAOC/ACOC operational direction functions as well as for staff/management functions via remote terminals. The full extent of programs and data on the WWOLS is not documented by DCA. However, key elements known to be resident in the WWOLS data base are:

(a) Facility data, describing the DCS dedicated equipment available at each operating location.

(b) Service data, listing of the circuits, links and trunks comprising the DCS transmission system.

1. The Facility/Link Data Base (DCAC 300-85-1 and Supplement) was established via the Communications Resource Data (CREDATA) reporting system. The system established and maintains an ADP data base of related files for collecting, storing, updating, processing and disseminating information concerning

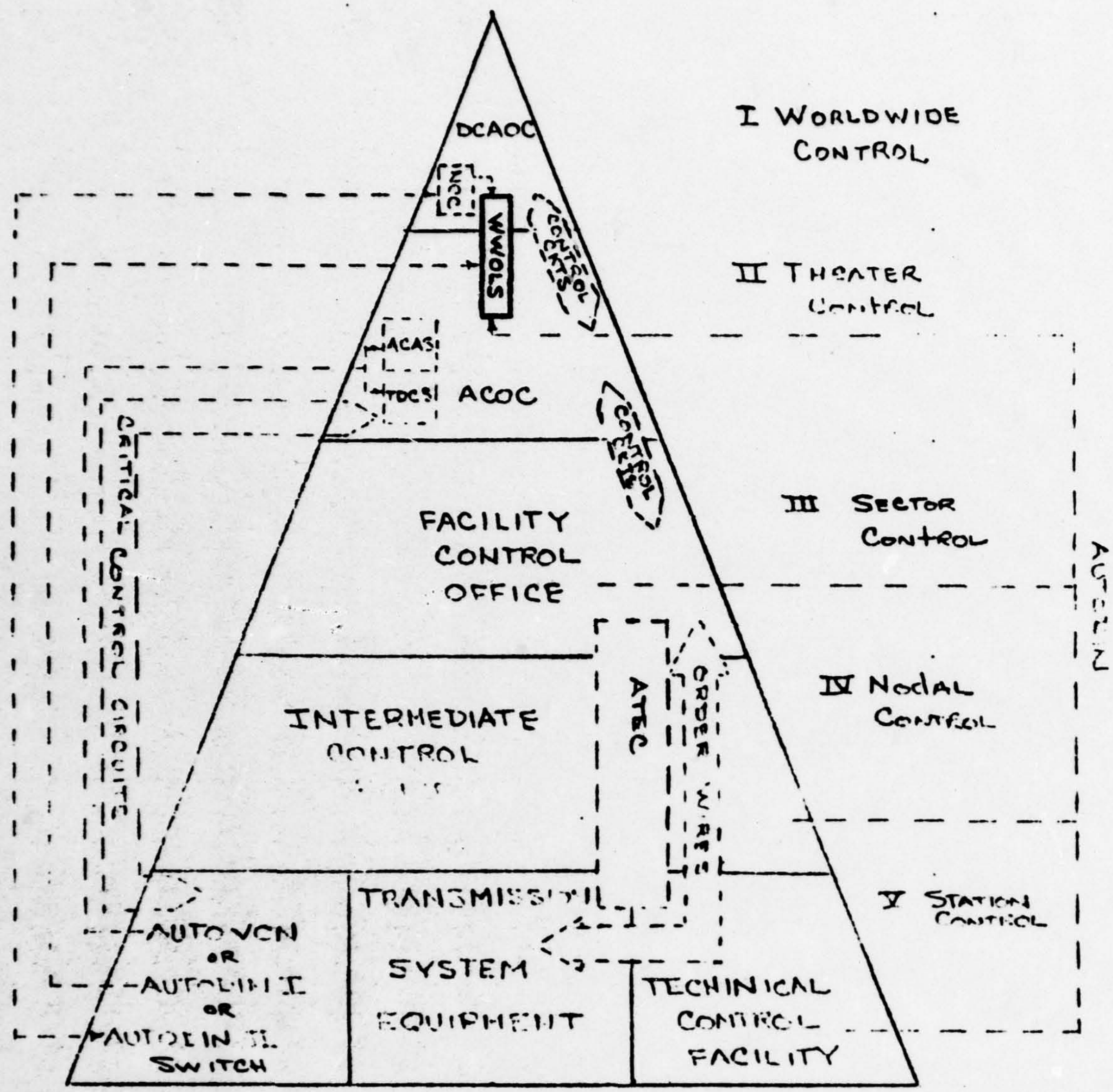


FIG 3 WWOLS RELATIONSHIP TO SYSCON

the communication resources of the DCS. The information is used for efficient planning, programming, engineering and operational direction of the DCS. It pertains principally to:

(1) The quantity and characteristics of the equipment used in the DCS (for both transmission media and switches).

(2) The sites/buildings/vans used

(3) The organization of the equipment to provide the transmission links that are basic service elements of the DCS

2. Service data (DCAC 310-65-1): The circuit/link/-trunk (CLT) file which reflects the DCS communications connectivity provided by the DCS equipments, facilities, and leased services. The circuit numbers, link numbers, trunk identifiers, and their associated file data identifies the transmission service structure of the DCS. All users, locations, routings, terminal and en-route facilities/equipments, type and speed of service, and restoral priorities are specified. When combined with the facility data (particularly for the switches of the switched networks), the combination is the communication capability/structure of the DCS.

3. Status data (DCAC 310-55-1): These data reflect exceptions to normal operating conditions and configuration. Currently this file is compiled from

daily event reporting and is only kept on the WWOLS for 10 days. AUTODIN switch traffic data is also an input to the WWOLS, however AUTOVON switch traffic and operating data is not interfaced to the WWOLS.

The facility and service data are current and permanent files on the WWOLS. The status data is entered into WWOLS via AUTODIN and SYSCON echelons.

C. Critical Control Circuits

Critical Control Circuits are dedicated (point-to-point) voice and data communications circuits utilized by the DCA Operations Control Complex (DOCC) within SYSCON for exercising operational direction over the DCS and receiving DCS status reports (see Figure 4). They interconnect:

a the DCAOC and the ACOC's (Level I & II)

b the ACOC's & the Level III FCO/RCOC

c the ACOC's & the Level V automatic switches (AUTOVON & AUTODIN)

They are the primary means by which the DCAOC & ACOC's exercise system operational control over the DCS. They are used to:

1. provide direction to subordinate elements eg implement restoral plans, implement minimize/traffic reduction plans
2. coordinate actions between switches and between switches and transmission facilities (external to

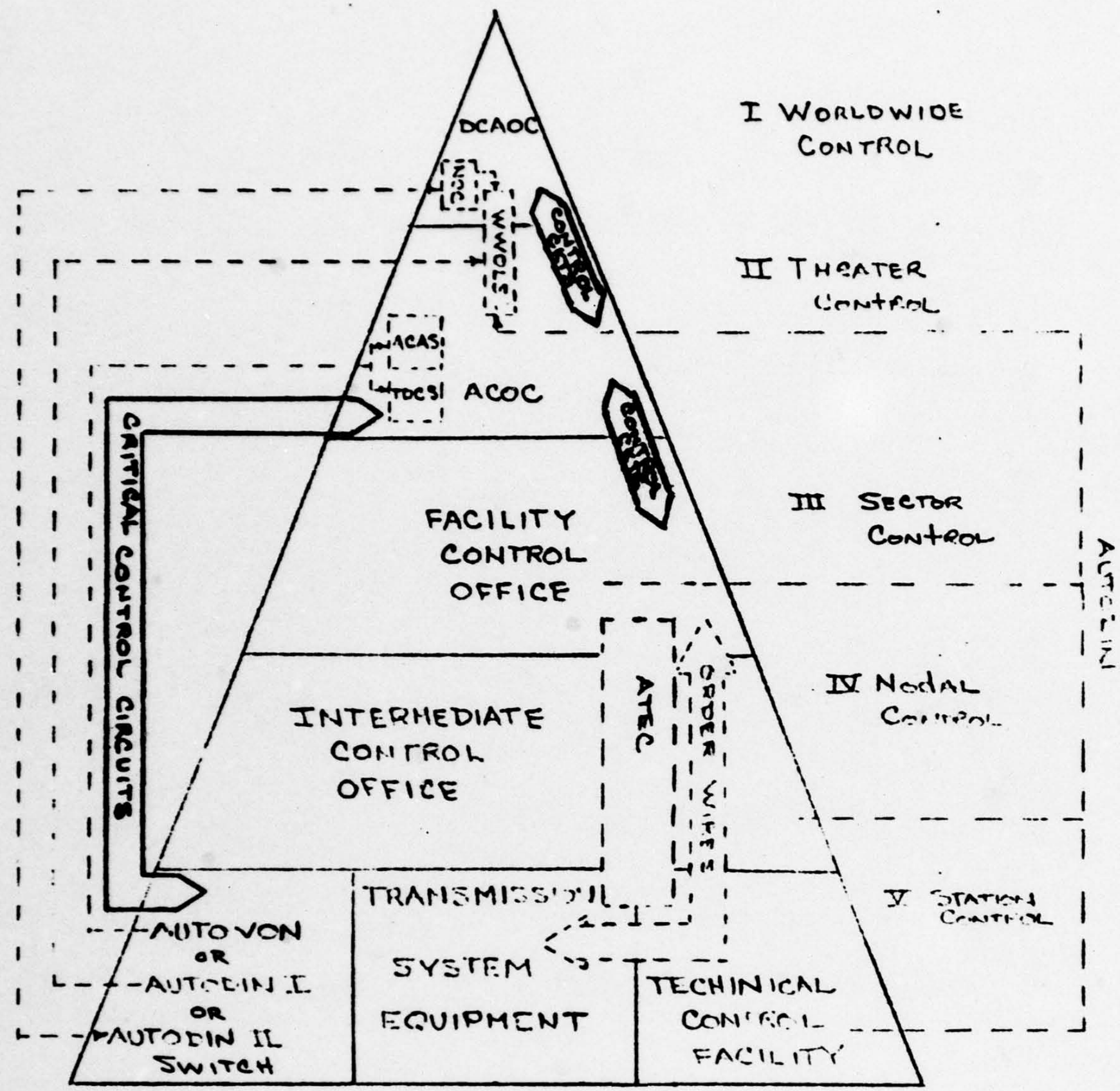


Fig 4 Critical Control Circuits

the switch)

3. resolve jurisdictional, responsibility and procedural conflicts between DCS elements
4. receive status reports or elaboration of status reports from lower echelons when urgent conditions exist

This communication, while authoritative and official, is informal and usually conversational. For significant events or directions with lasting effect, record communications via AUTODIN, letter or DCA circular are used to confirm actions and reports transmitted via critical control circuits. Critical control circuits may be implemented via precedence AUTOVON switched service in lieu of full period dedicated circuits to achieve similar results at less cost. These critical control circuits are not defined as orderwires. Orderwires are used at operating Levels III, IV and V to effect coordination and testing of the transmission media and network switches. In addition to the upward/-downward critical control circuits, the network switches have lateral communications for coordination of traffic handling and routing actions. These lateral traffic coordination circuits may be full period dedicated or switched (AUTOVON).

D. ORDER WIRES

Order wires are the primary coordination means between SYSCON Levels III, IV and V; the FCO, ICO, TCF & PTF. The majority of all DCS operations are accomplished at these levels. The orderwire circuits are essential for the maintenance of operational continuity. Thus, orderwires are essential to the TCF/PTF function in operating and controlling the transmission media of the DCS. Figure 5 highlights the orderwire relationship to the SYSCON Management Structure. The orderwire structure is not a candidate for implementing a management network. During stress conditions (i.e. failutes, restorals, etc.) in the DCS, orderwire traffic volume is high. Management data requirements would also be high during the same period. Orderwire traffic must have precedence during these stressed conditions as they are the only resource for immediate real-time actions necessary to restore satisfactory service. Orderwires have the highest circuit restoration priority and are not pre-empted for any other use. Wherever possible, orderwires are routed via transmission systems other than those they control. They are voice and data communications circuits networking telecommunications facilities manned by technical control and maintenance personnel, in exercising technical control of the DCS. These circuits are grouped into the following primary categories:

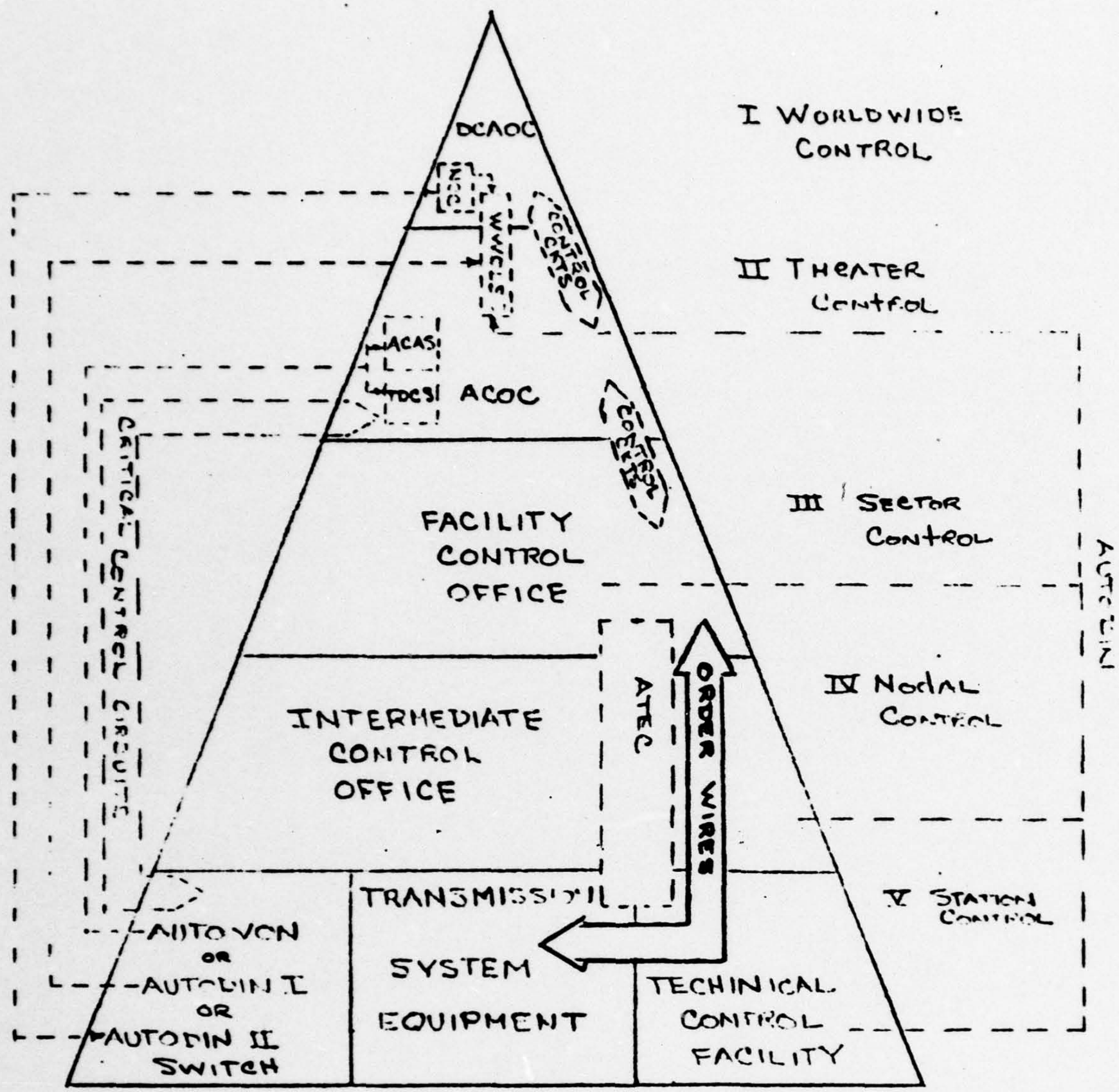


FIG 5 ORDER WIRES

1. Express Orderwire. These are voice and data communications circuits between Facility Control Office (FCO), Circuit Control Office (CCO), or Intermediate Control Office (ICO) for a large number of links, groups, trunks, or circuits.
2. Link Orderwire. The link orderwire provides the coordination circuits necessary to perform technical control functions at each end of a communications link. It also provides the communication between nodal site DCS stations through tandem connection of each individual link orderwire along the RF path.
3. Local Orderwire. These are communications circuits between the TCF and selected terminal locations in near proximity to the tech control.
4. System Orderwire. These are voice and data communications circuits which provide direct communications for coordination of control problems between TCF's outside the geographical area served by the express orderwire network.

Figure 6 provides a functional representation of the orderwires as it relates to different functional management elements. Figure 7 is a typical orderwire network following an area or sector concept.

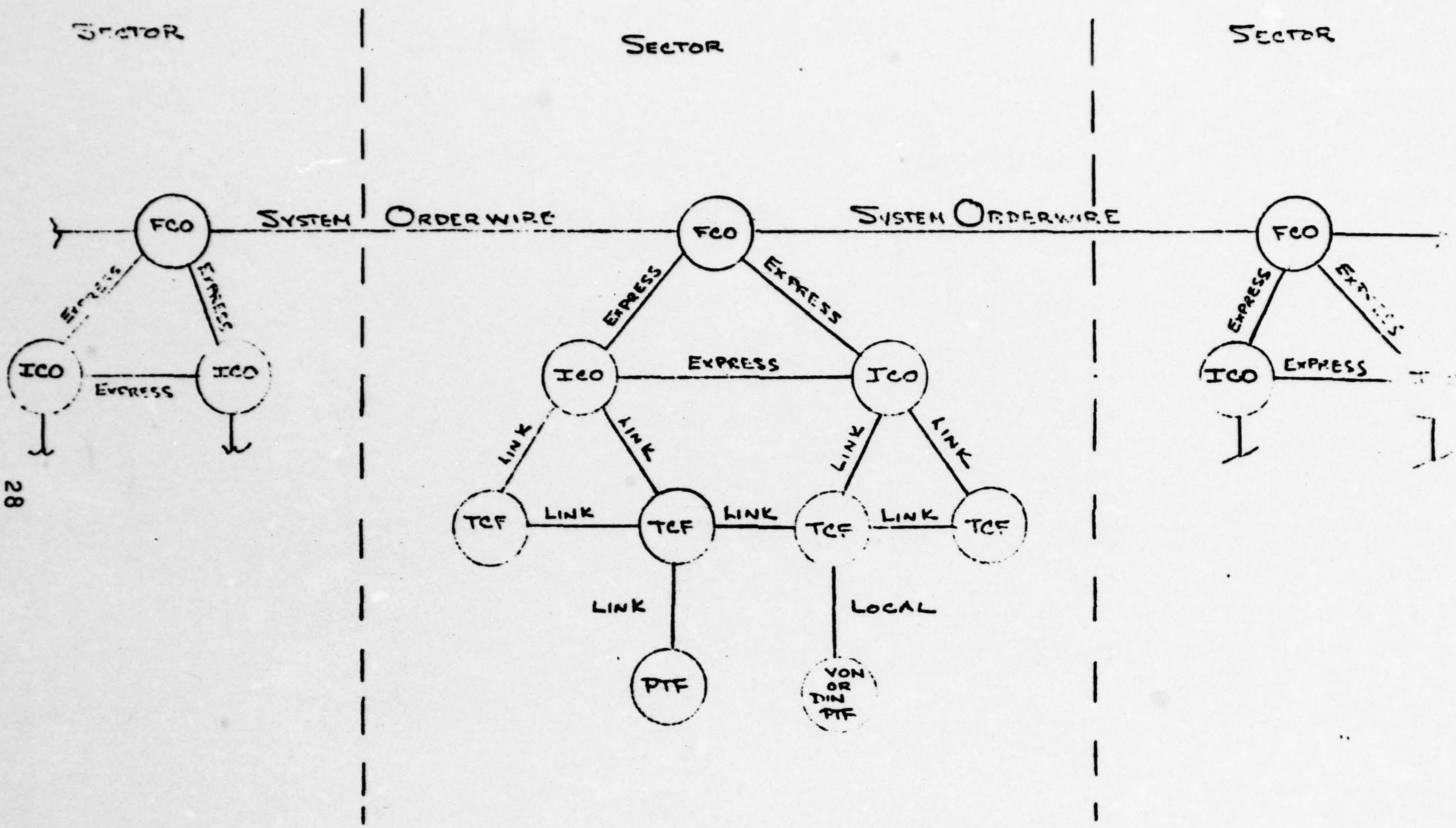


Fig 6 Functional Representation of Order Wire Structure

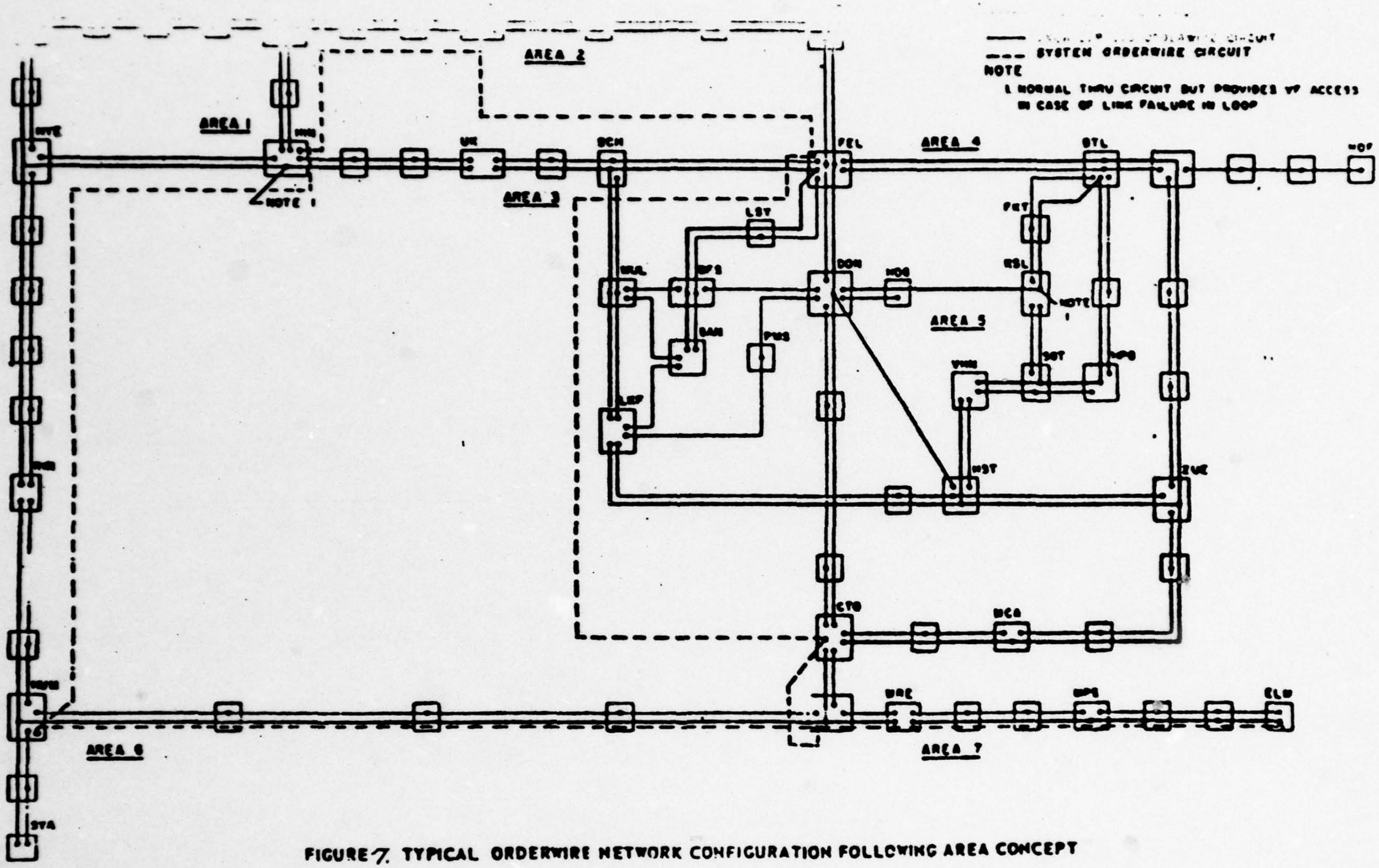


FIGURE 7. TYPICAL ORDERWIRE NETWORK CONFIGURATION FOLLOWING AREA CONCEPT

E. ATEC

The ATEC is an O & M oriented system with reporting capability, designed to support operational control of transmission systems. It is best described as a quality of service oriented measuring and reporting system. The ATEC structure overlays the Level III, IV and V SYSCON structure (see Figure 8). It provides automatic/-semi-automatic sensing and reporting of transmission media quality and status. Refer to Appendix II for the reporting structure for the ATEC system. Provision is made for manual entry of data/-commands at the operator console at Levels V, IV or III. Reports/communications within an ATEC element will have information structures and formats stylized for ATEC processors. External reports to the ACOC/WWOLS will be in DCAC 310-55-1 format. External reports are expected to be generated only when previously programmed reporting-time thresholds have been exceeded as in the current manual report system. The ATEC is expected to function in a hybrid environment; that is, some

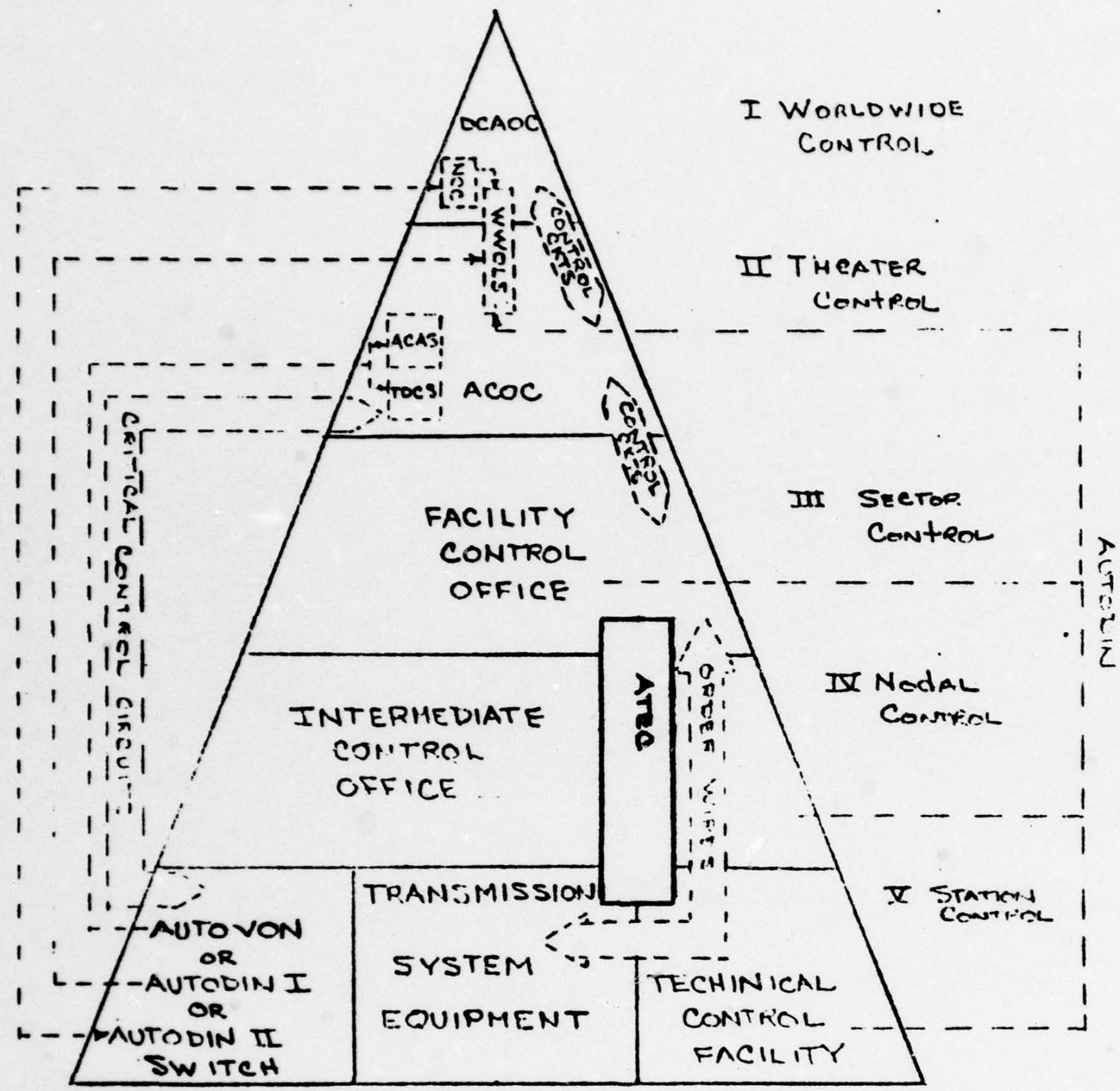


FIG 8 ATEC INTER-RELATIONSHIP

transmission systems will:

a. have full ATEC implementation

b. only have the stand-alone elements or some of the stand-alone elements without the nucleus sub-system.

c. remain manual TCF/PTF operation

The grade-of-service traffic monitoring systems of the automatic switched networks do not interface with the ATEC.

F. AUTODIN & AUTOVON Patch & Test Facilities.

AUTODIN & AUTOVON PTF's are colocated with the AUTODIN and AUTOVON automatic switch centers. These switch PTF's perform a function similar to a tech control PTF, since transmission system equipment terminates in the switches. The switch PTFs have orderwire connectivity to other PTF/-TCFs in the transmission systems (see Figure 9). These orderwires are used to coordinate circuit testing, circuit restoral and status reporting. Switch PTFs report status in DCAC 310-55-1 format either directly to the ACOC or as designated by DCA, if a reporting station, or to the nearest TCF if a reported-on station. Switch PTF status as a reporting or reported-on station is per DCA designation. Switch PTF also coordinate laterally at Level V with the respective AUTODIN & AUTOVON switch operators. Figure 9 presents this

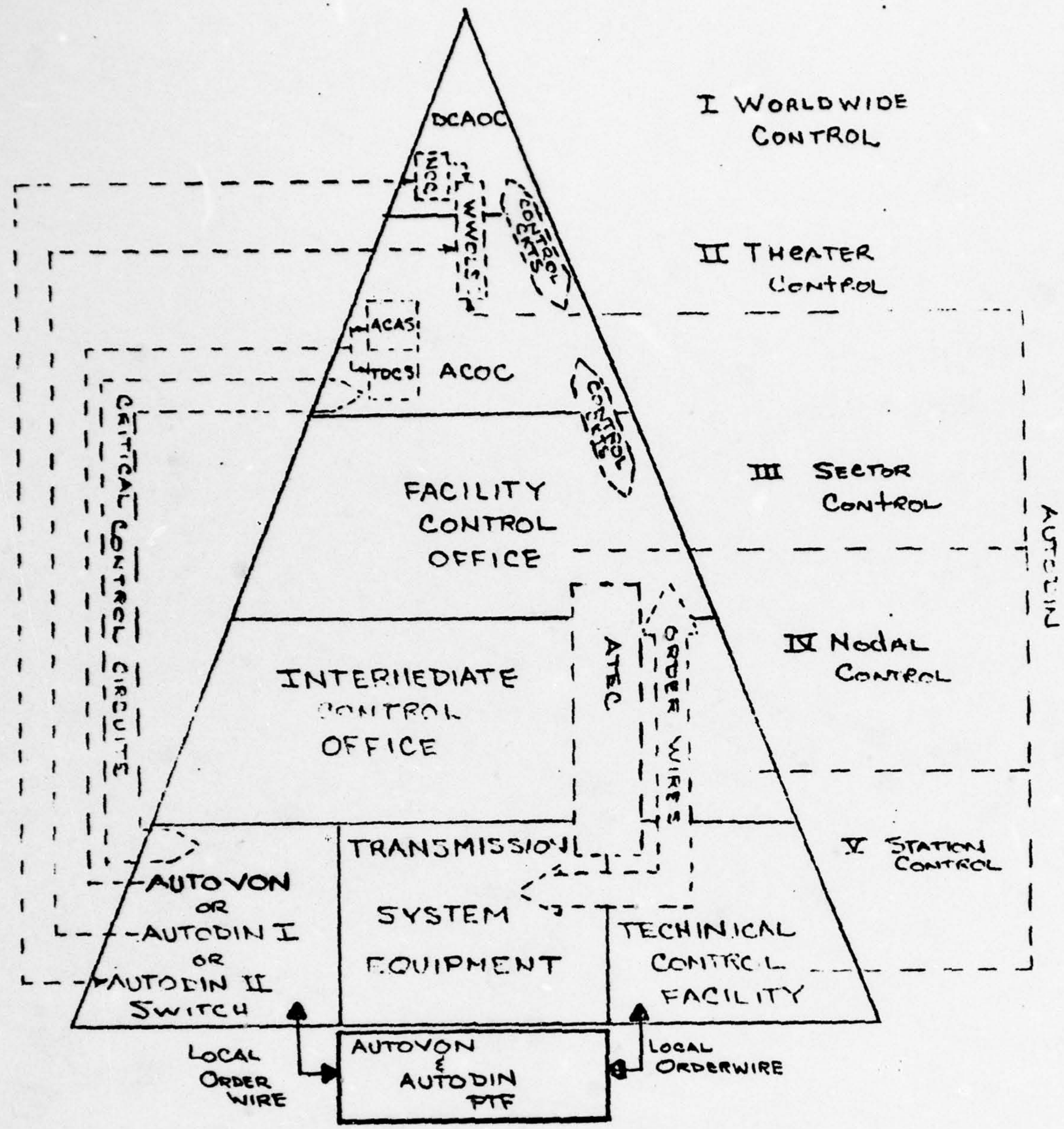


FIG 9 AUTOVON & AUTODIN PTF RELATIONSHIP TO SYSCON

relationship. The switch PTF's can coordinate with other switches through the use of traffic coordination circuits. They report status to the ACOC via critical control circuits as do the switch operations personnel. In any event, reporting will be in DCAC 310-55-1 format. The switch operators are traffic oriented and are only concerned with transmission media insofar as it effects the ports of the switch. This dichotomy between grade-of-service traffic oriented switch operators and quality-of-service transmission media oriented PTF personnel exists at every switch location. Necessarily they must work together to support switched network operation; hence the functional demarkation may be difficult to identify.

1. In our evaluation the PTF's of AUTOVON & AUTODIN are the only points in the DCS where real-time but informal traffic control and transmission exists. This occurs as these are the only points at Level V where both traffic monitoring and transmission monitoring coexist. TCF/PTF functions assume traffic requirements are satisfied by providing quality-of-service circuits in response to standing instructions, higher level direction, user complaints and coordination. The AUTOVON and AUTODIN PTF's, while performing the same functions as transmission media PTF's, also

perform coordination with their respective switch, other switches, the connecting transmission systems, the ACOC as well as with local users of the switch. The PTF's interface the switch traffic to the network and provide the quality of transmission service necessary for the network to pass traffic. This does not negate nor minimize the operation, coordination and reporting responsibilities of the switch operations personnel as oriented to automatic switch availability and internal switch traffic loading. It does, however, emphasize in a management by exception oriented control system that only breakdowns which may occur in this lateral coordination element or extremely complex problems can come to the attention of Level II and III control elements.

G. AUTOSEVOCOM

The AUTOSEVOCOM system is a manually operated switchboard system which provides secure digitized voice connectivity for authorized users. It is a subset of AUTOVON in that all long distance trunking and switching is derived from the AUTOVON data quality (special grade) circuits. Initial AUTOSEVOCOM switchboard to switchboard communication is established via AUTOVON circuits in a non-secure mode. Once connectivity is established, subscriber terminal equipment is patched on line for secure communications. The user may have the narrow band voice digitizing & encryption equipment for direct calling or he may have a wide band encryption terminal connected to a local switchboard. The local switchboard operator uses his narrow band (secure) trunking equipment to establish the call via AUTOVON and patches the wideband subscriber to the established narrow band connection. The switchboard operator is the focal point for any switched network or transmission media problems. There may be no PTF facility at the AUTOSEVOCOM switchboard location. In this case they must be serviced by either the AUTOVON PTF or a TCF, whichever is physically closer. AUTOSEVOCOM switchboards are classified as manual switches. Their status is reported to the ROCC Level III, if in existence, or directly to the ACOC Level II. Supporting transmission system status is reported via the servicing AUTOVON PTF or transmission system TCF.

H. Traffic Reporting/Monitoring Systems

Traffic monitoring, the availability and traffic load of the common switched networks, is accomplished by definition at Level V. Data collected is reported directly to Level II. Traffic monitoring and reporting does not occur in the facilities assigned to control of transmission systems and transmission equipment. Consequently, the control of traffic movement is first visible from management perspective, at Level II. It is at this level, that the correlation between transmission systems status and network (common user switches) can be accomplished. The traffic monitoring systems measure the ability of the switched networks to transmit volumes of traffic. Of interest will be:

- Length of each message
- Time to process the message within each switch (switch train make-up time)
- Message backlogs or queues
- Message volumes by precedence
- Peak traffic interval

Switching matrices are steered by a software driven processor. The general health of the processor and status of the software is also sensed by the traffic monitoring systems.

1. AUTOVON Network

(a) The AUTOVON network is a worldwide circuit switched system for voice and narrow band (3K Hz) data service. It has 2 segments:

- CONUS, where all services including switches and interconnecting circuits including subscriber access circuits are leased.

- Overseas 490L AUTOVON, where the switches are US military owned and operated and interconnecting circuits are US military leased or owned.

Network control responsibility for AUTOVON has been delegated to the DCA areas in which the switches are located and is exercised as a part of the Area Communications Operations Center (ACOC) function. In the overseas AUTOVON, network control is exercised from the DCA-PAC and DCA-EUR ACOC's. The CONUS AUTOVON is different, since the near-real-time status information from the switches is provided to the AT&T-operated Dranesville Operations Control Center. The CONUS ACOC, colocated with the DCAOC, exercises operational direction over the CONUS AUTOVON through Dranesville and is appraised of CONUS network status by Dranesville. Dranesville is authorized to implement up to 100 percent directionalization and alternate route cancellation without prior consultation with the DCA-CONUS ACOC. Other network controls must be approved by the DCA-CONUS ACOC before implementation. In the event that communication between the ACOC and Dranesville are disrupted, Dranesville is authorized to implement whatever controls are necessary to protect the network. The NCS/DCA Operations Center (NCS/DCAOC) is responsible for maintaining global AUTOVON status and for resolving interarea problems.

2. CONUS AUTOVON

(a) Near-real-time indications are reported automatically from the switches to the Dranesville Control Center. This system is functionally identical to the AUTOVON Centralized Alarm System (ACAS), see Appendix III, deployed in the Overseas AUTOVON system. This system provides near-real-time status of traffic pressure and flow within each switch. Specific network control principles analysis and problem solving actions are also described in Appendix III. The near-real-time indications are analyzed with switch traffic data obtained from switch personnel to determine appropriate control actions.

(b) The CONUS/HAWAII AUTOVON leased service switches only report summary management data monthly to DCA (DECCO) via mail (as per DECCO contract). The reports reflect leased service availability for contractural payment purposes and traffic sample data (per contract) for traffic engineering. Normal user problems are reported to the telephone company long-lines division (usually by the base communications office). Only problems that reach a sufficient user-irritation level are user reported to DCA elements. The irritated user/base communications office may report the problem to a TCF (if available) which may generate an outage report. Alternatively, this user will complain to his telecommunications certification office, who will contact DECCO through administrative channels. In either case, all events are logged by the DCAOC. Information may or may not be entered into the WWOLS. Sampled traffic information is also available for statistical analysis.

3. Overseas AUTOVON

The overseas AUTOVON switches report status and problems to their ACOC's via:

(a) AUTODIN I for entry into the WWOLS

(b) AUTOVON for verbal coordination

(c) AUTOVON for the Transmission Data Collection System (TDCS) communication

(d) Dedicated circuits for the AUTOVON Centralized Alarm Systems (ACAS)

Reporting criteria, frequency, and schedules are established by the DCA Area and executed by switch personnel. The key elements for near-real-time traffic monitoring and long term data collection are the TDCS units and ACAS at the 490L AUTOVON sites.

4. TDCS. Figure 10 reflects the TDCS relationship between levels of the SYSCON management structure. Figure 11 indicates the TDCS locations and their AUTOVON connectivity. Note the Panama location is not assigned to an ACOC with a TDCS (i.e. DCA CONUS ACOC). Figure 12 shows a block diagram of the TDCS both for the Switch Site Unit (SSU) and for the ACOC. Both figures 11 & 12 reflect the capability of the TDCS:

   (a) to automatically transfer data from the SSU to the ACOC

   (b) to permit the ACOC to request data/data collection from the SSU.
   (This capability is not presently used. The ACOC TDCS is now only used in an off-line mode).

   The TDCS/SSU block diagram reflects its major functions:

   (c) Rapid memory reload function with magnetic tape storage interfaced to the AUTOVON switch memory. The AUTOVON switch matrix is a software driven "stored program switch."

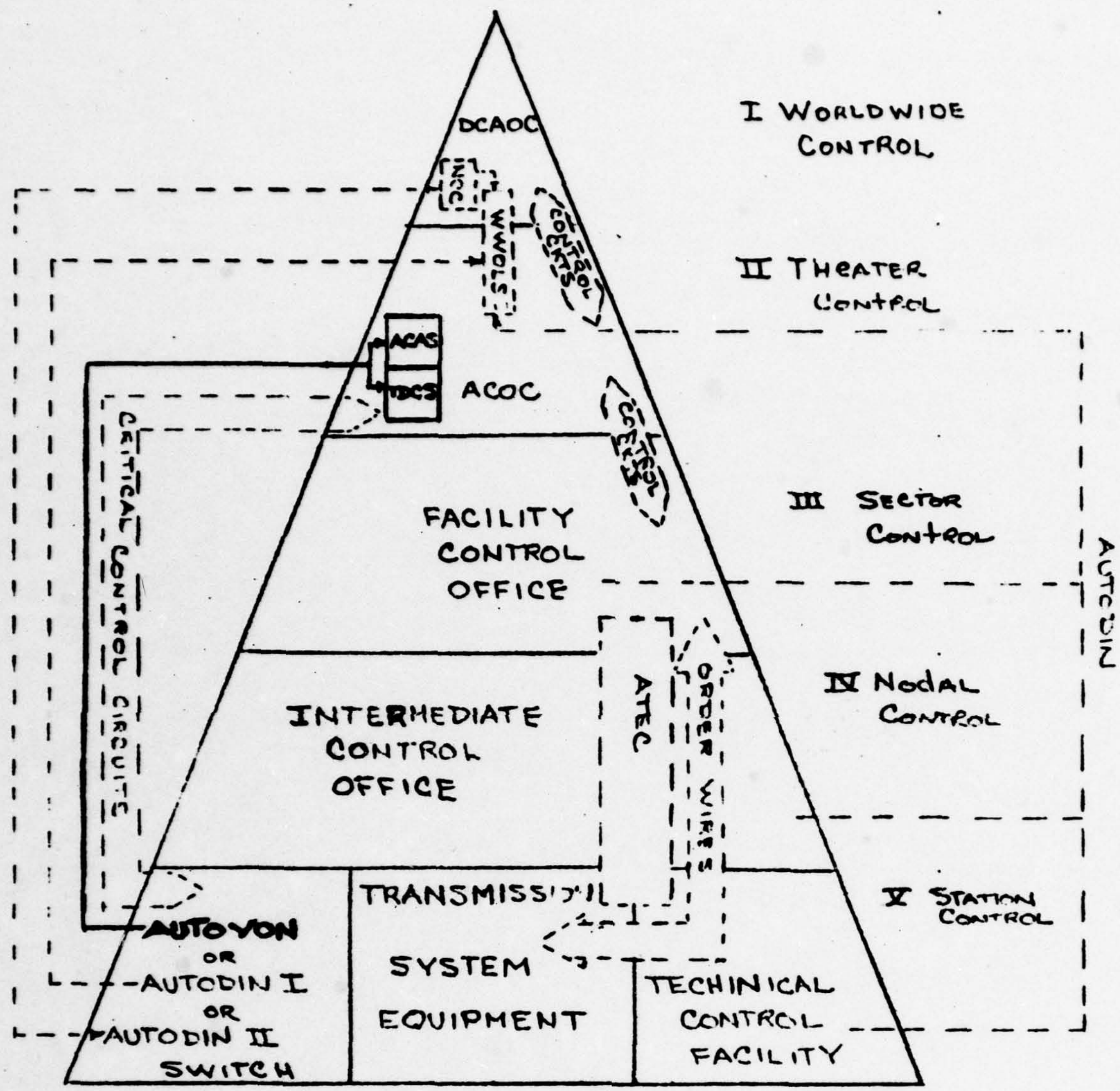


FIG 10 AUTOVON - TDCS & ACAS

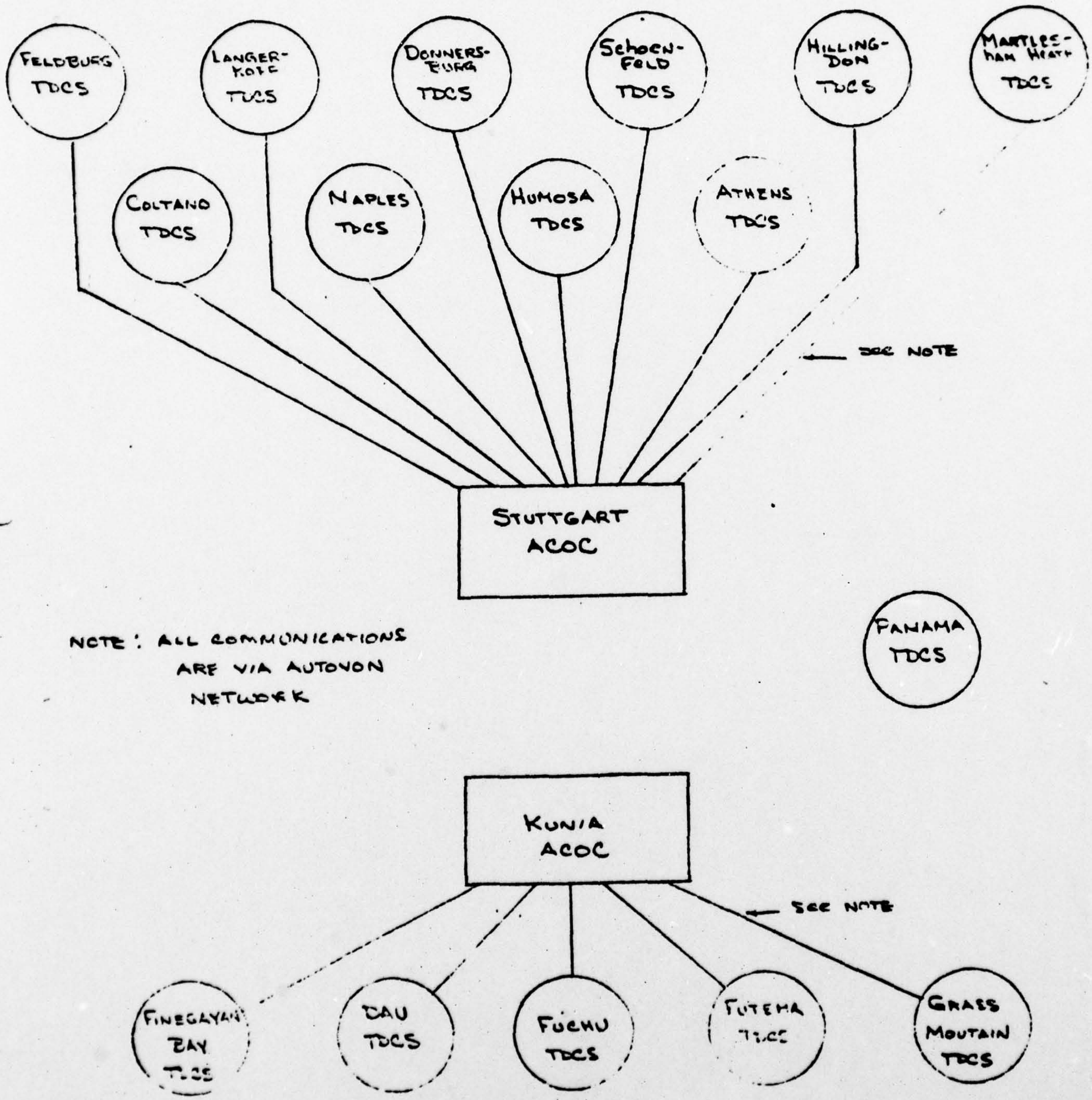


Fig. 11 Traffic Data Collection System (TDCS)

VG-37,071

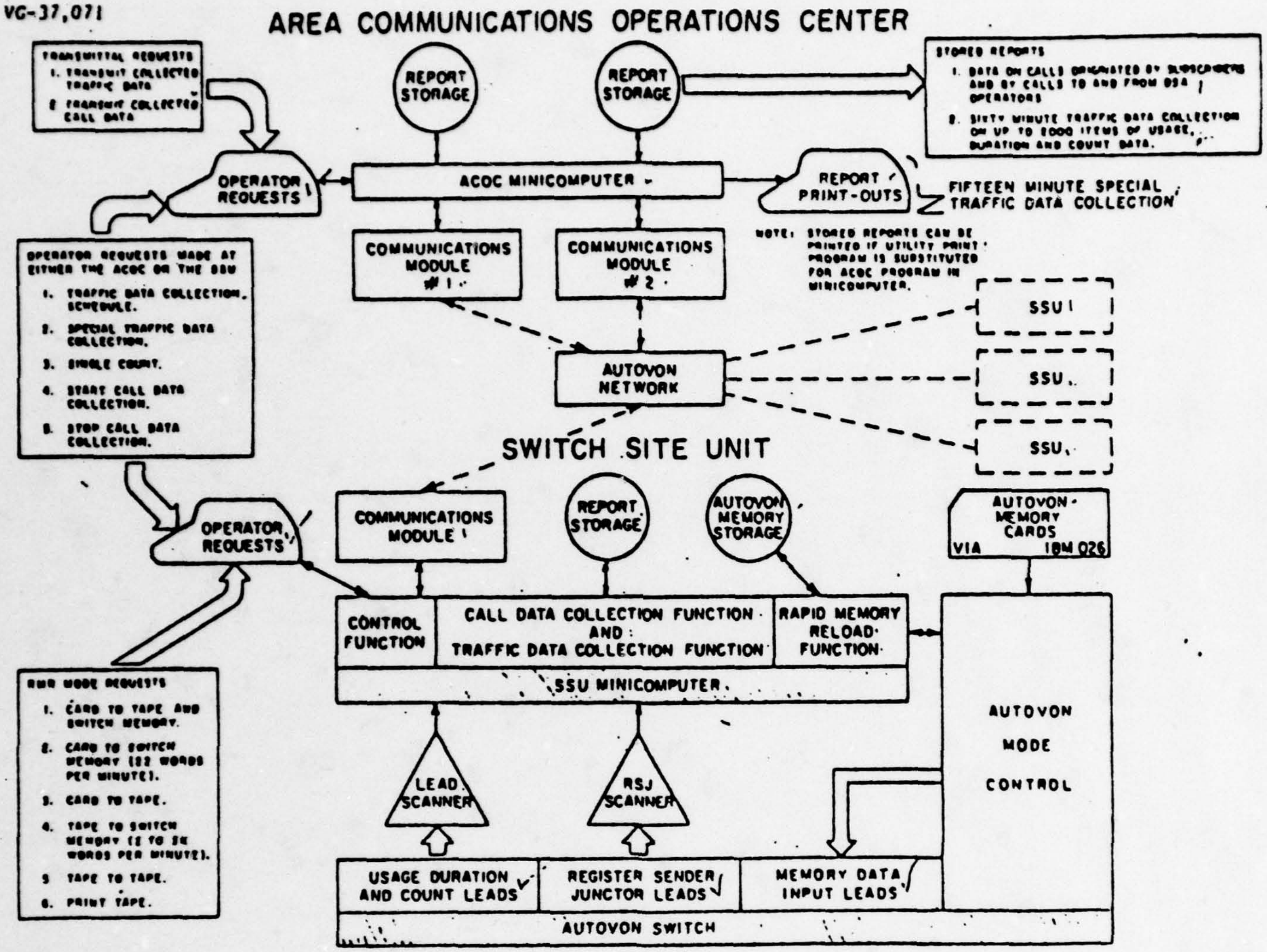


Figure 12 TRAFFIC DATA COLLECTION SYSTEM

(d) Scanner interface to the AUTOVON switch (sensing leads)

(e) Data collection functions (programs) with magnetic tape storage

(f) Communications module for AUTOVON transfer of data/instructions (not presently used)

All TDCS functions operate through its minicomputer.

The primary function of the SSU is rapid memory reload of the AUTOVON switch [eg tape to memory vice card reader (IBM 026) to memory]. The secondary function is collection of traffic data which is of 2 types:

(1) Call collection information which consists of:

a) Initial entry:

- Originating trunk number
- Precedence digit
- Route digit
- Called number
- Terminating trunk number
- Time of final matrix connection

b) Release time entry:

- Originating trunk number
- Time when call terminated

Data is collected when directed at the

SSU and recorded on magnetic tape as raw data (no correlation of initial and released time entries).

(2) Tapes are mailed monthly to the ACOC's for processing.

(3) Switch operating functions (traffic data collection) sensed via the SSU scanner interface are:

a) trunks (external switch circuits)

b) supervisory equipments

c) register-sender junctors (mini-processors).

All conditions that are programmed for sensing are recorded as counts of events or time-weighted (duration/usage) events and stored in a 200 x 10 word matrix in core memory. All conditions to be sensed or combinations thereof along with the specific matrix word where that count is to be stored are specified for each count to be recorded. The set of up to 2,000 (200 x 10) different count instructions comprises the Traffic Data Collection Program Module (TDCPM) of the SSU. When collected, this data (200 x 10) is transferred to magnetic tape in hourly segments. The tape is mailed to the ACOC. The SSU has a direct transmission capability via AUTOVON to communicate with the TDCS unit at the ACOC but it is not presently used to monitor operational status concerning switch traffic volumes and call completion delays for near real time reporting. Remote query formats are extremely detailed and complex to format prior to transmission. The amount of fine grain detail data presented by the system precludes efficient utilization of the responded data for real time system operational control. Its only significant use at the present time is long term management and statistical analysis. Consequently, transmission facilities and appropriate control elements still reside at the switches.

5. AUTOVON Centralized Alarm System (ACAS)

The ACAS provides the overseas ACOC's the near-real-time indications necessary for network control. The ACAS is only installed at overseas switches, with network control resident at the DCA-Europe and DCA-Pacific ACOC's. CONUS AUTOVON switches have the functional equal to ACAS, however procured on a special case basis. Near-real-time status information from the CONUS AUTOVON switches is provided to the AT&T-operated Dranesville Operations Control Complex. The displays at the ACOC's are actually telemetered representatives of the local displays at each switch.

Information is transferred via full period dedicated 75bps circuits. The functional relationship between the ACOC's and the AUTOVON switches is shown in Figure 10. The ACAS network is shown in Figure 13. Refer to Appendix III for a full description of ACAS. The ACAS provides near-real-time indications displayed at the ACOC and at each AUTOVON SWITCH.

(a) Traffic pressure and flow within the switch

(b) Components-out-of-service

(c) Trunk status

6. AUTODIN I

The AUTODIN I system is a world-wide store and forward message switched network which is leased in CONUS and HAWAII and government owned and operated overseas. In contrast with AUTOVON, the leased switches have government operated PTF's. This is a necessity because the leased transmission system is operated by one contractor and the leased AUTODIN switch by another contractor. For contractural purposes, both must receive direction from the leasing agency. The purpose of the government PTF in this situation is to assess all operational difficulties and provide appropriate administrative

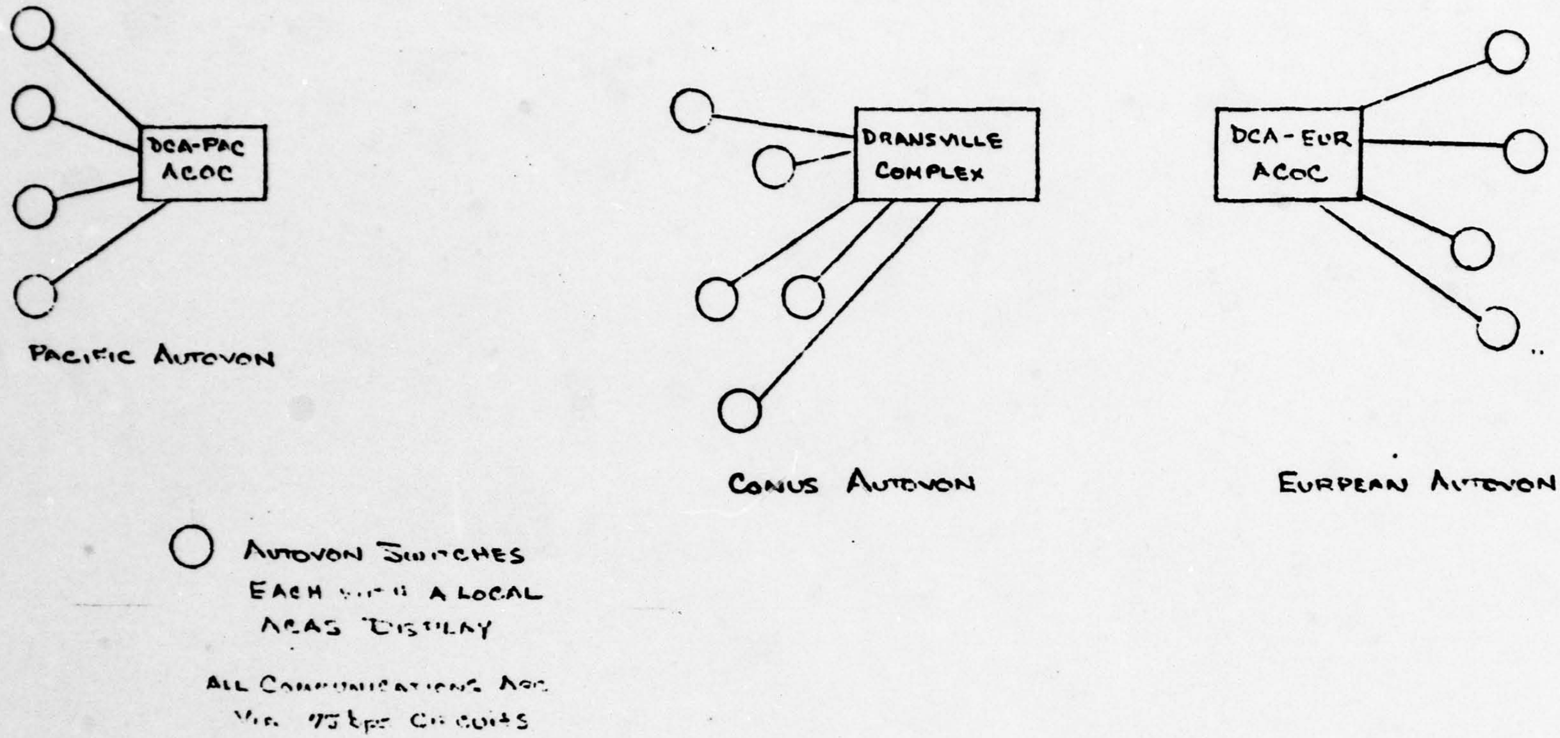


Fig 13 AUTOVON Centralized Alarm System (ACAS)

guidance to the contractors for their technical action. All reports pertaining to this guidance are filed with the CONUS ACOC and bear special significance because of their contractural implications.

In addition to those reports, the switch military liason also sends a monthly summary report to DECCO on leased systems availability (for contractural payment purposes). All AUTODIN I switch status and traffic reports are collected by the switch personnel and sent to the ACOC/WWOLS per the schedule established by the ACOC (see Figure 14). The key operational reports are:

(1) The bihourly report of message backlogs (queues) in the switch

(2) Switch equipment status reports

The key management reports include:

(a) Daily and monthly summary messages of traffic volume totals in terms of message and line blocks sent and received per trunk and subscriber

(b) Monthly message header extract of one-day's switched traffic which is magnetically taped and mailed to the ACOC.

(c) Weekly message report summary of high precedence traffic delays

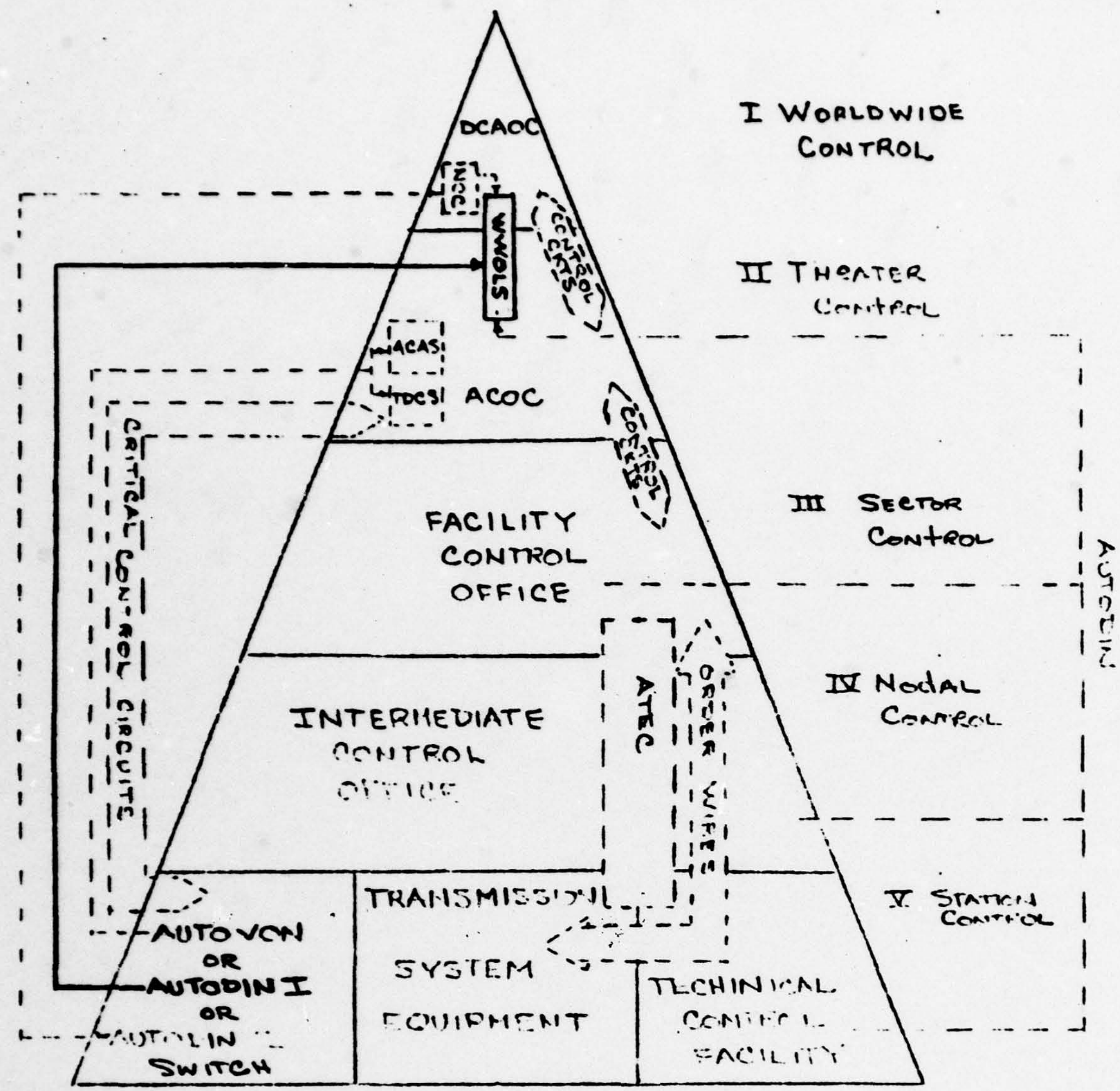


Fig 14 AUTODIN I

7. AUTODIN II

The AUTODIN II (phase I) system is a leased CONUS only packet-switched network. The switches will be co-located with the present leased AUTODIN I switches which will then derive their interswitch connectivity through the AUTODIN II system. The AUTODIN II status/traffic reporting will be similar to AUTODIN I except that:

(a) All reports will be sent via AUTODIN II to the Nodal Control Center (NCC) at the DCAOC for consolidation and subsequent reporting into the WWOLS (see Figure 15) rather than to the ACOC/WWOLS

(b) Reporting will be highly automated. Traffic measuring reports will be automatically generated from the operators CRT/Keyboard console. Critical information will be displayed in protected fields with illuminating data added by the operator.

(c) The NCC can request current data or status from the switch and direct operational changes in the switch program (eg traffic routing tables).

(d) The DCAOC rather than the ACOC will establish normal reporting schedules.

This implies that reporting of information may be adjusted as necessary to provide real-time network

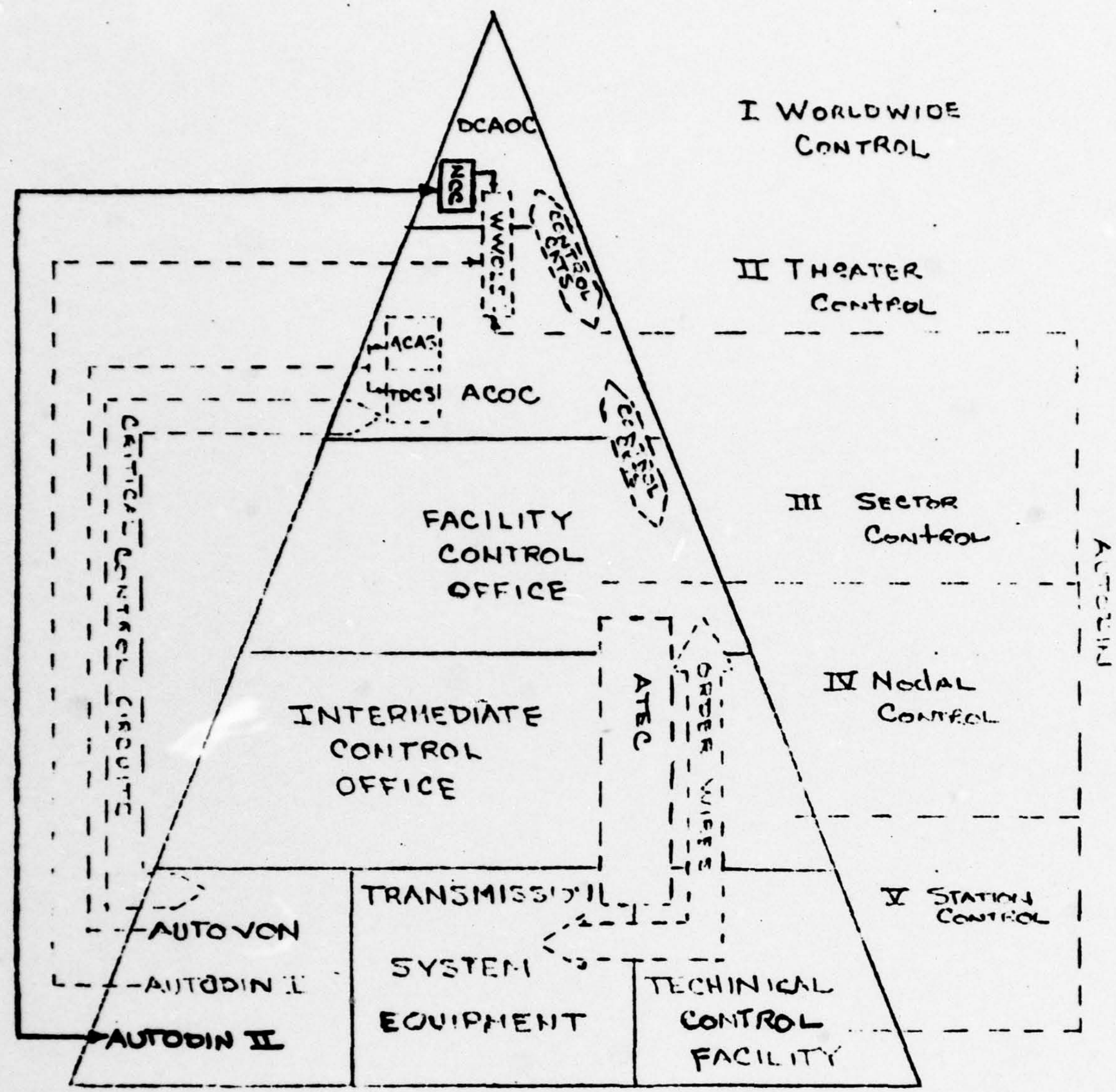


FIG 15 AUTODIN II

operational monitoring for control (See Figure 16 for the System Control Functional Diagram).

8. AUTOSEVOCOM

AUTOSEVOCOM is a manually operated (switchboard) network which uses AUTOVON for its communications connectivity. Its traffic data is a once-a-month sample of switchboard traffic that is collected by the switchboard operator and mailed to the ACOC. The ACOC directs the schedule for collection of data.

I. Traffic Control at Level V

Level V facilities, although catagorized as reporting or reported-on-stations, physically can be typified as:

1. Technical Control Facilities supporting communications relay centers within the transmission system
2. Technical Control Facilities or transmission system nodes where AUTODIN and AUTOVON switch centers reside
3. Patch and Test Facilities for transmission system equipment, located within AUTODIN and AUTOVON switches and AUTOSEVOCOM manual switch centers.

It is this latter category that requires expansion and discussion.

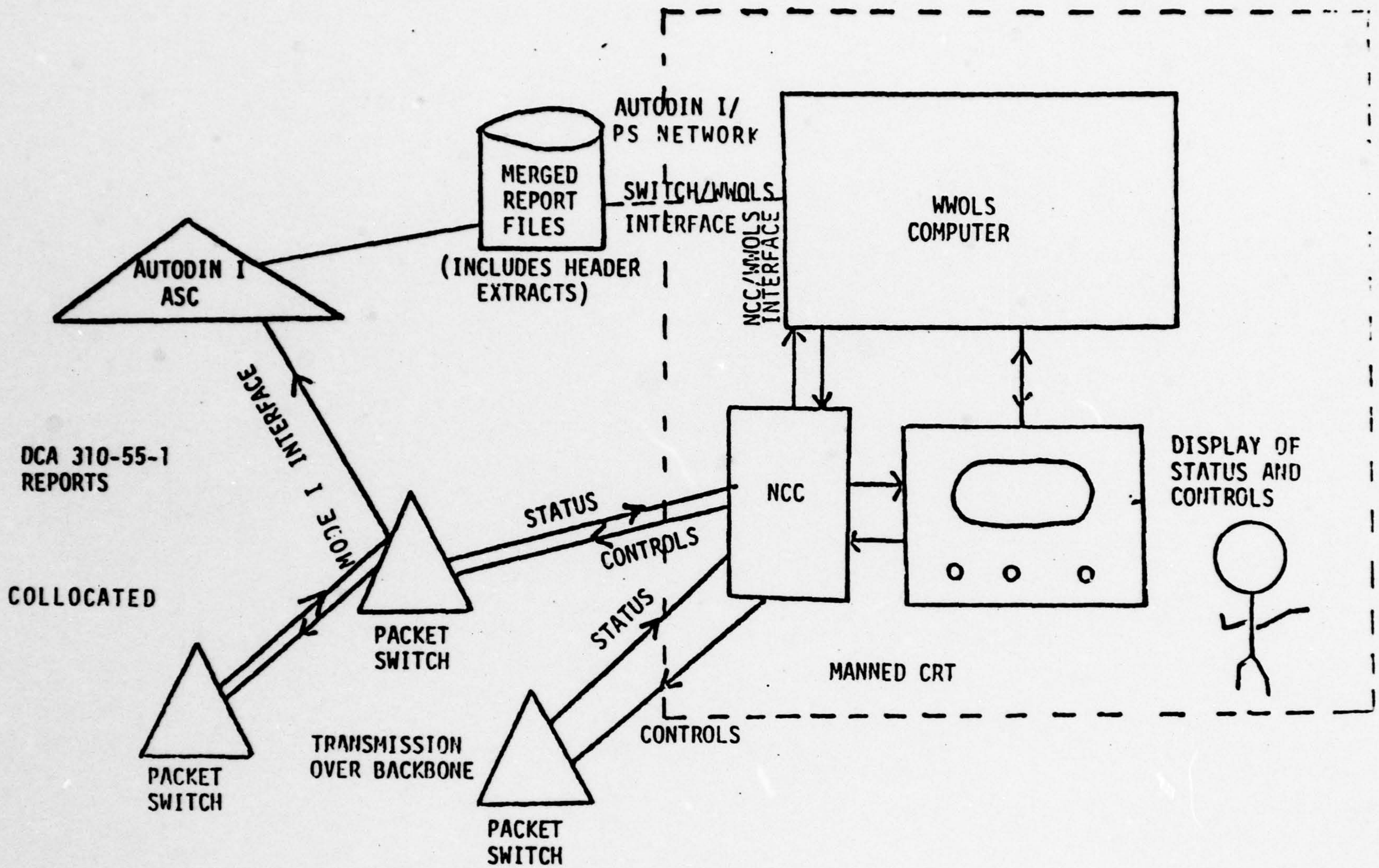


Figure 16 Phase I System Control Functional Diagram

Transmission equipment includes modems, encryption devices, transmission line appliques, patch facilities and other equipment necessary to establish transmission media termination within the switch centers. Accordingly as reported-on-stations, the status of these equipments are reported to the nearest serving TCF. This status is then reported through the proper echelons and reflects transmission media status to the ACOC (Level II).

The existing reporting structure requires traffic monitoring data be directed from the switch network nodes directly to the ACOC (Level II). Consequently, the ACOC is the only formal point in the reporting structure where traffic and transmission monitoring data can be collated, analyzed, and appropriate direction derived.

However, an informal traffic control occurs in the liaison that exists between the transmission media TCF's and switch PTF's, and between the switch PTF's and switch operators. It is at this level (Level V) that the practical real-time efforts are accomplished to insure switch traffic flow coincides with transmission system availability, thus minimizing traffic backlogs within the switches.

All of these actions are accomplished using local orderwires or intercomm, in narrative form. No formal procedure exists for reporting the conduct of these coordinating activities. The formalized channels available for reporting traffic or transmission status data can, however, monitor the results of these actions. This data, therefore, may be slightly distorted in reflecting the true actions performed at Level V.

It is not our purpose to deny access to these liaison channels through an improved reporting and operational control system. An efficient management by exception system recognizes the ability to resolve problems at the lowest level of control. It is important that the value of this base level SYSCON activity be recognized and encouraged.

J. Earth Satellite and Ground Stations

The Earth Satellite and Ground Stations which are part of the DCS functionally resemble manned radio relay sites; however, their resource value in terms of cost, reliability, and serviceability requires special management and operational control emphasis.

1. Circuit and trunk interfaces to the ground stations are controlled through normal SYSCON Level V operation and management techniques. A PTF is present at each ground station which interfaces with the nearest TCF as a "reported-on" facility.

2. The earth satellite and ground station up-link and down-link are monitored and controlled from SYSCON Level II for these reasons:

(a) Multiple ground stations separated by widely separated geographical distances use the same satellite as a relay. The Level II ACOC's are best positioned to act as a common control point

(b) The positioning, power consumption, and power reserves of each satellite represent critical resources which must be carefully monitored and controlled. These factors determine the satellite's ability to support traffic movement which is controlled from SYSCON Level II.

(c) The availability of communications satellites during stressed periods of DOD activity constitutes a strategic resource. Consequently their status and availability is a high interest item deserving higher level management and control.

3. Status and control of circuits and trunks utilizing satellite links is managed and controlled like every other Level V circuit or trunk.

4. Status of the satellite links and facilities is controlled and monitored directly by the appropriate ACOC. Information is transferred between

ground stations and the ACOC via critical control circuits as shown in Figure 4.

K. OTHER REPORTS

Other data is developed on an as-required basis, which cannot be easily categorized as transmission or traffic monitoring. These are:

- Test & Acceptance reports
- Technical Evaluation Program
- Performance Evaluation Program

1. Test & Acceptance/Technical Evaluation

When military DCS facilities (or portions thereof) are installed, they are tested against design criteria (T & A). These T & A results and other operating criteria form the basis for establishment of station operating standards. Periodic Technical Evaluations (TE) are performed on operating systems (eg radio links, automatic switches). In the TE (DCAC 310-70-57), the subject system is adjusted for optimal performance. The performance results obtained are used to confirm or modify existing operating standards. Thus each operating station as a set of stylized equipment operating standards representing the optimum DCS networking operation support capability within that site. These reports can provide status updates to the facility data files.

2. Test and Acceptance (T & A) data for facilities/equipments constitute initial status reporting. As such, it serves as the basis for initial operating standards. T & A may be performed using the TEP guidelines or by other means. A copy of the report will be kept at the DCS station or site. Subsequent TEP's will use previous TEP/T & A data for reference and will be used to confirm or modify the existing operating standards for the station/site. T & A for circuits is performed in accordance with DCAC 310-70-1 Circuit level T & A gauges newly implemented circuit capabilty to meet the specifications in the TSO or to qualify a previously out of service circuit for restoral. If specifications are met, the circuit is activated or restored. If not, the circuit derivation equipment is worked on until specifications are satisfied or the circuit is accepted with exception (subject to user concurrence) which is recorded in the circuit file (see DCAC 310-65-1 Chapter 2).

3. Technical Evaluation Program (TEP) is status oriented, but is not reported daily (DCAC 310-70-57/Chapter 2 and Supplements 1, 2 & 3). The Technical Evaluation Program is equipment and link derived. It is the most comprehensive

statement of facility and link quality by virtue of its detailed measurement approach. It is used to collect, analyze and evaluate performance and design data on DCS equipment and components and to develop operational, maintenance and engineering criteria, standards, methods and procedures. It also provides technical data to plan for the modernization of facilities, transmission links and subsystems and to develop operational characteristics and deterioration patterns for use in the future design, engineering and improvement of the DCS.

The operational baseline/performance standards that are developed are then used in the performance monitoring and performance evaluation programs.

The Technical evaluations are conducted by the MILDEP's according to a schedule worked out jointly with DCA Areas. The reports are narrative plus data sheets that are submitted by cover letter to DCA and interested agencies. Data is not currently automated.

4. Performance Evaluations

The DCS status is periodically checked and reported at each site by operating station personnel (O & M agency) and by DCA performance evaluation teams. In accordance with DCAC 310-55-1, the station personnel daily report deviations from standards that exceed established reporting thresholds. They also report performance monitoring quality assurance data (DCAC 310-70-57) daily and specified conditions "as occurs." The DCA evaluation teams check the effectiveness of personnel and equipment, operating plans and procedures, and records against the standards and directives applicable to that station. This check also serves to validate data submitted by the station (eg All reports and measured parameters consistent with previous station reports). Only discrepancies found are reported in the performance evaluation report. These reports provide status update to the services data files. The entire status reporting mechanism effectiveness is also qualified and graded.

Performance Evaluations of DCS stations (DCAC 310-70-57 Supplement 5) are conducted periodically or as required by DCA Areas and Regions. The test teams evaluate any or all facets of the DCS station against established standards and directives. Only discrepancies found in the areas evaluated (eg maintenance, operations, training, equipment, procedures, records) are reported. The report is a status oriented narrative letter using data sheets only to support the narrative.

IV. TYPES OF DATA

A. The data needed to manage and operate the DCS is basically of three types: Facility Data, Service Data, & Status Information Data.

1. Equipment/communications facility data refers to the installed hardware at a government owned facility which is committed to the DCS. The data describes station/site in terms of installed equipment and associated capabilities, and the transmission link which the equipment supports (if the link is not a leased utility). A Technical Evaluation Program (TEP) quantifies and reports the station equipment capabilities and is used in part to establish equipment operating standards.

2. DCS services refers to the circuit connectivity and traffic capacity of the DCS. The transmission media services of the DCS are described in the Circuit and Trunk files. When combined with the switching station capabilities, the combination relates the switched network (AUTOVON, AUTODIN, AUTOSEVOCOM) to the transmission systems, thus describing the overall service structure of the DCS.

3. Status information provides summary and real time performance reports for the equipment, facilities and services of the DCS. That is, equipment, facility, link, trunk, and circuit, switch outages and degradations and traffic volumes are reported by each DCS reporting station on a near-real-time and as a daily summary when pre-

established thresholds or standards are violated. Quality assurance data on transmission equipment is also transmitted daily by each reporting station.

B. CATEGORIES OF DATA

The remainder of this section categorizes the different types and sources of data as:

1. Raw Data - Source data from non-formatted sensors or manually generated inputs.
2. Formatted Data - Raw data which at a minimum is coded in recognizable characters and may additionally be placed in consistently structured fields or words.
3. Collated Data - Raw and/or formatted data which has been developed or reduced to concise reports either by reduction of redundant or meaningless elements or by analytical means.

C. SOURCES FOR DATA IN TRANSMISSION SYSTEMS

1. Technical Control/Patch & Test Facility Data

   Non-formatted (raw data)exits in the TCF/PTF's in the form of transmission equipment alarms and measured or observed data.

   a. Transmission equipment alarms for the present day analog FDM systems are limited to detection of pilot tone presence. Some FDM systems were procured with their own customized alarm and monitor systems. They were usually limited to the detection of gross alarm conditions exemplifying catastrophic failures. Presently the only method that exists to determine the health of these FDM systems is manual measurement of selected parameters at manned facilities. Primary parameters measured at all technical controls are narrow band channel (4KHz) oriented. From these parameters the health of the transmission system circuit or trunk can be determined. Specific parameters for analog circuits are:

- Audio Level
- Idle channel noise
- Impulse noise
- Test Tone level
- Frequency response
- Delay distortion
- Harmonic distortion
- Phase jitter

Digital circuits are predominately measured at PTF's at rates between 61.12 and 9600 bps. Measurements include:

- Voltage level
- Average, peak or bias disortion

Measurements are taken at group and supergroup entry points by those stations so equipped. Measurements obtained are:

- Pilot tone level
- Slotted noise level
- Group and Super Group Level
- Intermodulation Distortion

baseband measurements, the composite video insertion and drop signals at radio interfaces, can also be observed. These are primarily used to determine the status of the radio link. These measurements include:

- Baseband loading
- Baseband slot noise

The reporting technical control consolidates the data and collates the information to determine performance quality, isolate fault, determine reason for outage or appropriate restoral needs. The act of collation is accomplished by the thought processes of the tech control operator. The collated data is then formatted per DCAC-310-55-1 and reported.

b. Digital transmission systems, presently under procurement, embody more specific transmission equipment alarms. The major system components of the digital system, the digital radio and multiplex equipment, will be procured with built-in test equipment to automatically generate status information and alarms in more meaningful detail. For the digital radio the data or alarms are:

- Bit error rate (BER) performance
- Receive signal level (RSL) via an automatic gain control (AGC) in the receiver

- Combined performance failure
- Failure of any power supply
- Jitter degradation
- Transmitter forward power

Multiplex alarms are:

- Power supply monitor
- Loss of frame
- Loss of output
- Loss of input
- Loop back conditions
- Loss of port
- Fault detection from unit self test
- Switch over monitor

c. These alarms are to be locally processed (local meaning at equipment installation point) for transmission over a digital orderwire to the monitoring TCF/PTF. The local processor may be indiginous to the digital system procurement or part of the ATEC procurement. This uncollated data is automatically sensed and telemetry formatted for transmission. The receiving technical control may still accomplish manual measurements, collate this data with transmission equipment alarms received by telemetry or from local processors, and provide status reporting. This status data is thus formatted and collated. DCAC 310-55-1 still applies.

d. Status reports resulting from parameter excursion beyond established thresholds are time sensitive, in that excursions are not reported unless the threshold is exceeded for specific pre-established time. Outage occurrances below this threshold are not reported. Time thresholds are weighted by the nature of their impact on system operation:

(1) One minute - DCS station outages, station or switch failure or isolations. Isolation is the loss of all transmission connectivity for mission traffic to adjacent DCS stations

(2) Less than fifteen minutes - high priority user circuit outages such as CINC's or command post circuits

(3) Greater than fifteen minutes - Link and trunk outages not resulting in station isolation and DCS subscriber outages or isolation

(4) One hour - hazardous conditions (HAZCON)

(5) Four hours - outages of AUTOSEVOCOM switchboards

(6) No time limit - low priority circuit outages are not reported. These can

be most easily categorized as circuits with a "zero" restoration priority.

2. AUTODIN I Patch & Test Facilities

   a. Transmission equipment alarms and measurement of assigned circuits are the raw data available to these facilities. Transmission equipment alarms consist of:

      - Modem loss of carrier
      - Crypto out-of-sync

   b. Audio circuit measurements are strictly narrowband (4KHz) and are identical to those established in a technical control facility. Digital measurements are also identical to those previously described.

   c. As a reported-on station, raw data obtained from transmission equipment alarms and circuit measurements provided to the connecting TCF. This data is transmitted to the TCF via orderwire if the TCF is not co-located with the switch. In any event, the data must be sufficiently formatted and collated to be transmitted. The TCF performs the analysis, arrives at a conclusion as to fault, reason for outage and appropriate restoral, and formats and collates this conclusion for status reporting.

   d. It must be remembered that the AUTODIN switch operator also submits status reporting to the ACOC. If transmission system events impact the flow of traffic through the switch, a status report providing traffic movement impact will be transmitted to the ACOC. The event time, reason for outage and action taken code may be identical to that indicated by the TCF. These two reports may then be collated into a single status report at the ACOC. Such reports may be referred to as "COMSPOTS." Their generation and processing is governed by DCAC 310-85-1.

3. AUTODIN II Patch & Test Facilities (CONUS only)
Transmission equipment alarms and circuit measurement data shall be automatically sensed in the AUTODIN II PTF. As this system is presently under design, exact details as to how this is to be accomplished is not known. Alarms shall be visually displayed and reported to the PTF operator's console. As necessary, transmission measurements shall also be taken by PTF personnel on trunk circuits. Coordination is accomplished with commercial carrier for intra-CONUS circuits. Data is collated and the reason-for-outage determined. The PTF console operator inserts the reason-for-outage code in an unprotected field of a machine generated DCAC 310-55-1 report prior to release. Therefore formatted, collated data, manually and automatically sensed, is generated in record form to the ACOC.

4. AUTOVON PTF - Overseas

a. The inter-operability mechanisms for an AUTOVON PTF and its serving TCF are identical to those for AUTODIN I PTF. There is a basic difference, however, due to the nature of the narrow-band signals being processed.

(1) The quasi-analog tones and digital signals present in the AUTODIN PTF are essentially constant frequency/constant amplitude in nature because of the action of the modems and the constant keying provided by COMSEC equipments. Such signals are not readily available in AUTOVON. The highly subjective nature and inconsistent presence of voice signals does not allow easy in-service testing.

(2) This is being changed by the implementation of an out-of-band tone system. When not in use (on-hook) a 2600Hz idle channel tone is inserted by the switch on all 4 wire trunks. When the trunk is in-use the tone switches to 1800Hz. Since this tone is above the Cmsg passband for voice, it will not interfere with conversational traffic. It will also allow in-service testing for AUTOVON trunks.

(3) A series of ATEC in band AUTOVON trunk tests are being prepared for AUTOVON serving TCF's. The nature of these tests is not known at this time. It is known, however, that ATEC stand-alones will not be available in AUTOVON PTF's which are not colocated with TCF's.

(4) The automatic scanning ability of ATEC will shift the majority of all 4 wire circuit and trunk testing activities to the TCF if the in-service tests for AUTOVON are effective. This is as it should be. The function of the AUTO-VON PTF would then revert to a mainten-ance role. Those actions described in paragraph 2c of this section would apply.

(5) Conus AUTOVON

Conus AUTOVON is a leased service provid-ed by AT&T. Lease stipulations allow circuits and trunks serving the switches to be re-routed under the authority of the Dranesville control center. This routing flexibility precludes a rigid definition of service tech controls op-erated by AT&T. Primary tech controls are at the AUTOVON switch sites. Testing is accomplished between switches. Faulty circuits and trunks are re-routed under Dranesville control.

b. Contract stipulations do not provide DCA with a tabulation of all leased service problems. Only those problems identifiable as a degradation in customer service at the time of occurance or a degradation in switch throughput capacity identified in the 30 day test reports are known.

c. Primary mode for problem identification through customer participation occurs when service degradation or non-availability is identified at the Base or Post Telephone Exchange interfaces with AUTOVON. At that time contract actions of the type noted in Section III Ala(2) take effect.

5. PTF/TCF Relationship

a. The interactions between TCF's and PTF's for the switched networks have been previously described because of their unique roles as working level interfaces between transmission systems and switched networks. Their unique ability to make real-time operational adjustments to maintain system performance is largely based on the following factors:

(1) The ability to identify circuit and trunk level degradations at the earliest possible time.

(2) The ability to fault isolate rapidly and effectively. This involves intercommunication between the PTF and TCF.

(3) The ability to assess customer impact and take appropriate and adequate restoral actions.

b. It is also significant these actions be conveniently and accurately documented as status reports. In those instances where higher level support is necessary to clear a problem, much time can be lost bringing others up to date on what has previously transpired. Additional value accrues when management analyists can review these data to see if longer range support is required. Such actions include equipment replacement, changes to operating policies and technical criteria, re-direction of assets, and identifying equipment substandard performance.

Other PTF's:

c. This basic PTF/TCF relationship must exist with those PTF's which are part of the transmission system. Such PTF's exist at either trunk and link interfaces or at DCS/Base or Post interfaces. Examples include

(1) Radio relays

(2) Satellite ground stations

(3) Base/Post Telephone Exchange

6. ATEC Data

a. The ATEC System is designed to:

(1) Automatically sense in-service circuit parameters in the background scan mode

(2) Semi-automatically sense, under operator control, out-of-service parameters.

(3) Fallback to manual sensing in-service and out-of-service circuit parameters during periods of failure.

Specific narrowband and wideband measurements for analog systems are detailed in Appendix IV.

b. The ATEC System provides the capability for in-service measurement of voice frequency, analog and digital circuits on a bridge-on non-interference basis. Out-of-tolerance signals shall be detected in under fifteen minutes. Through modular additions, the system capacity is four thousand voice frequency monitor points and one thousand twenty-four digital monitor points. Out-of-service channel measurements to include insertion of modulator and unmodulated test tones, measurement of channel characteristics and comparison to applicable standards, shall be accomplished in less than ten minutes.

c. Wideband measurements shall also be on a bridge-on monitoring, in-service, non-interference basis. Selected portions of all available interfaces in a FDM, wide-band digital or hybrid transmission system shall be measured. Test signal injection at selected VF interfaces and measurement of resultant signal parameters at other selected points shall be simultaneously accomplished. Major tech controls and PTF's shall be equipped to scan up to thirty-two transmit/receive base band signals within thirty minutes, in a normal scan. Any single station shall have sixteen transmitter outputs and for each signal, measure the two parameters of forward power and modulation level. Thirty-two radio receive signals shall also be measured at any single station. One parameter, convertible to receive signal level,shall be measured. Threshold violations, both amber and red, shall be reported to station level (Level V) and node level (Level IV) in one minute.

d. Equipment and facility alarms shall be detected and measured by the ATEC System for both analog and digital transmission systems. These alarms shall be visually displayed at the station and automatically transferred to the nodal control (Level III). Time element includes a change of state condition within thirty seconds. Some alarms shall be displayed at the nodal control as two states, major and minor; or three states, good=green, minor=amber, and major=red. Correlation and collation of single station alarms with other ATEC measured elements and other station alarms shall be accomplished at the nucleus control subsystem, Level IV.

Fault isolation shall be automatic at Level IV. The sequence shall be generated by the alarm conditions or through node control command to measure a sequence of circuit parameters. Processed results, for two fundamental categories of signal quality and equipment/facility alarms, shall be reported to the nodal control within two minutes. Coordination between nodal control areas shall be accomplished by the Sector Control.

e. Routine quality control measurements shall be accomplished automatically and be directed toward

- Equipment alignment
- Link/route performance assessment
- End-to-end testing
- Network performance assessment

Fully automated measurements shall be made in nominally two minutes but no greater than ten minutes. Interactive measurements, man-machine interfaces, shall not exceed fifteen minutes.

f. The Sector Control (Level III) shall consolidate all status information derived from the nodal (Level IV) control levels, which in turn consolidate information from station control levels (Level V).

A sector control level status display will provide link and station oriented status for up to five nodal control locations. Nodal control displays will be link oriented for up to sixty-four links, and station oriented for up to sixteen stations.

g. Telemetered information shall flow as follows:

(1) Station and nodal functional areas - eight stations shall be displayed in series and share the same digital link to the nodal control.

(2) Between the nodal control and a single sector control

(3) Between a nodal control and eight links to subordinate stations

(4) Between the nodal control and a communication nodal control element of the TCCF

(5) Between the Nodal Control and two links to other SYSCON functions yet undefined.

(6) Between the Sector Control and the ACOC

(7) Between the Sector Control and Subordinate Nodal Controls.

h. Sector Control telemetry shall allow for:

(1) Exchange of information with other Sector Controls for fault isolation and performance assessment

(2) Transmitting status reports to the ACOC

(3) Receipt of direction and control information from the ACOC

i. Nodal Control telemetry to/from the Sector Control shall allow for:

(1) Coordination of fault isolation and measurements with other nodal controls through the Sector Control

(2) Status and summary reporting to the Sector Control

(3) Receipt of direction and control information.

j. Nodal Control telemetery to/from subordinate station(s) shall include:

(1) Commands for specific parameter measurements to Measurement Acquisition Sub System (MAS) elements

(2) Commands for special scan sequences to MAS elements

(3) Commands to alter scan sequences to MAS elements

(4) Commands for out-of-service tests to MAS elements

(5) Commands to direct changes to the MAS element data bases

(6) Text messages for coordination between personnel at node control and subordinate stations

(7) Notification by the MAS of detected threshold violations (by exception reporting) and alarm conditions to MAS

(8) MAS response to commands for measured values and equipment/facility status to node control.

k. ATEC parameter measurement is conducted under two modes:

- Normal scan
- Monitor immediate scan

(1) Normal scan shall be the normal mode of operation. It shall occur normally under direct control of the Nodal Control and during the degraded mode under stand-alone operation at the station level. Normal scan consists of A/D conversion of the test channel processing for the parameter measurement, comparison to a stored number(s), determination if red or amber, and generation of a report. The report is sent directly to node control, and if requested,to the station level Technical Controller. Reports are of two formats:

(a) One containing parameter values and status for all channel parameters

(b) One containing parameter values and status for only those parameter values with a status of red or amber.

After each scan the in-service measurement equipment shall perform a self test, report these results to the nodal control, then commence a new scan.

(2) A monitor immediate scan can be requested by the node controller, station controller, or

automated through resident algorithms. Monitor immediate scans shall allow designation of a specific circuit by CCSD, a group or a single circuit in a multiplex group. The normal scan mode is interrupted for the monitor immediate scan. Measurements, calculations and parameter status determination is identical to normal scan mode. All parameter values and status are reported to the requester. Normal scan continues at the point of interruption.

1. Within the ATEC System the categories of data are dependent upon the level at which the data is reported. These are:

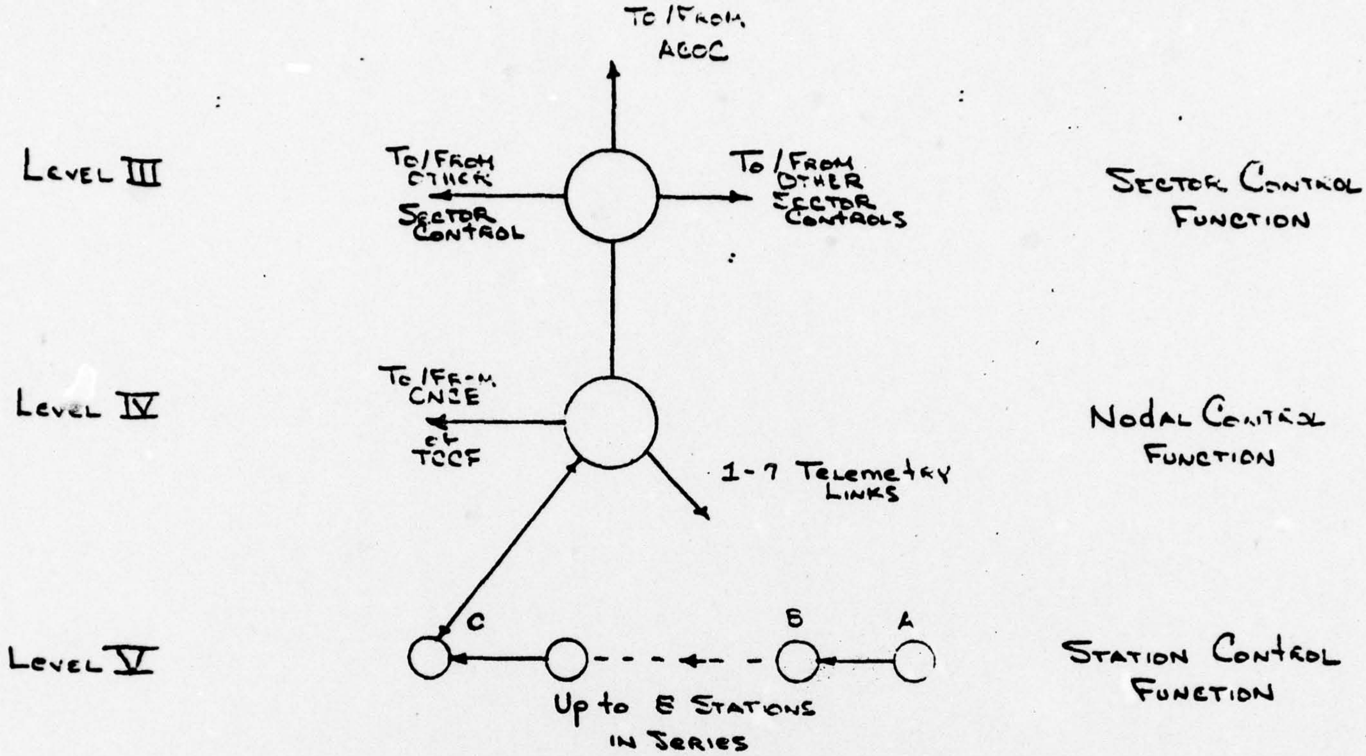
   (1) Station control measurement status data - formatted for telemetry, not collated

   (2) Station control equipment facility status alarms - formatted for telemetry, not collated

   (3) Nodal control status data - formatted for telemetry and collated

   (4) Sector control status data - formatted per DCAC 310-55-1 and collated.

Figure 17 provides a network representation of the ATEC System and how it correlates to the SYSCON Management Structure.



EXAMPLE STATION CONFIGURATION

A- UNMANNED - BASEBAND MEASUREMENT FUNCTION ONLY

B- PTF - ALL MEASUREMENT FUNCTIONS

C- TCF - ALL MEASUREMENT FUNCTIONS

ALL CIRCUITS ARE DATA ORDERWIRES FOR TELEMETRY

FIG 17 ATEC FUNCTONAL NETWORK VS SYSCON LEVELS

D. Data Derived from Traffic Monitoring Systems

1. Traffic monitoring systems provide the status of the switched networks within the DCS; that is, AUTOVON, AUTODIN, and AUTOSEVOCOM. The data discussed herein is derived from the switches only. Data derived from the respective patch and test facilities has been discussed previously.

   a. The AUTODIN, AUTOVON and AUTOSEVOCOM networks rely on the DCS transmission media for network connectivity. The networks are, themselves, interconnected. AUTOVON is often considered the base network which supports all others. Specifically, these networks interface each other in that:

      (1) AUTODIN I uses AUTOVON to implement overflow traffic trunks or re-route of normal trunks between switches

      (2) AUTODIN II will use AUTOVON to provide service to dial-up subscribers

      (3) AUTOSEVOCOM uses AUTOVON for all of its major communications connectivity.

2. AUTODIN I

   a. Status of the respective AUTODIN I switches is derived from two sources:

      (1) Switch fault and traffic data is automatically sensed by the switch processor and reported out to the maintenance console

(2) Peripheral support equipment to the switch are alarmed and displayed at the maintenance console.

b. Equipment alarms or processor reports associated with port outages are directed to the AUTODIN PTF operator for resolution. This coordination is informal, and in narrative form. Status reporting for these outages are the responsibility of the AUTODIN PTF.

c. Data in AUTODIN I for this type report is therefore sensed automatically by the processor and threshold settings of the equipment alarms. It is collated by the operator and formatted for reporting DCA 310-55-1.

d. Other reports common to AUTODIN I and II are automatically sensed, formatted, collated and reported.

3. AUTODIN II

a. AUTODIN II data are initiated by:

(1) The packet switch network program

(2) Interrogation by the Nodal Control Center (NCC) of AUTODIN II at the DCAOC

b. The procurement specification requires Items (1) and (2) be automatically sensed, formatted (DCAC-310-55-1 format desired), collated and automatically reported from the Level V packet switch node. Automatic reporting, however, is presently being defined under the AUTODIN II design and may evolve to switch console intervention for actual transmission of the report. Switch control operator intervention is considered semi-automatic reporting. Although the data will be automatically sensed, formatted and collated, manual manipulation will be required to report all elements.

c. The AUTODIN II network uses distributed control among the NCC, the PSN's and the PSN-PTF's to permit independent operation. Overall network control resides at the NCC.

d. The distributed System control embodies four major functions: (1) network control, (2) traffic and routing control, (3) performance assessment and status and security monitoring, and (4) Patch and Test Facility (PTF). Network control includes transmission and switch restoral, network configuration control, reconstitution, and the addition or deletion of subscribers and coordination to detect and resolve network related subscriber problems. Traffic and routing control includes the control of traffic congestion and routing modifications. Performance assessment and status and security monitoring provides switch, subscriber, transmission, and network data to determine the status and security and performance of the system as it is currently operating and over an extended period of time. The PTF performs the quality assurance monitoring, patching, testing, coordinating, restoring, and reporting functions necessary for effective technical supervision and control over backbone and access circuits traversing or terminating in a facility.

e. The PSN's are responsible for: (1) the operation of the switch functions; (2) status reporting to the NCC, the PTF, other switches, and its own subscribers; (3) fault detection and isolation; (4) implementing control actions directed from the NCC and PTF and locally determined control; (5) identifying subscriber problems; and (6) security reporting to the NCC.

f. The reported status elements are:

PSN-TO-NCC STATUS ELEMENTS

(1) Packet throughput by precedence (including format errors and header extracts).

(2) Number of retransmissions (on a link and end-to-end basis).

(3) Input, relay, and output buffer utilization by priority.

(4) Security mismatch (on occurrence).

(5) Interlace detection.

(6) Fault occurrence which might cause compromise.

(7) Time log of operators' actions with switch.

(8) Acknowledgement that an NCC control directive was implemented (on occurence).

(9) Switch/line outage and reason (on occurrence).

(10) Switch Hazardous Condition HAZCON (on occurrence).

(11) Program reload/restart (on occurrence).

(12) Packet Preemption/Discard.

(13) Traces (on demand).

g. The NCC as an integral part of the DCAOC, has two primary responsibilities: the day-to-day system control and operational direction of the network and the collection and dissemination of statistical information to management functions (via the WWOLS).

h. NCC-TO-PSN CONTROLS

(1) Order status reports on an exception basis.

(2) Request diagnostic test.

(3) Change reporting thresholds and sampling intervals.

(4) Select different program modules for utilization count measurements.

(5) Change of approved parameters, tables, and program modules.

i. The following functions at the PSN's have been identified as critical to the operation of the network and as such require continuous monitoring and exception reporting to the NCC. In all cases, reporting of improper operation of these critical functions shall identify those subscribers affected.

(1) Duplicate or lost Packet Protection

(2) Switch Buffering Allocation.

(3) Source Switch Connection Control

(4) Source Switch Category/Precedence Origination Control.

(5) Source Switch Control for Access Denial.

(6) Source Switch Time-Out Control.

(7) Inhibit or Discard of Traffic.

(8) Destination Switch Time-Out Control.

(9) Source and Destination Switch Security Level and TCC Violations.

(10) Switch Directory Table Updates.

(11) Switch Outage and Reload.

(12) Interlace detection.

(13) Detection of potentially compromising hardware/software faults.

Again, the desired reporting format is DCAC 310-55-1. Downward control (NCC to PSN) format is not yet defined.

4. COMMON REPORTS FOR AUTODIN I and II.

a. The key operational control reports from the switches include:

(1) Queues (backlog traffic) in the switch by precedence: bihourly for AUTODIN I; undefined for AUTODIN II

(2) DCAC 310-55-1 by exception status reports reflecting condition and performance of the switch, switch components, and connecting circuits and equipment

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(3) Critic service messages: an as-occurs message to alert enroute stations that a critic message is being processed. This may be expanded to include other high precedence/alarm messages to insure rapid processing (as in a flight-following mode) and any message tracing through the network.

b. Other switch reports primarily for management include:

(1) High precedence traffic delays: AUTODIN I, weekly summary; AUTODIN II, as occurs (possibly a status report via DCAC 310-55-1). [This will probably become an operational report in the future because of command and control networks to be operated within the AUTODIN II network].

(2) System software problems (DCAC 310-D70-13): as occurs. Note switch impact/status is reflected via DCAC 310-55-1 reports.

(3) Action notice (within 24 hours). Notice of implementation of system modification including circuit changes, table changes and new programs (DCAC 310-D70-30).

(4) Daily constant and monthly summary (DCAC 310-D70-30): Report of traffic volume totals in terms of messages and line blocks/packets transceived per trunk and subscriber.

(5) Communications operations monthly summary (COMOPS); report of all tributary traffic and related efficiencies. This is related to the monthly summary but the exact relation is as yet undefined.

(6) Header extract (DCAC 310-070-30): Monthly report of a one day sample of switch traffic as reflected by the message headers.

c. Switch oriented reports from management:

(1) AMIE update (DCAC 310-D70-50) by DCA areas to WWOLS: AUTODIN Management Index File of characteristics of configuration of AUTODIN i.e. subscriber terminal equipment and access lines/-interswitch trunk connectivity: AUTODIN I, semi-weekly; AUTODIN II, as occurs

(2) Daily switch report from the ACOC's TO DCA identifying significant problems ancountered, e.g. media failures, equipment problems, switch failures, traffic queues. Prepared by - AUTODIN I: presently by the switch; later by WWOLS. AUTODIN II: WWOLS.

(3) Routing Indicator Index (Directory) from DCA(533) - a master list of existing routing indicators used in AUTODIN and other record networks (JANAP 128). Used to update the routing tables in the AUTODIN switches.

d. AUTODIN I & II are highly similar in general function and in requirements for operational and management control. They differ mainly in the degree of automation, the availability and accessibility of switch data, and the speed and mode of service. AUTODIN II reports are collected and collated at the NCC for transfer to the WWOLS, are submitted frequently, and are prepared with a high degree of automation. AUTODIN I reports are interfaced to the WWOLS at the ACOC, are submitted frequently only for urgent status conditions, and are prepared with little automation (manual or manually-directed extract and compilation of reports).

AUTODIN I data is manually, semi-automatically and automatically sensed data that is formatted and collated before reporting from Level V. Again, the DCAC 310-55-1 status reports reflect events that have existed until some reporting time threshold has been exceeded. Switch operator reports reflect the condition/traffic within the switch itself. Switch PTF reports reflect the status of the transmission media interfacing and external to the switch.

5. AUTOVON

a. The AUTOVON switch data is manually and automatically sensed. Specifics are:

(1) Processor detected failures and problems - automatically sensed

(2) Equipment alarms - automatically sensed, manual measurements made to verify fault

(3) Traffic Flow Monitoring System - automatically

sensed by the AUTOVON Centralized Alarm System (ACAS)

(4) Traffic Data Collection - automatically sensed by the Traffic Data Collection System which is manually directed.

b. Processor detected failure and outages are reported to the operations console. Data is formatted, collated with any other necessary information and reported IAW DCAC 310-55-1. Equipment alarms are also displayed at the operator's console. Fault isolation is accomplished as necessary, the data formatted, collated and reported. Trunk alarms reflecting transmission media outages are directed to the AUTOVON PT&F.

c. The Traffic Data Collection System (TDCS) is installed at overseas AUTOVON switch locations and the overseas ACOC's. Further detail is provided in Appendix VII. The two basic functions are:

- Traffic Data Collection
- Call Data Collection

d. The Traffic Data Collection function of the TDCS gathers the traffic data regarding trunk usage, call duration and call count data during scheduled periods. The schedule specifies data collection over consecutive sixty-minute intervals for a specific period each day starting on a specific date and time. A period may be seven consecutive days with the capability to schedule twelve separate periods in one request. The schedule is loaded by instruction from local teletypewriter input at the SSU. Special Request data collection, for up to 20 selected items over a fifteen-minute interval, can be indicated at the Switch Site Unit (SSU) or the Alarm and Display Panel. Data under a Special Request is printed at the SSU teletype.

e. The Call Data Collection function of the TDCS collects data on the calls originated by local subscribers and collects data on calls to AUTOVON operators. Data collected consists of call identification and time of connection and release. This data is collected during selected periods when no other TDCS SSU function is in progress. Call data collection is started and stopped by local site entry or ACOC instructions. All Call Data is recorded on magnetic tape. The tapes are forwarded at 30-day intervals to the appropriate DCA areas for analysis.

f. Transport of TDCS Data:

The TDCS is designed to automatically transfer data via the AUTOVON system. However, due to problems encountered in the use of this data for real-time operational control of AUTOVON, data is presently mailed. A description of the communications capability follows. Three modes of communications are available. The types and uses are:

(1) Automatic mode - The normal communications mode - calls over the system are automatically initiated without operator assistance.

(2) Semi-Automatic Mode - An operator can establish voice calls from the TDCS to selected AUTOVON stations. This mode blocks the automatic mode. Value of this mode is constrained to testing dial up operation and transmission facilities.

(3) Manual Mode - An operator can establish voice calls to any AUTOVON telephone. This mode blocks the automatic mode. This mode allows for testing transmission facilities and allows connection to test terminations.

g. The transmission of instructions and data between a TDCS SSU and TDCS ACOC is fully automatic. Two procedures are followed to transmit data:

(1) Transmission Procedure I - used for transmission of requests from an ACOC to an SSU to initiate specific data collection, load scheduled traffic data collection, or to start or stop call data collection, and to forward special request data from the SSU to an ACOC.

(2) Transmission Procedure II - used for transmission of requests from an ACOC to SSU of the value of a single count, transmission of data from scheduled traffic data collection. System and the transmission of data from call data collect-

ion. This procedure is also used for the response and transmissions resulting from these requests.

h. AUTOVON Centralized Alarm System (ACAS)

The ACAS provides the network controller the near-real-time indications necessary for network control. The ACAS is only installed at overseas switches, with network control resident at the DCA-Europe and DCA-Pacific ACOC's. CONUS AUTOVON switches have the functional equal to ACAS, however procured on a special case basis. Near-real-time status information from the CONUS AUTOVON switches is provided to the AT&T-operated Dranesville Operations Control Complex. Refer to Appendix III for a full description of ACAS. The ACAS provides near-real-time indications of:

(1) Traffic pressure and flow within the switch

(2) Components-out-of-service

(3) Trunk status

These indications are displayed at the ACOC's for each switch, appropriate alarm indications provide status. Data is sensed automatically and formatted for telemetry purposes. Transmission of data is over 75 BPS circuits. No collation of the ACAS data is performed.

6. NETWORK CONTROL FUNCTIONS

a. Network Control principles include:

(1) Use of minimum controls for routing of traffic - maintain predetermined routing plans. Do not over-control if changes are necessary.

(2) Use all available capacity

(3) Reduce multi-link alternate routing when network is overloaded

(4) Give preference to terminating traffic

(5) Inhibit switch congestion

b. Network Controls are:

(1) Decentralization

(2) Line Load Control

(3) Destination Code Cancellation

(4) Change Routing Plans

(5) Restrict Operator Attempts

(6) Impose MINIMIZE

(7) Make-Busy Access Lines

c. The data obtained from ACAS, TDCS and switch personnel is verified and analyzed by ACOC personnel to determine network control actions. The actions are in turn measured via the ACAS to determine effectiveness. As soon as the network can function normally, controls are removed. Therefore, the data reported by the AUTOVON switches is collated and analyzed as conditions warrant to overcome critical conditions. However, transmission media status data does not appear to enter into the problem-solving effort.

d. DCA Circular 310-V70-44, Overseas AUTOVON Network Control Procedures is provided in its entirety in Appendix III. The discussion Chapter 2, paragraph 5, Traffic Data, should be substituted with the discussion of TDCS, as this system has been implemented for Overseas AUTOVON.

7. AUTOSEVOCOM

a. The AUTOSEVOCOM operator receives status data from:

(1) Customer complaints

(2) Equipment alarms - modems and crypto

b. Customer complaint data is obviously not formatted nor automatically sensed. Transmission media problems, derived from the equipment alarms, are directed to the serving TCF or *AUTOVON PTF* as previously designated. No transmission measurement equipment is available at the AUTOSEVOCOM location.

c. Status reports on equipments (modems, crypto, switchboard) are rendered in DCAC 310-55-1 format. Collation, if any, is accomplished by the AUTOSEVOCOM operator.

d. Quarterly traffic surveys are compiled by the switch operator, manually. These reports are mailed to the ACOC.

8. TEST ACCEPTANCE DATA

a. T&A data is derived manually through appropriate circuit measurements, using test procedures defined on DCAC-310-70-1. No specified format for this data exists; however, DCAC 310-55-1 reporting format can be used. The data is retained at the station or site. Data is reported to the level requesting the circuit change. For newly established circuits, activation status to include acceptance as specified or with exceptions, is used to update the circuit file.

9. TECHNICAL EVALUATION PROGRAM

Data is derived manually and recorded in a report format. Reports are in narrative form with data sheets. The report is mailed to DCA and other interested agencies. Periods of evaluation are per DCA schedule.

10. PERFORMANCE EVALUATION DATA

Performance evaluations are conducted periodically or as required by DCA. Data is obtained manually with only descrepancies recorded. No specified format is followed. A narrative letter report is rendered with technical data sheets to support the narrative.

11. OTHER DATA REPORTS FROM LEVEL 5:

a. Facility (CREDATA/DCAC 300-85-1) update reports are submitted to DCAOC by each DCS reporting station on an as-occurs basis. Each station mails a report of any changes and reconfigurations of equipments at their station or their reported-on stations.

b. Quarterly the DCAOC mails a computer printout of the data to the respective station for update and review. Negative reports are required. Update reports profile the type and quantity of station equipment which is dedicated to support the DCS. This includes all active operational and spare equipment, but neglects station batteries, patch bays, distribution frames, and similar support hardware. Data is manually generated and maintained in a standard format which is collated by the ACOC.

E. PROCESSING OF DATA

1. Status Report Data - Level II

a. The status reports (DCAC 310-55-1) received from reporting stations, both traffic and transmission monitoring, are entered into the WWOLS at the ACOC, Level II. This data is retained for a period of 10 days. The ACOC provides communication SPOT (COMSPOT) reports to the DCAOC. These reports are assembled and collated data which is assembled at the resident ACOC WWOLS. Reports are transmitted via AUTODIN to DCAOC and affected theatre commanders. COMSPOT reports are generated as soon as possible after being notified of a reportable situation, major change or termination of a situation within the DCS. COMSPOTS will:

(1) Advise of threatening or disruptive situations affecting the DCS

(2) Advise of major change in the status of a previously reported situation

(3) Advise as to the time disruption or threat was terminated

Situations which shall cause initiation of a COMSPOT are in Appendix V.

b. The COMSPOT has additional use as a reference tool. Associated with each COMSPOT report is a "non-perishable" subject. This constitutes a "key word" in the software used by WWOLS. It may be used as a reference when searching for status reports associated with that COMSPOT.

2. Status Report Data - Level I

a. The DCS Communications Status (COMSTAT) report is a concise formatted and collated entry in the status report for the entire DCS. This report is prepared by the DCAOC and submitted to the JCS and other specified organizations. It is submitted daily for the preceding 24-hour period. During JCS imposed exercises, general war situations, and national emergencies, reports are generated every 12 hours.

b. The purpose of the COMSTAT is to provide the JCS, unified and specified commands, military services, and other addressees, as designated, with summary information on the global communications events that have occurred during the reporting period within the Defense Communications System (DCS). The COMSTAT should:

c. (1) Disclose cases of existing or impending degradation of important facilities of the Defense Communications System (DCS), such as subsystems, networks, and transmission media of the DCS.

(2) Disclose cases where failure of the DCS has or will have impact on user requirements for service.

(3) Disclose conditions that threaten the effectiveness of the DCS or its ability to provide the required quality of service.

d. The COMSTAT report content is as reflected in Appendix VI.

F. The CIRCUIT/LINK/TRUNK (CLT) file is formatted, collated data on file in the WWOLS. It is maintained and updated only at levels 2 and 1 by the circuit allocation engineers of the DOCC staff. It lists all:

a. Circuit numbers (CCSD) and their associated data:

(1) Purpose of circuit

(2) Circuit parameters required

(3) User and user location

(4) User terminals and terminal equipment including Crypto equipment

(5) Restoration priority

(6) Period of operation and type of operation (e.g. full duplex)

(7) Type of modulation and signaling rate and type of signaling

(8) Routing of circuit including trunks traversed

(9) Enroute facilities and their locations

(10) Equipments used at enroute facilities, e.g. equalizers, echo suppressors, regenerative repeaters

(11) Trunk cross reference number if the circuit itself carries multiplexed traffic.

b. Trunks identification numbers and their associated data:

(1) Location and type of facility at trunk terminals

(2) Type of trunk and media traversed

(3) Trunk terminal equipment

(4) Trunk bandwidth and capacity (number and types of channels)

(5) Links traversed by link number, card locations and facilities, transmission media and modulation

(6) Assigned group/master group on each link

(7) Route number

(8) Period of operation and type of operation (e.g. full duplex)

(9) Restoration priority

(10) Circuit cross reference number if the circuit itself is the trunk (e.g. multiplexed TTY signals)

(11) All channels and circuit numbers on the trunk with associated circuit data

a. User location and facility

b. Restoration priority

c. Period of operation and type of operation

d. Type of modulation and modulation rate.

APPENDIX I

SYSTEM DESCRIPTION OF THE WORLD WIDE ON-LINE SYSTEM (WWOLS)

This appendix is provided as a functional description only. IBM 360/30 and 1410 equipments are presently being reconfigured. The 360/30's will be augumented with more storage. The 1410's will be replaced; partially through the increased 360/30 memory and partly by installation of an IBM 370/145 at the DCAOC.

1 General

1.1 Definition. The World Wide On-Line System (WWOLS) is a complex of four separate facilities interconnected through the AUTODIN system. Figure 1 is a block diagram of the WWOLS. Each site currently has the same system and applications software, centrally developed and maintained by DCA, which processes data originating at many worldwide locations. System products are generated at each location and automatically processed throughout the four site network; each site depends on the availability of processing time throughout the network for timely system product generation. The overall network configuration deals with information for control, allocations, engineering, performance, and administrative functions; each site also has limited capability to produce special reports for O&M, and for MILDEP Agencies.

1.2 Data Base. The overall system is basically decentralized with each DCA area center having its own data base and a standalone capability in case of emergency. The area center data bases are monitored and collectively maintained at the central WWOLS site (required for world wide analysis). The WWOLS also provides maintenance and processing of special files and more detailed analyses necessary to support worldwide DCS operations.

1.3 Availability of Data. Data is made available through the use of AUTODIN as a communications network. A number of field activities currently have on-line access to WWOLS data files via AUTODIN; control data is automatically passed to O&M agencies as it is received from reporting stations.

2 System Configuration

2.1 Main Processors. A WWOLS site is made up of two main processors; an IBM 1410 (acquired in 1963), and an IBM 360/30 which serves as both a data processor and AUTODIN terminal (acquired in 1969). The collective core size of all four sites is one-half the core size of an IBM 370/155 (such as the type at DCED). The collective Direct Access Disk Storage capability of the four WWOLS IBM 360/30's is approximately the same as that of the IBM 370/155 at DCEC. The comparison of the WWOLS equipment with a larger processor is presented to place the processors in the proper perspective with their capabilities. The IBM 1410 at DCAOC is being replaced with an IBM 370/145.

2.2 Communications Processor. A communications processor (NOVA Mini-Computer) interfaces the WWOLS computer with CRT and TTY devices; the two main processors in turn are inter-connected to each other (via TIC unit) and to AUTODIN via a nonprogrammable IBM 2701 interface device. The design philosophy, based on current requirements, uses the NOVA communication processor for telecommunication interfacing only.

3 WWOLS IBM 1410 Processor

3.1 Description. The IBM 1410 is a second-generation computer originally designed as a batch oriented system. This system has been in operation for over 10 years, 7 days a week, 24 hours a day. This equipment has been very reliable to date; however, future reliability must consider the availability of skilled people and the age of the equipment. This equipment is scheduled for retirement by December, 1977, at the latest, and therefore should not be considered for a role in the PS network control and management. This involves a two-phase effort, both of which are in progress. Phase I will expand the core memory of 360/30's to 512K bytes. The second phase implements revised software and operating procedures to allow cutover.

3.2 Function. The IBM 1410 is currently used for the storage, manipulation, and presentation of large bodies of data; the data is oriented towards communications resources (CRE data and CLT index). The data in the IBM 1410 system is made available to on-line CRT devices, authorized AUTODIN subscribers, and on-line I/O devices on a 24-hour basis. Data is collected from the IBM 360/30, and processed as historical data in the IBM 1410. Some functions performed in the area centers are planned for centralization at DCAOC.

4 WWOLS IBM 360/30 Processor

4.1 Description. The IBM 360/30 is a third-generation computer which interfaces with AUTODIN, the communications processor, and the IBM 1410. This system has been considered the nucleus of WWOLS for the last 2 years.

4.2 Function. As available processing time decreased on the IBM 1410, applications were shifted to the IBM 360/30. Today, the IBM 360/30 is considered the clearing house for all telecommunications traffic, and applications are being shifted to it from the IBM 1410 to allow orderly phaseout of the 1410. The IBM 360/30 is considered the last available source of processing time for the WWOLS. Current peak processing periods have already pushed this processor to its practical limits.

APPENDIX II

ATEC Reporting Structure

The ATEC subsystems will parallel the SYSCON levels. This functional arrangement along with an illustration of the ATEC system information flow is shown in Figure II-1. While the sector, nodal, and station controls will normally operate together as a system, they must have a degraded mode capability whereby the nodal and station control levels can function without a higher level control.

<u>Sector Control Functional Area</u> (Level III FCO)

The sector control functional area provides capabilities for coordination among adjacent FCOs and among each of the nodal sites within the jurisdiction of an FCO. Authorized outages within the Sector Area will be controlled by the sector and coordinated with the Area Communications Operations Center (ACOC) as required. Principal responsibility for the accuracy of the ATEC data base rests with the sector control functional area for all subordinate ATEC equipments. The sector control data base will include a complete record of the DCS connectivity for the intra and intertheater and the connectivity of ATEC station control equipments to the transmission system for that sector control's jurisdiction. The sector control data base will also contain connectivity information to completely describe the ATEC equipment configuration within that sector to include thresholds. Thresholds must be controlled by the ACOC for the theater. No measurements are made at this level.

Responsibility for preparing transmission system preplanned alternate route actions and coordinating their implementation resides in the sector control functional area. This responsibility will consist of circuits and above and network reallocation and will be coordinated with the ACOC as required.

The sector control functional area requires the gathering of status and periodic reports from the subordinate nodal controls in order to assess the quality of service and equipment utilization within the jurisdiction of an FCO. Impact of problems on networks will be analyzed and required reaction to problems is initiated at the sector level. This information is consolidated, analyzed and forwarded to the ACOC at the Theater Control Level.

The sector control requirements will be satisfied by the Sector Control Subsystem (SCS).

<u>Nodal Control Functional Area</u> (Level IV ICO)

The nodal control is primarily tasked with concentrating and

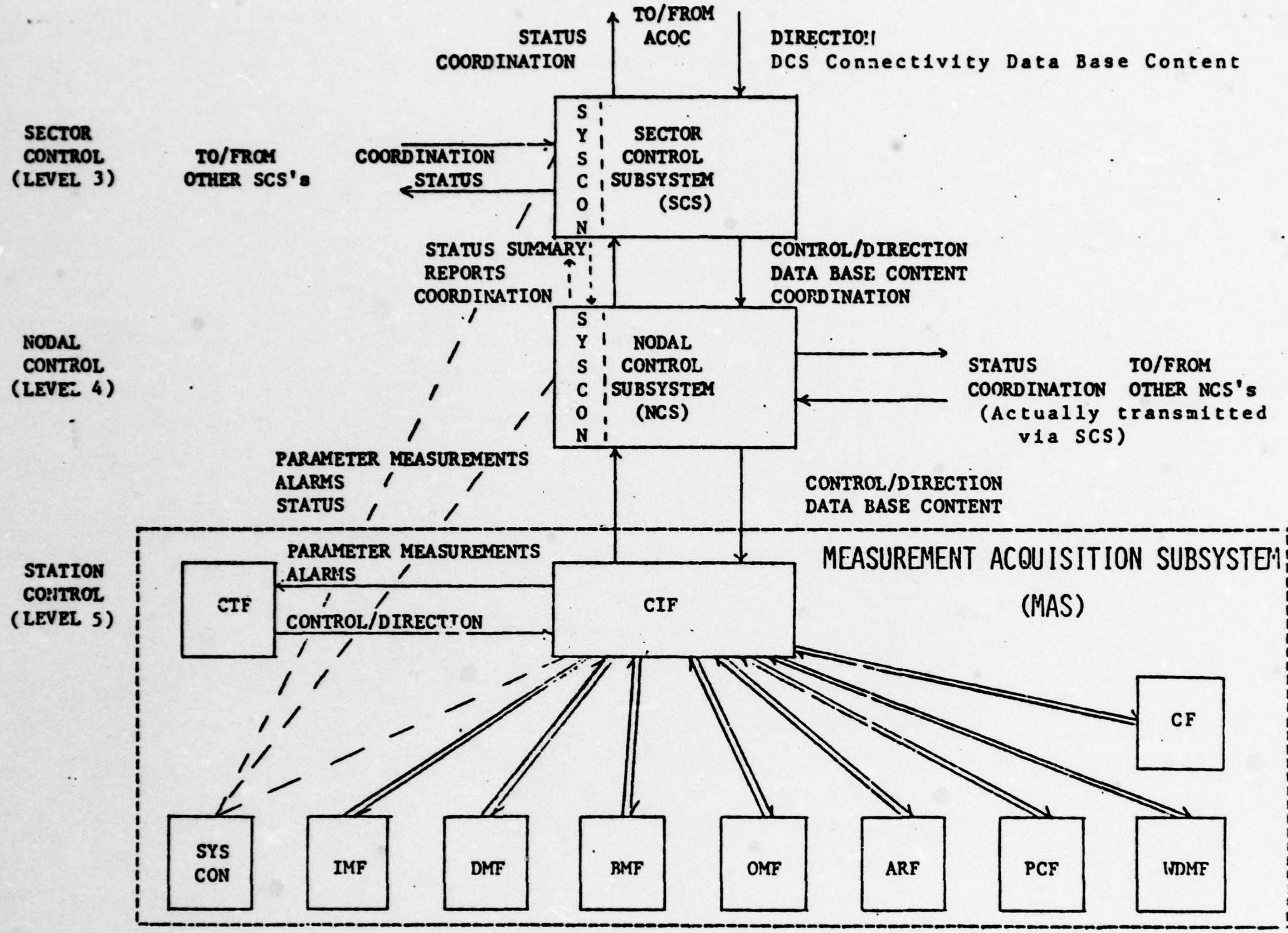

FIGURE II-1 SYSCON TEC INFORMATION FLOW

reducing data into meaningful results, correlating parameter measurements, identifying performance degradation, isolating faults, maintaining a dynamic data base of system resources and connectivity, and facilitating optimal altroute and restoral actions. Additional responsibilities include reporting upward to the SCS, coordination and control of station level actions, providing summary statistics, execution of specific test procedures, and identification and transfer of responsibility for system and network problems, which are beyond the capability of this function, to the SCS. No measurements are made at this level.

The nodal control functional area will provide the capability to direct and control the operations of all station equipments that are subordinate to the nodal control. The nodal control functional area includes the coordination of all interstation automated testing and fault isolation within the jurisdiction of an NCS.

Information regarding quality of service within its span of control is gathered and consolidated at the nodal control level. Status and periodic reports will be provided to the sector control functional area.

Direction and coordination of circuit level alternate route actions within the jurisdiction of an NCS is the responsibility of the nodal control functional area.

The nodal control data base will be a subset of the sector control data base and will include connectivity of the DCS transmission facilities and ATEC equipment, and all information necessary to control station level elements that are subordinate to an ICO.

The nodal control requirements will be satisfied by the Nodal Control Subsystem (NCS).

Station Control Functional Area (Level V TCF)

The station control functional area will include the data acquisition and information transfer capabilities required by the nodal control functional area in order to accomplish performance assessment, quality control, and status evaluation of all transmission systems, equipment, and facilities within a DCS station. In addition, a local station control capability will be provided to control the operations of station elements when interaction with the NCS is not possible.

a. In-service measurement of VF circuits including parameter measurements, threshold comparison and alarming. These functions will be accomplished in the In-Service Measurement Function (IMF).

b. In-service measurement of DC circuits including parameter measurement, threshold comparison and alarming. These functions will be accomplished by the DC Measurement Function (DMF).

c. Baseband measurement to include parameter measurement, threshold comparison and alarming at selected frequencies and bandwidths within the baseband. These functions will be accomplished by the Baseband Measurement Function (BMF).

d. Out-of-service measurement capability on VF channels operated either locally or remotely (e.g. a nodal controller) to include test signal injection onto a VF circuit and measurement of channel parameters based on these test signals. These functions will be accomplished by the Out-of-Service Measurement Function (OMF).

e. Detection of equipment and facility change-of-state alarms for both analog and digital systems, to include local status display as well as remote status reporting. These functions will be accomplished by the Alarm Reporting Function (ARF).

f. Measurement and conversion to meaningful units of specific analog and digital transmission system parameters to include transmitting output power and receive signal level alarming. For analog systems this will also include baseband signal levels, pilot tone level and frequency, and slotted noise level. These functions will be accomplished by units of the Parameter Converter Function (PCF).

g. Data interchange between the detection and measurement elements of the ATEC System, the Technical Controller and the NCS will be centralized at a station. This function will be accomplished by the Communication Interface Function (CIF).

h. A man-machine interface is required for Technical Controller to communicate to, and receive information from, the Nodal Control subsystem and other measurement functions. These functions will be accomplished by the Controller Terminal Function (CTF).

i. In-service measurement of wideband digital multiplex hierarchies and mission bit streams and equipments to include parameter measurements, threshold comparison and alarming. These measurements will be accomplished by the Wideband Digital Measurement Function (WDMF).

j. Control to include transmission equipment substitution, generators and environmental equipment is required. These control functions will be satisfied by the Control Function (CF)

The primary requirement of the Measurement Acquisition Subsystem (MAS) is in-service parameter measurement, detection and alarming on exceeded thresholds and passing this "by exception information" to the station level and the Nodal Control level. All parameters measured will be provided upon station or nodal control demand (manually or automatically initiated).

APPENDIX VIII

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APPENDIX B
TUTORIAL ON LOOP COMMUNICATION NETWORKS

B.1 Introduction

A communications loop is a closed, ring-connected set of nodes providing data flow unidirectionally from one node to the next. Each link between nodes is a single twisted pair of wires carrying a serial data stream in a self-clocking code. Full connectivity is achieved by associating a destination address with each packet of data carried on the loop. A node to whom a packet of data is not addressed acts simply as a "delayed repeater", having no effect on that data other than introducing some delay. The concept of a data exchange loop has been described extensively in the literature of computer communications by Pierce, Newhall, Farber, Fraser, Reames, et al. Loops may be distributed such that each node contains its own power supply and cabinet and is located near the equipment it interfaces or local such that all nodes are connected within a single cabinet with cable connections to interfaced equipment.

Burroughs has considerable experience in developing loop communications systems utilizing microprocessors. A prototype loop network is currently in operation at the Burroughs Corporation's Advanced Development Organization (ADO) at Paoli, Pa. The prototype network was developed in conjunction with three Corporate sponsored product development projects investigating aspects of distributed processing in the areas of systems, hardware, and network operating software. A variety of computers and peripherals (e.g. B721's, 4-interpreter D-machine, B776's, CONRAC and TD800 CRT terminals, REDACTRON word processing system, etc.) are connected to the communications loop via a Burroughs developed interface node which is configured around a Burroughs Mini-D microprocessor. A detailed description of the ADO loop is given in Section B.8.1.

The communications loop concept was extended in the Exploratory Systems Control Model (ESM) developed at ADO for DCA (Defense Communications Agency). In this system, three interconnected loops interfacing DIGITAL PDP11/40 minicomputers and Burroughs TD800 CRT terminals provide a powerful simulation tool for studying various DCS system control architectures. In addition to the nodal control Mini-D microprocessor, a second more powerful Mini-D microprocessor is provided at each node to implement various protocols, distributed and fail-soft network control, and specialized equipment interfacing. The loop system developed for the ESM Contract (DCA 100-75-C-0054) provides an environment with high speed and survivability. The ESM node is able to handle an effective loop data rate of up to 25,000 characters per second. A detailed description is given in Section B.8.3

Burroughs is currently implementing a more advanced loop for the ESM Development (ESMD) contract using BDS microprocessors as control and interface processors (CIP's). The BDS (Basic Data System) microprocessor is used as the engine for the B80 microcomputer system. The ESMD loop is described in Section B.8.3.

A loop communication system configured around microprocessors has the advantages of modularity, simple upgrade by adding additional nodes, and low cost.

B.2 General Operation

A functional block diagram of a communication loop node is given in Figure B.1. The Loop Interface Unit (LIU) is responsible for reading data addressed to the node and writing data on the loop. The Control and Interface Processor (CIP) is a microcomputer that provides a data communications interface to the external device. The memory is used for program storage, routing tables, and intransit queue storage. The external interface provides a hardware connection to the external equipment to be connected to the loop.

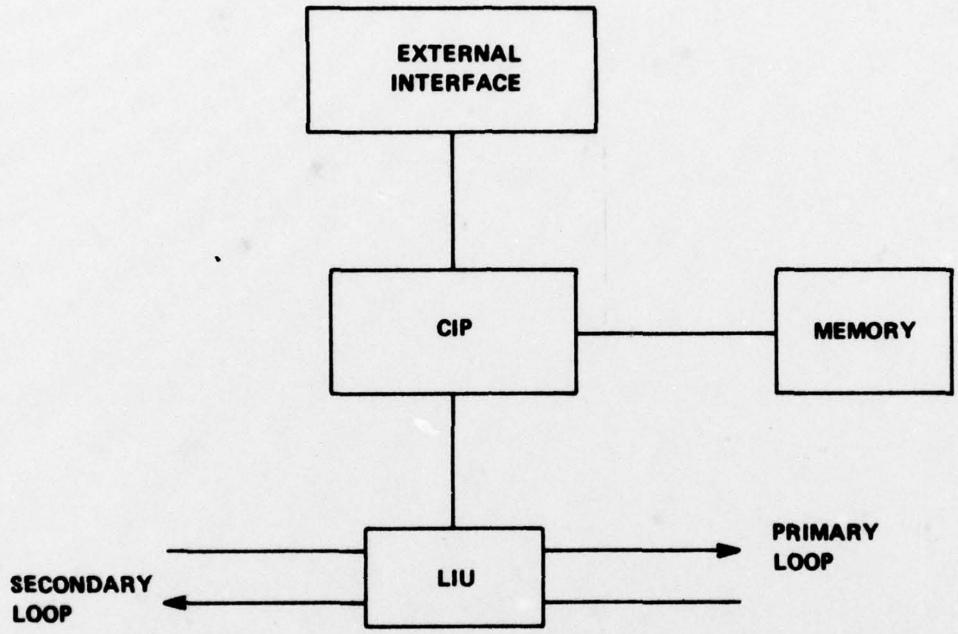


Figure B-1. Communication Loop Node

The three loop systems described below (ADO, ESM, ESMD) all correspond to the block diagram of Figure B-1. The ADO node primarily implemented the LIU portion of the figure. An enhanced Mini-D Microprocessor (B7*) was used to implement the node. Control and data memory implemented the CIP function to a limited extent. The ESM node also used a Mini-D to implement the LIU function but added a second, faster, more powerful Mini-D with additional control and data memory to perform the CIP function. The ESMD node uses a hard wired BDLC (Burroughs Data Link Control) protocol implementing LIU and a BDS microcomputer with 32K bytes of memory.

B.3 Modularity - Adaptability Features

The basic Burroughs loop node is a module composed of a hard-wired LIU, an nBDS (a single-card, double speed n-channel version of the BDS) acting as a CIP with 16 kilobytes of semiconductor memory. To this, an interface is added for the external device involved such as line interfaces, disk interfaces, or B800 minicomputers.

The entire system will be composed of loops which are groups of these modules connected together in ring fashion. To physically add a module, the loop is broken at one point (which causes automatic loop-back so that service is not interrupted), the new module is connected and when connection is complete, the loop will establish itself in its original form except that the new module has been added. Once the module is added, the system will not recognize it until routing tables have been updated and the module has been loaded and tested.

Similarly, when a module fails, the loop will recognize the failure and cut the failed module out of the system by forced loop-back from the module's nearest neighbors. The module may then be replaced and the loop will return to normal operaton. In the meantime, the other modules will still be in operation so that degradation will be graceful in that only the operation of the failed module will have been lost. For an explanation of loop-back, see Section B.8.3, "ESMD Loop".

Modules can be added to a loop until a high percentage of the throughput capacity of the loop has been used up.

At that point, another loop should be developed with gateway nodes connecting the new loop to other nearby loops so that all can act in concert. Nodes from the older loops can be moved to the new loop if it appears advantageous. None of this will stop the activity of the system.

B.4 Loop Throughput Capability

Loop throughput (total number of message units that can be sent over the loop per unit time without undue message delay to the receiving modules) is a function of line speed, loop discipline and the definition of "undue" message delay. Reames [1] provides an insight to three different loop disciplines and how they compare. Loop types will be named according to this article.

The Newhall loop can transmit only one message on the loop at a time and has the lowest throughput but has the advantage of simplicity and cannot be clogged by misdirected messages. It also shows some advantage in ease of detection and deletion of certain types of faults.

The Pierce loop can transmit multiple messages, but the small fixed packet size causes greater overhead than in the DLCN loop. The DLCN loop uses queues within each LIU that can expand or contract to hold upstream messages in temporary storage. This allows packets of variable size to be transmitted and allows multiple transmissions. Loop clogging is possible in both cases, however, and special means must be employed to "declog" the loops under certain error conditions.

The Burroughs loop frequency can be as high as four to five megabits/second but a conservative value of two megabits/seconds will be used. A Newhall loop can produce a throughput in excess of 1.5 megabits/second at this frequency without undue delay. The Pierce and DLCN throughputs can be even higher.

Suppose the average node writes 15 packets of 2000 bits each per second for a total of 30000 bits/second. At that rate a Newhall loop can support 50 nodes. The maximum delay for a node to wait to write is 50 packets or 50 x 2000/2000000 = 1/20 second. The average wait is about 1/50 second. This is less than 1/3 of the processing time of the packet through the BDS so that the queue increase within the BDS owing to loop write delay is very short. The total average delay owing to loop write delay is estimated at only about 1/25 second.

B.5 Multiple Loops - Addressing Schemes

Burroughs has built a multiple loop system and has installed it (see B.8). This system has proved the capability for providing multiple loop systems and has acted as a vehicle for testing multiple loop addressing schemes.

Figure B-2 exemplifies a multiple loop system. Three loops are shown connected via gateway nodes. Gateway 2 of loop 1 connects to gateway 1 of loop 2 via a hard wire connection independent of the loops. Similarly loop 1 connects to loop 3 and loop 3 connects to loop 2 via gateways. Each loop is independent of the other loops.

The C-R symbol on each loop is a clock-retimer which is used only when loop nodes are not contained within a single cabinet. Thus, the C-R function can be ignored.

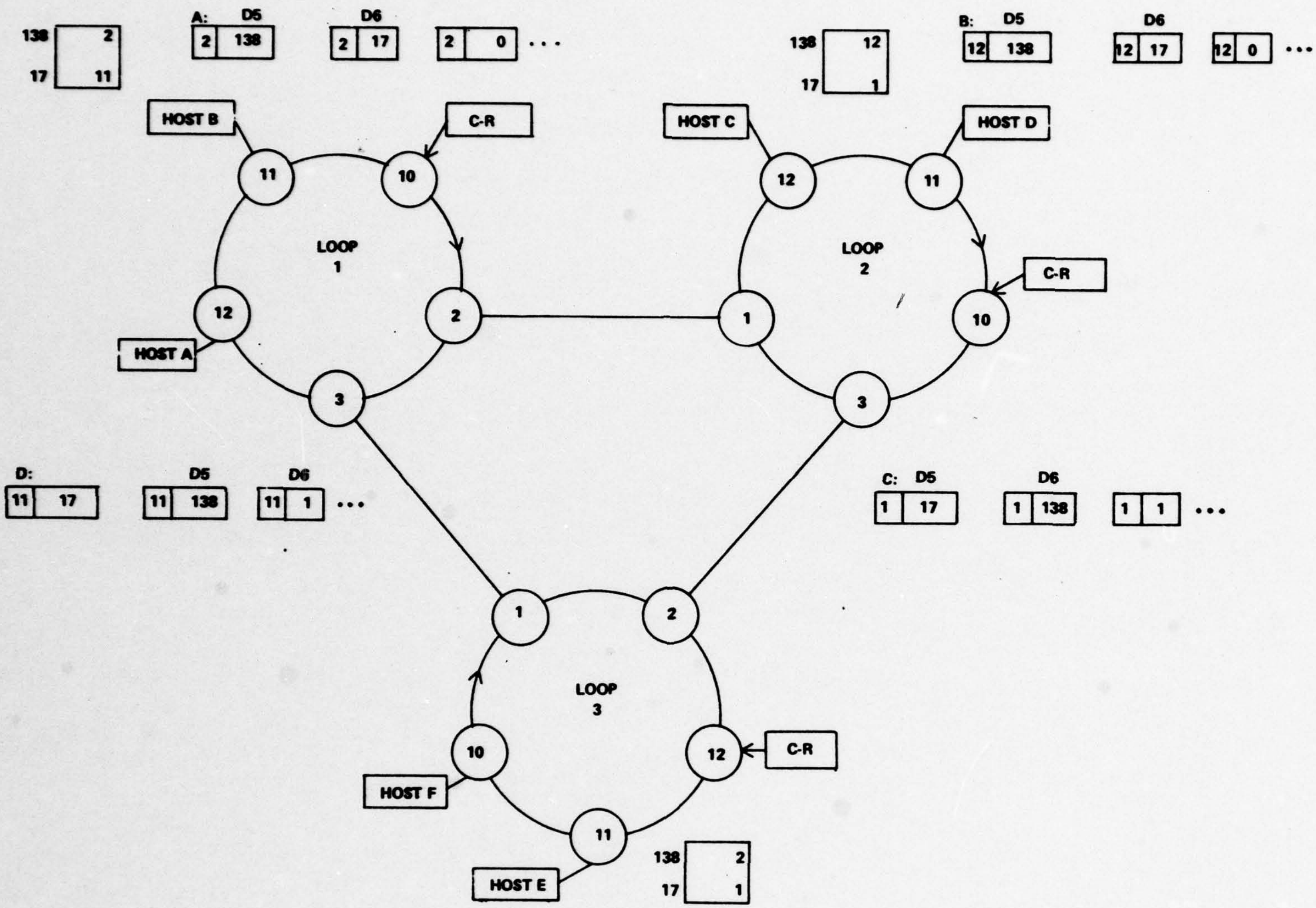


Figure B-2. Method of Addressing

The small circles are nodes and the numbers within the circles represent the "functional address" of the node. The functional address is the local address unique within the loop. In addition, each node had a "logical identifier" unique within the system. The protocol that relates these two entities is called the "address directed protocol" described below.

The address directed protocol is implemented in the nodes by means of a simple table look-up. The table is stored in a 256-word page in each nodal data memory, and it maps logical ID's to nodal functional addresses. For each data memory location on the conversion page corresponding to a particular logical ID, there is an 8-bit representation of the functional address of the node associated with that logical ID. A node wishing to send a message to logical ID of value X sends each information word of the message preceded by an address word having the value contained in location X of the node's conversion table page. Rapid reconfiguration of the network is possible using this scheme merely by modifying this page in each node's memory.

An example of this method of addressing is illustrated in Figure 2.1-2. The read addresses of the nodes are given for each node. Note that gateway node read addresses equal the loop number of the loop to which they interface. Suppose that host B wishes to send a packet to logical ID 138 which resides on host C. Host B uses its own logical ID 17 as the source logical ID which will be used as the destination logical ID for the return ACK or NAK type packet.

Host B supplies the information words to the CIP which determines the functional write address for logical ID 138, and it sends a packet onto the loop having the form of packet A when it receives a WT. Gateway Node 2 on Loop 1 reads the packet destined to it and sends the information words across the interface to Loop 2. Gateway Node 1 of Loop 2 then looks in its conversion table and sends packet B onto the loop. Node 12 of Loop 2 reads the packet and determines whether the check character checks or not. If we assume check, the CIP delivers information words to Host C and sends an ACK type packet having the form of packet C to logical ID 17. The packet is read by Gateway Node 1 of Loop 2 which transfers the information words to Gateway Node 2 of Loop 1. Finally packet D is sent on Loop 1 which is read by Node 11 which pairs the ACK to a packet on its outstanding packet list. Note that if the connection between Loop 1 and Loop 2 was inoperable, alternate routing could be used if the CIP connected to Host B sent its packet to Gateway Node 3 of Loop 1 and indicated alternate routing. The packet would thus reach Loop 2 via the Gateway nodes of Loop 3. An originating node can determine whether or not a packet ever reached its destination by waiting for an ACK or NAK within a certain predetermined amount of time. If a NAK is received or there is no response, the originating node may try again to send the packet, possibly by an alternate route. Alternate routing is implemented merely by changing the address words to the functional address of the other gateway node on the loop.

In addition, certain logical ID's may be used to indicate control messages and special messages such as broadcast messages where every node in the loop picks up the messages and passes it on. The originating node then quenches the message.

B.6. Reliability

It has been estimated that the mean time between failures (MTBF) for the LIU is 22000 hours and that for a BDS with memory is 10000 hours giving a combined value of 7000 hours. A single LIU failure causes automatic loop-back. Two concurrent failures are required to destroy the full loop connectivity. If the mean time to repair is four hours (mostly travel time) then the LIU availability for a 20 node loop is $1-4x20/22000 = 0.9964$ and the loop availability is $1 - (1-0.9964)^2/2 = 0.999994$.

For a loop with 20 BDS microcomputers, there will be one BDS failure per 500 hours. Unless the function of the BDS is duplicated, then that function will fail (such as the single BDS line handlers of the NP) but the system will continue to operate. Where duplicated functions exist, then a single failure is not sufficient to lose the function.

Much of this high availability depends on automatic loop-back which is described in B.8.3.

Power supply availabilities are also very high individually. With double power supplies the availability figures are extremely high.

All of the above is intended to indicate the very high reliability that might be expected for the system. Failures that take place may remove a function or reduce throughput but very seldom will a subsystem fail. The numbers themselves are only exemplary and cannot be considered a guarantee.

B.7. Applications

Loops have been applied to data communications network modeling applications which provide user transparency, distributed processing, electronic mail handling, a distributed file system, a distributed data base system, a terminal handler and shows capability of providing a distributed message switch and a multi-protocol interface.

The ADO loop (see B.8.1) provides connection between many CRT terminals, a card punch and a high speed printer to a number of B700 minicomputers. Any CRT may be attached to any B700 and any B700 can use the card punch or the line printer via the loop. The system permits the posting of electronic mail and provides for transfers of files from one B700 to another.

The ESM multiloop network (see B.8.2) provides the access of two CRT's to two minicomputers in a user transparent mode. The user need not know the machine he is using (or sharing). Files are distributed between the two machines and the user at a CRT may access file records without being concerned about their location. A distributed data base system is being added to the ESM that will be transparent to the user as well.

The ESMD (see B .8.3) will add a fourth loop to the network. This loop will be the latest form using BDS microcomputers and loop-back. A Burroughs B776 minicomputer will also supply additional file capacity and may be used as a journal for the rest of the system. The nodes on this loop will provide a multiple protocol interface to the outside world. External protocols will include SDLC, TCCF, Autodin II phase I mode VI and an instrumentation interface. Thus, many different external systems will be able to interface with the ESM/ESMD combination.

B.8 Example Loop Communication Systems

B.8.1 ADO Loop

The Advanced Development Organization (ADO) Loop located at Paoli, PA has implemented a loop network that is used for software development in a laboratory environment. Various processors, terminals, and peripherals are connected together as shown in Figure B-3. The loop has been operational since March 1976, and nodes are added

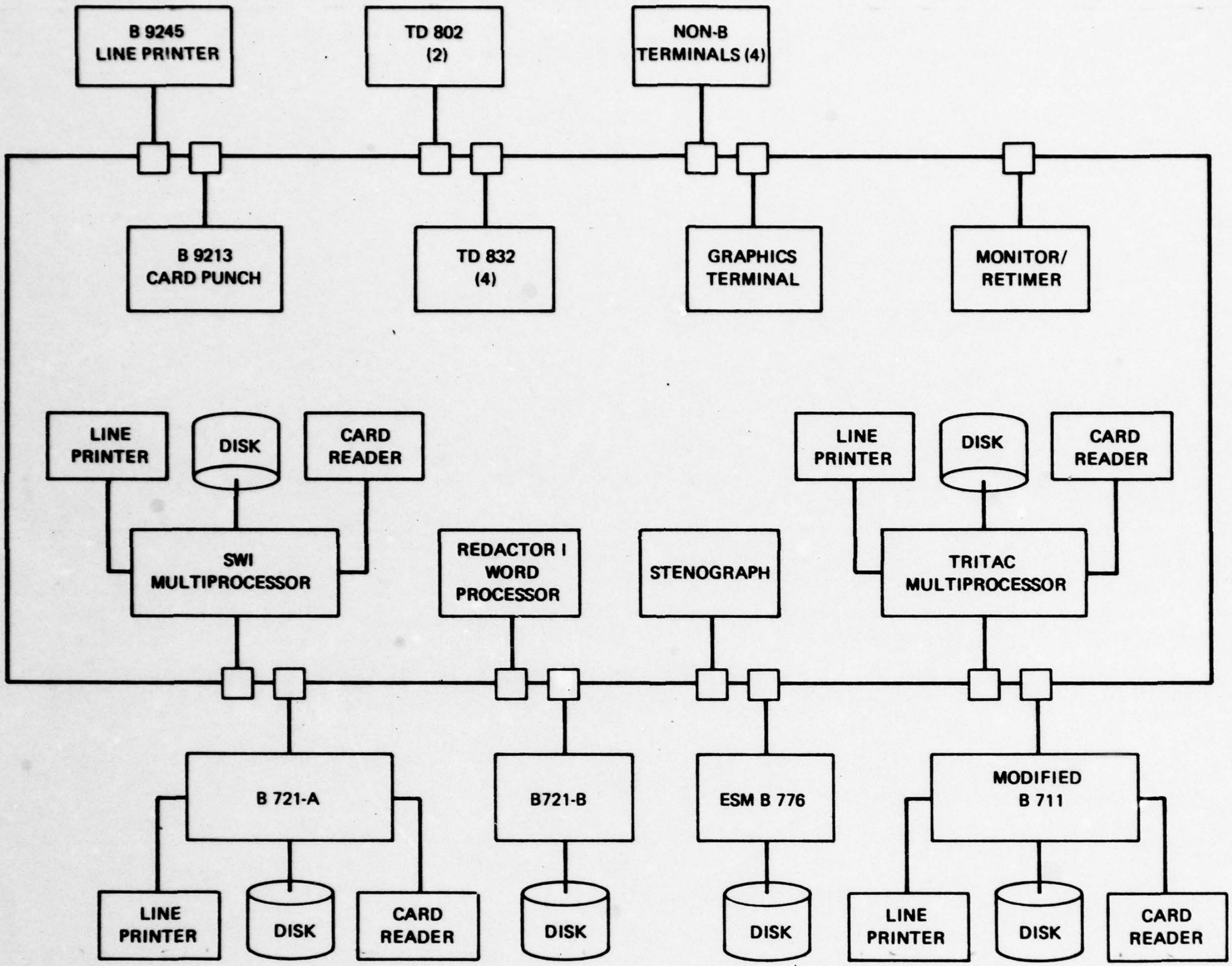


Figure B-3. Advanced Development Organization Loop as equipment becomes available. The loop indicated in the figure represents a 6/8/77 configuration; since that time nodes have been added for another B776 processor, a BDS hardware and software development system, and a touch-sensitive display terminal for a current total of 24 nodes. The nodes consist of 5 cards which reside in a 6 x 7 x 13 inch cabinet with power supply. The loop is contained within a building ring of the Paoli facility with processors located in various laboratories and terminals in offices.

Utilities which have been developed for the system include a file transfer utility which allows files to be transferred between the various disks in the system, a terminal attach facility which allows terminals on the loop to function like local terminals to various processors, a resource allocator utility which indicates the availability of processors and terminals in the system, common sharing of line printer and card punch by all processors in the system, and a message switch system which is used for setting up meetings.

B.8.2. ESM Multiloop Network

B.8.2.1. System Elements and Connectivity

The ESM is a communications system used to interconnect terminals to host computers so that any terminal can interface with any host for information transfer. To accomplish this, each ring is supplied with devices called "nodes" that act as interfaces from ring to CRT, from ring to host, and from ring to ring. The ring-to-ring nodes are called "gateway" nodes. Each node is the same physically as any other node except for a small amount of special separable hardware for each type of node. The major difference between nodes is in the software of the nodes.

The nodes provide all the necessary communications functions of queueing, parity checking, ACKing, NAKing, retransmitting, alternate routing, etc. The hosts and terminals need only supply the data processing functions and need not be concerned with the communications functions.

The ESM configuration is shown in Table B-1 and Figure B-4. The Government-furnished hosts are DEC PDP-11/40 computers. The gateway node interchanges are via cables in the ESM configuration, but in principle can be via any communications medium such as telephone, microwave relay, optical transmission or satellite relay.

The terms "loop" and "ring" are interchangable. Each loop is housed in a separate cabinet in this implementation, but this is not a necessity. A loop could, as easily, extend throughout a building or facility. The ESM configuration at Burroughs Advanced Development Organization is shown on the following pages.

Table B-1. ESM Components (see Figure B-4)

Ring 1:	2 Gateway nodes (one to Ring 2 and one to Ring 3)
	1 Host Node to Interface GFE System Control Processor A
	1 GFE Host System Control Processor A
Ring 2:	2 Gateway Nodes (one to Ring 1 and one to Ring 3)
	1 Host Node to Interface GFE System Control Processor B
	1 GFE Host System Control Processor B
	1 CRT Node to Interface CRT Terminal
	1 CRT Terminal
Ring 3:	2 Gateway Nodes (one to Ring 1 and one to Ring 2)
	1 Node to interface future Host processor or terminal
	1 CRT Node to Interface CRT Terminal
	1 CRT Terminal

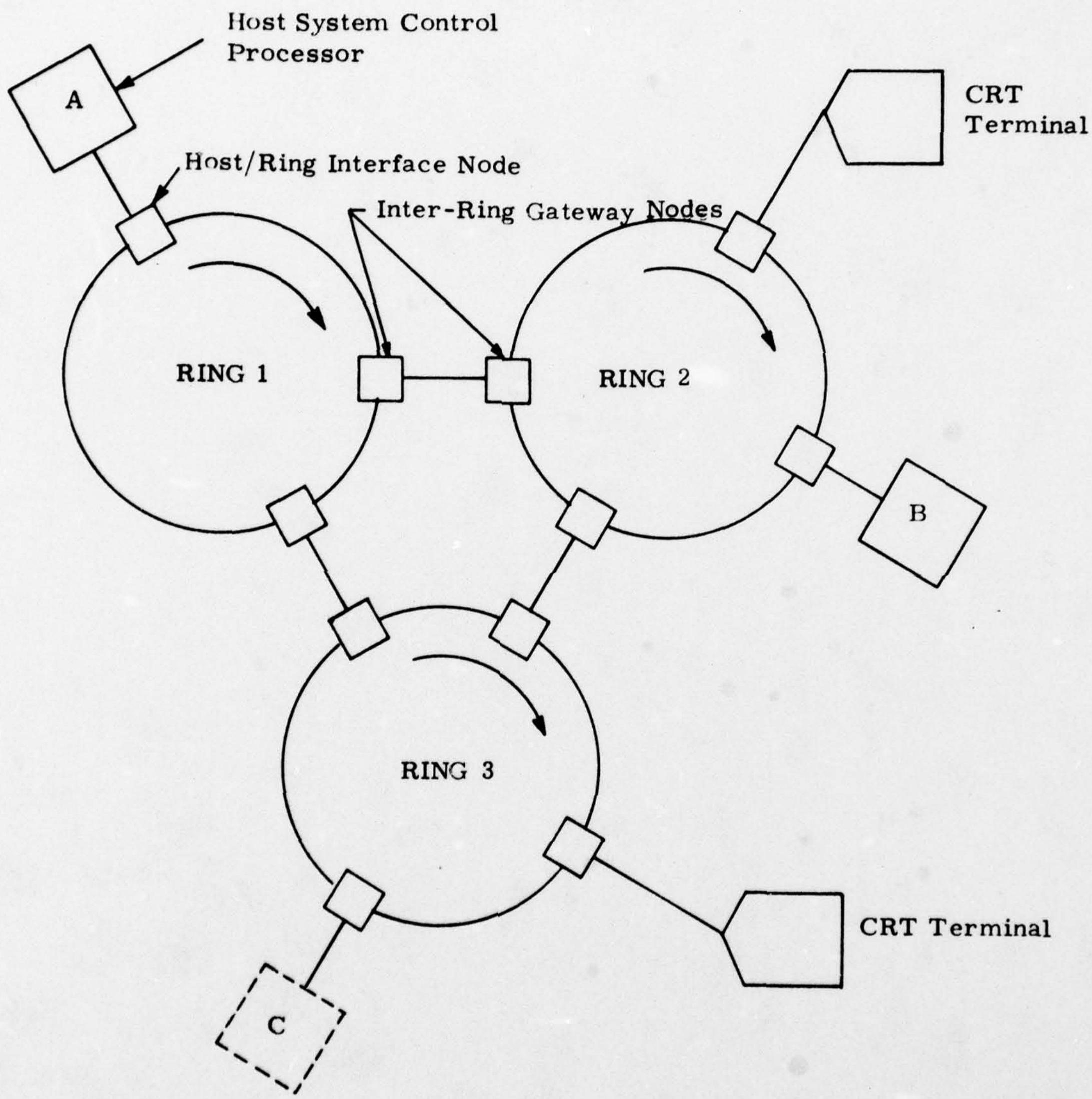
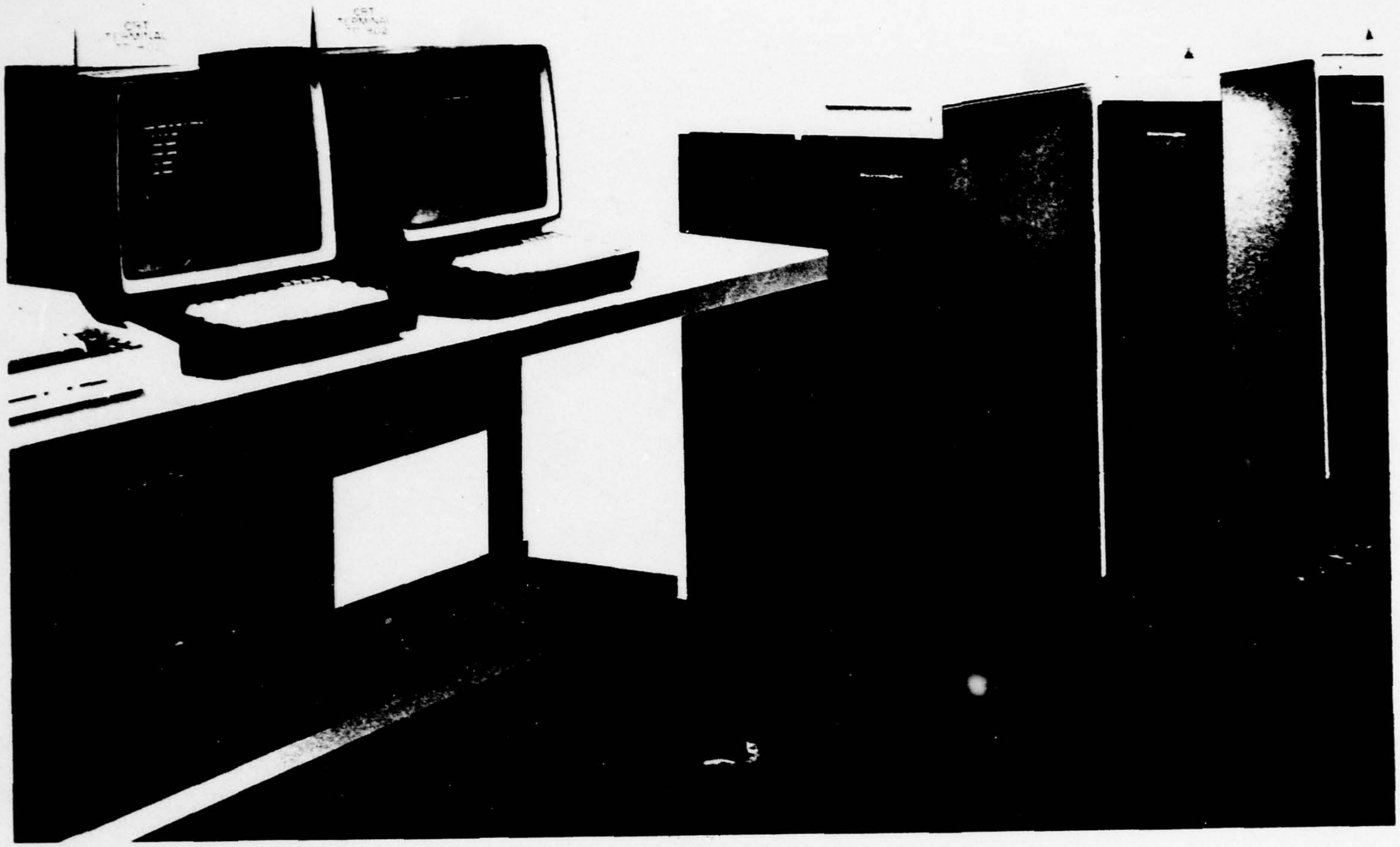
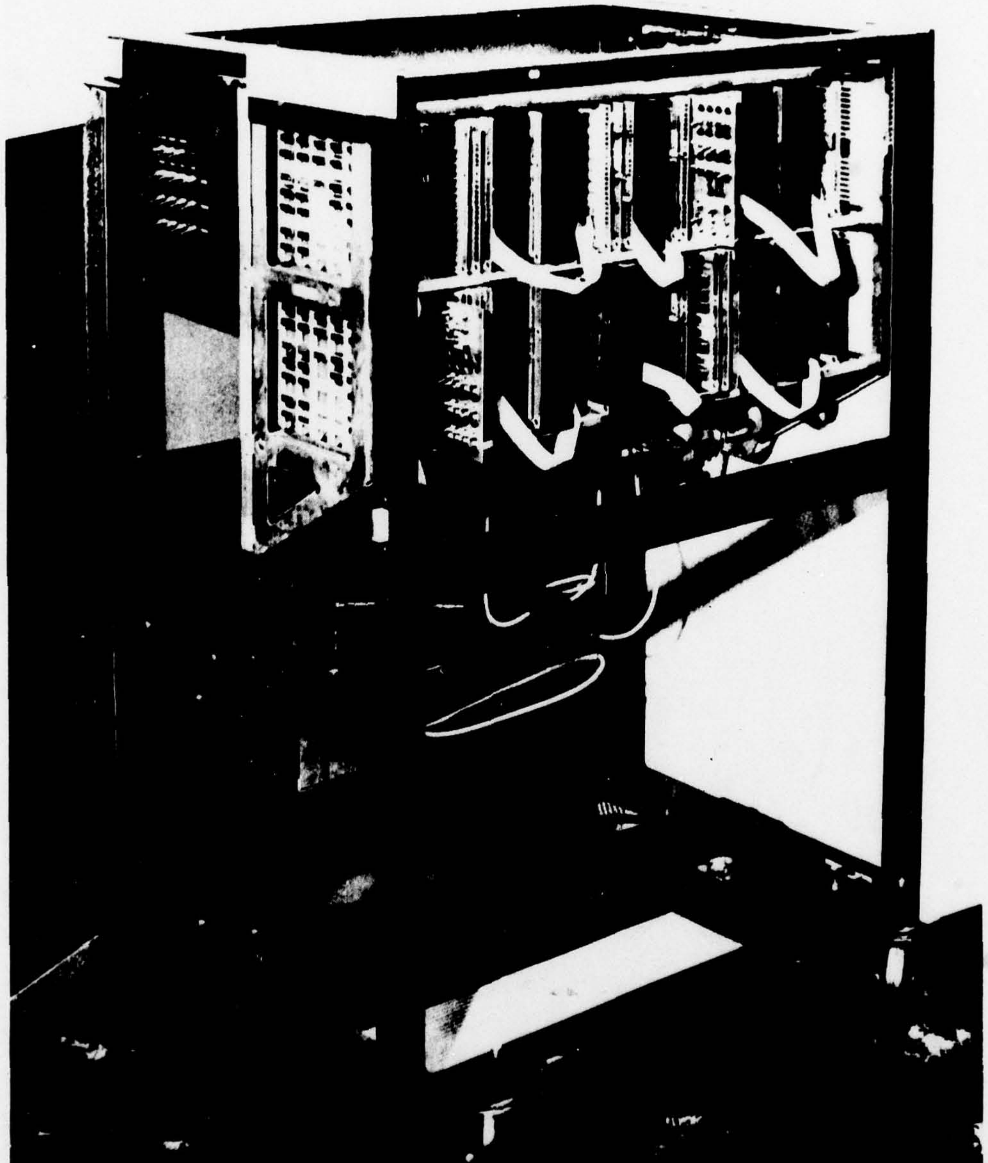


Figure B-4. ESM Configuration



Exploratory Systems Control Model (ESM)



ESM Cabinet, Side Panels Removed

B.8.2.2 Features of the ESM

The ESM is designed to be transparent to the user. Regardless of the CRT used and the host on which a particular activity takes place, the activity will take place for the CRT that calls for it. When a message is transmitted from a CRT, suitable control bytes are added to the message by the CRT node and directed to the node of a nearby host. When the host receives the message, it will either handle the message completely if it can or it will pass it on to another host, via the ESM, for cooperative handling of the message. This is done under program control using the content of the CRT message and the added control bytes. The CRT will then receive a response from one of the hosts.

This response will generally be part of the "user language" which is designed to provide directions for further dialog as well as replies to previous messages. The language is designed to be modular so that it can be easily updated and enhanced.

Messages are sent in the form of packets of length not greater than 256 bytes. As each packet is sent, the sending node holds it for acknowledgement (ACK) from the receiving node. When an ACK is received by the sending node, it frees the packet space. If a non-acknowledgement (NAK) is received, the message is resent or sent by an alternate route. Absence of an ACK or NAK after a timeout period is considered to be a NAK. After a suitable number of resends without an ACK, the message may be reported "not sent".

Nodes automatically provide input and output queueing for the external device. Sufficient extra memory space is provided in each node to permit receipt of line control protocols from the loop and to act on these protocols. This is done to prevent a deadly embrace condition within the node. If the input queue (from the loop to the external device) is full, new input messages are rejected. Room always exists for the receipt of ACKs and NAKs and other line protocol messages. These are acted upon with dispatch so that they do not reside in data memory for a long period. If the output queue is full, the external device is prevented from sending to the node.

The loop protocols are designed to be non-blocking and self-polling. Each node in the loop has its turn to write onto the loop and if any noise exists on the loop from prior transmissions, it is overwritten by the new transmission. Nodes share the polling activity and any loss of polling is restarted automatically.

ACKs and NAKs are generated by end-user nodes when they receive packets. Each packet is tested against a longitudinal parity byte in the packet. A good check results in an ACK and a bad check results in an NAK.

The user language resides in the hosts. This user language provides dialog and directions to the user so that he can operate the ESM after a very short learning cycle. A file facility exists in the user language which permits the user to access and update file records residing on either host without the need for user knowledge of where they reside. This aspect of the user language permits a distributed file storage capability that is transparent to the user. The user language provides several other modes of operation such as CRT-to-CRT messages and a system inquiry and update capability.

The modeling of a particular system control architecture is a separate programming problem. The user language program may be used to set up the files for the model and to access the files but the architecture modeling program must be added by the user. He may elect either to add the model to the user language or to write a separate program that interfaces to the file modes of the user language.

B.8.2.3. Functional Description

The Exploratory Systems Control Model (ESM) is implemented in the form of three interconnected communication loops, each consisting of up to four nodes. Each node is made up of two parallel processing Burroughs Mini-D B7* microprocessors. The nodes on each loop are of two types: Local (L) nodes which interface either a host computer or a terminal device to the loop, and Gateway (G) nodes which interface to a similar node in another loop to implement loop-to-loop transfers. The ESM provides for highly decentralized operation, high reliability, high survivability, modularity, ease of modification, and failsoft operation. The implemented protocols and associated nodal software (written in microcode) provide a user-transparent, distributed communications scheme in which messages, which are sent to logical destinations, are routed automatically to their correct hardware destinations. The system provides for the implementation of various control and text type messages (or packets) which may be used to modify various memory locations within the nodal software, or which may be used to indicate broadcast, acknowledgement (ACK), or negative acknowledgement (NAK) type messages. Also provided is the ability to implement automatic alternate routing for the case of an inoperative gateway node, and rapid reconfiguration for the case of added or deleted nodes.

The ESM loop protocol provides the foundation for extensive error detection and recovery strategies. The extent and sophistication of these error recovery schemes are limited only by the amount of programming performed either in the host computers or in the nodes. Thus, the ESM loop protocol provides a system control architecture that is relatively secure from total failure.

Communications Network

The communications elements that comprise the basic ESM Multiloop System are shown in Figure B-5. There are three communications loops each having one or two local nodes and two gateway nodes. Local nodes are associated with Host computer attachment or CRT attachment to a loop, and gateway nodes are involved in loop-to-loop attachment.

All nodes are the same with each having a line interface unit (LIU) and a B7* microprocessor nodal control unit (NCU). The LIU and the NCU provide for loop interface and protocol handling. Each node includes a second B7* microprocessor which controls the node and acts as an interface for external equipment. This second microprocessor is called the Control and Interface Equipment (CIE). Each CIE is essentially the same as any other CIE except for microprogram. For L-nodes, the CIE interfaces with external equipment; for G-nodes, the CIE interfaces with another CIE of an adjacent loop. A generalized node configuration is shown in Figure B-6.

Each node can pass data through its LIU along its loop, extract data from the loop for storage in the NCU, or take data from the NCU and inject it into the stream of data circulating in the loop. The CIE gives general directions to the NCU and may take data from, or give data to, the NCU. The NCU operating with a 1MHz or lower clock speed is synchronous with the LIU and the data stream. The CIE operates asynchronously and at a higher (8.96 MHz) clock rate.

Each loop has a Clock-Retimer (CR) which establishes the frame format for the loop and restandardizes the time slots and data elements on the loop.

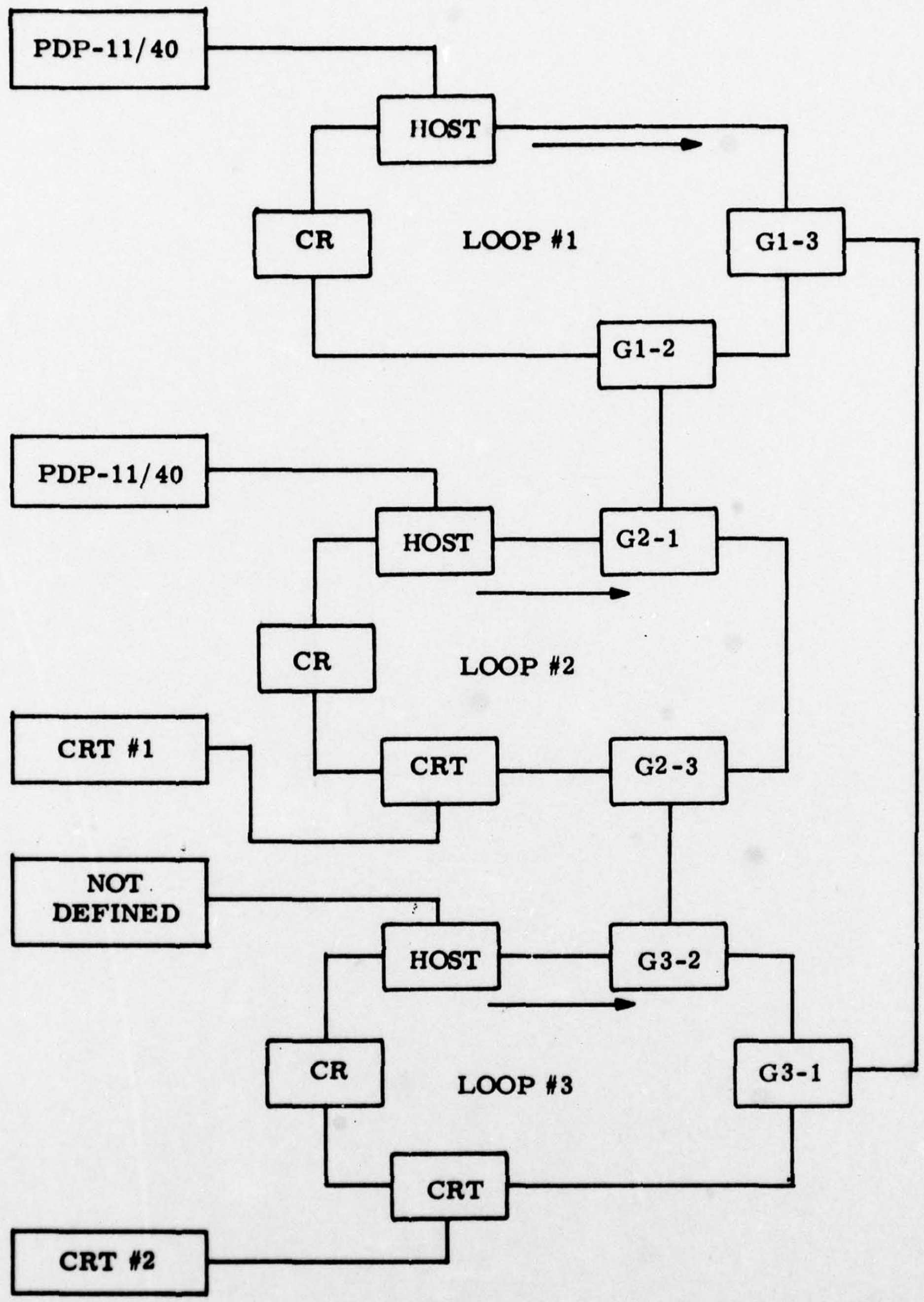


Figure B-5. Function Configuration

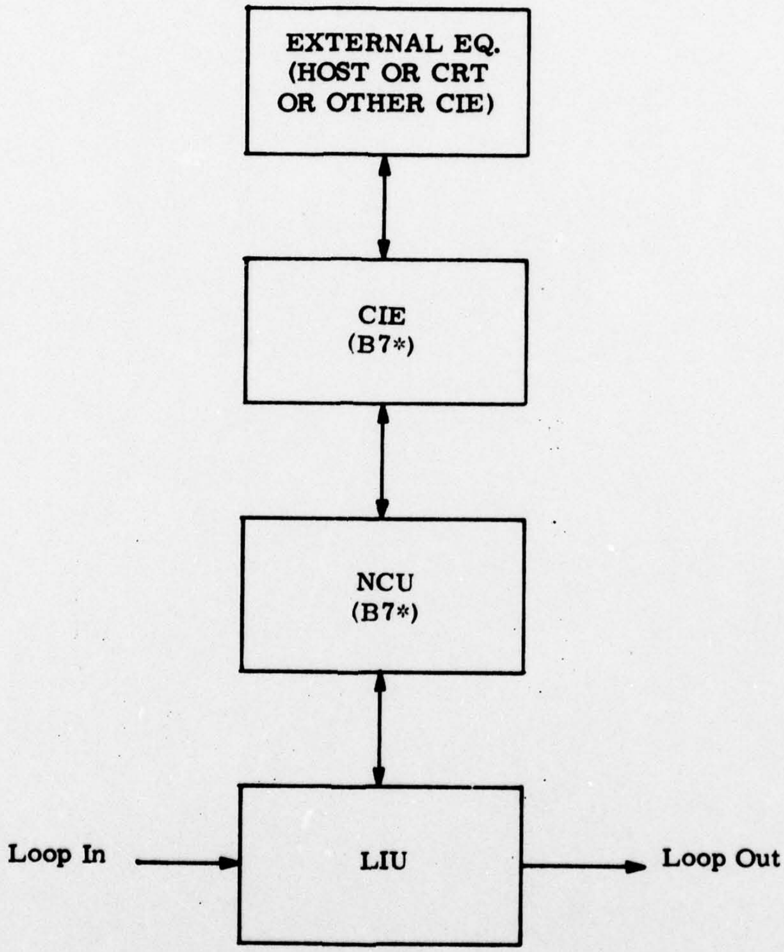


Figure B-6. Generalized Node Configuration

The Data Stream

The data stream is a bit-serial set of frames. Each frame is 20T in duration and contains 20 time slots, each of which is T in duration. Each 20T frame is divided into two fields, an address field followed by an information field, each 10T in duration. T is selectable in one of three values as determined by the card mounted switches. Values of T available are 1.04 us, 3.57 us and 83.3 us. These correspond to loop rates (including overhead bits) of 960 KBps, 280 KBps and 12KBps, respectively. Actual information rates are somewhat lower as indicated later.

The first two time slots of each field provide synchronization and identify the type of field; the last eight provide a byte of information called the address word and the information word, respectively.

Typical address and information fields are shown in Figure B-7. A transition occurs at each T start to provide clocks except at the synchronization points (shown as a dot at the 1T point in Figure and at the 11 T point in Figure B-7b). A mark (high level) after the dot means Address (A in Figure B-7a); a space (low level) after the dot means Information (I in Figure B-7b). In the address and information words that follow A and I, transitions always occur each T. A mark after each transition, in the second half of each time period T, means One; a space means Zero. The maximum frame rate, therefore, is 50,000 per second based on a T of 1 us. The node can write only once in two frames because of a delay caused by address and data insertion. Therefore, the effective loop capacity is 25,000 characters per second for a T of 1 us. For the actual T's provided by the ESM, the following are the effective loop capacities:

T	Loop Capacity	Loop Rate	Information Rate
1.04 us	24,000 ch/s	960 KBps	192 KBps
3.57 us	7,000 ch/s	280 KBps	56 KBps
83.3 us	300 ch/s	12 KBps	2400 Bps

A node has three modes of operation, namely; repeat, read and write. The repeat mode involves no NCU control. In this mode the node supplies a 10T delay and reforms the pulses so that the node acts as a delay repeater.

When the NCU desires to read, it sets an 8-bit address in the LIU address register and places the LIU in Read mode. The NCU then inhibits its own clock and thereby shuts off.

The LIU senses address fields in the data stream. When an address word does not match the node address, the node acts as a delay repeater. When an address word matches the node address the LIU sets the address word to zero and removes the clock inhibit of the NCU so that the NCU starts at the proper time for the data word to be read into its external input register.

When the NCU desires to write, it sets the 8-bit address register of the LIU and places the LIU in the Write mode. The NCU then inhibits its own clock and shuts itself off.

The LIU removes the clock inhibit of the NCU so that the NCU starts at the proper time to output its address into the address frame of the data stream of the loop and to output the content of an output register into the information frame of the data stream of the loop. When the Write is complete a new address may be placed in the address register of the LIU. The NCU then enters the Read mode.

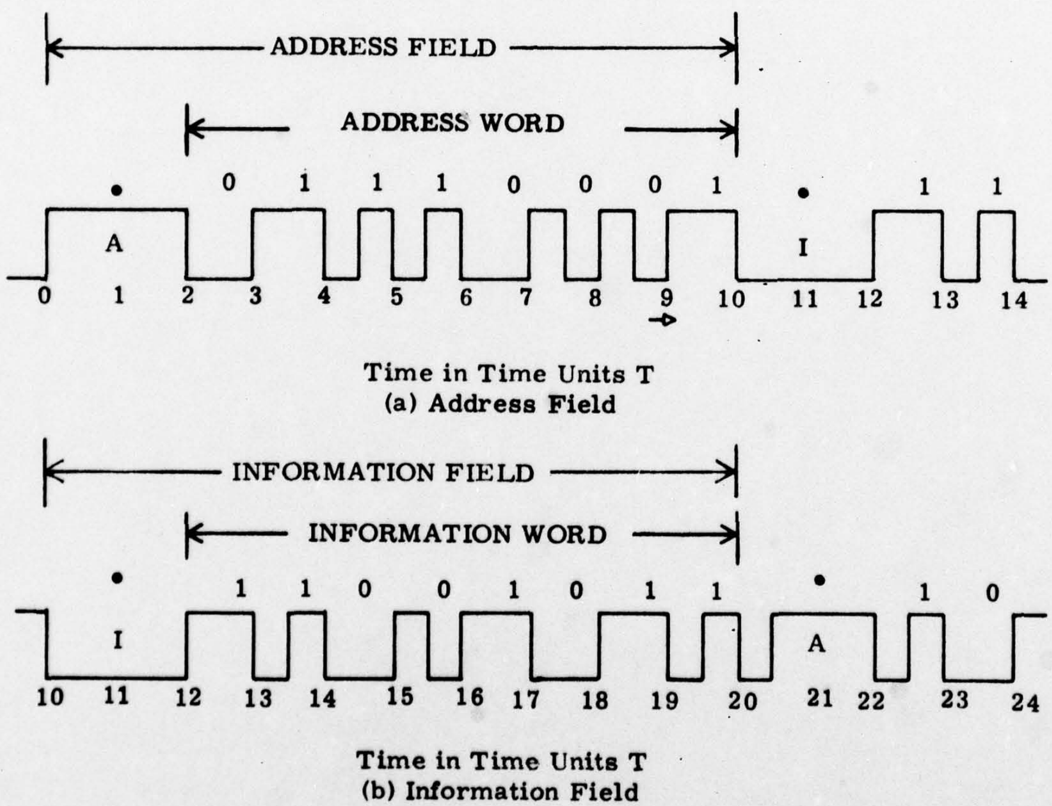


Figure B-7. Address and Information Field Formats

The CIE processor controls the NCU by instructing it to go into a Read or a Write mode and thus controls data transfer between itself and the NCU.

Packet Description

A packet is a sequence of alternating address and information fields consisting of, at most, 256 frames. A message consists of an ordered set of packets.

The ESM loop protocol is implemented by protocol type information words which are written into the beginning and end information words (i.e., header and trailer) of a packet. These protocol type information words, which will be referred to as "protocol characters", are actually data patterns which make up the address fields that precede every information field. The existing protocol characters and their location within a packet are given in Table B-2.

Table B-2. ESM Protocol Characters

D1	Packet Sequence Number
D2	Message Sequence Number
D3	Control Character
D4	Broadcast Character
D5	Destination Logical ID
D6	Source Logical ID
D7 ⋮ DN-2	Packet Information which is ignored by node and is destined for host or another CIE
DN-1	End-of-Packet Character (EOP)
DN	Longitudinal Parity Check (LPC).

In Table B-2, N is the overall packet length equal to, at most, 256 characters. Characters D1 - D6, DN-1 and DN are the protocol characters and D7 to DN-2 are the packet information characters. The packet information characters may use any desired code such as ASCII, EBCDIC, etc.

D5 can handle 256 unique logical ID's. Several of these, however, are reserved. The value 255 is reserved for the "write token" or free packet which will be described later. A few will be reserved for special control purposes such as Broadcast. The value zero should not be used because it represents the null value. The same remarks apply to D6. D3 is for control purposes as shown in Figure B-8.

D4 is used only for Broadcast messages wherein a proper Broadcast D5 is used and D3 has the value 1 in the seventh bit positon. During Broadcast, D4 is marked by certain nodes to ensure that each node receives the message once and only once. Broadcast mode will be explained in detail later.

D1 assures the assembly of packets into a message through the use of consecutive packet numbers within a message. Similarly, D2 provides a message sequence number to allow for separation of messages from a given logical ID.

The control word D3 provides for the implementation of control packets corresponding to functions defined in Figure 2.1-8. Since they may consist of only a small number of control-oriented characters, these control packets represent only a small overhead in loop traffic. For example, a NAD or ACK type control packet consists of only eight characters:

	D1 - Packet sequence number
	D2 - Message sequence number
ACK or	D3 - Control ACK or NAK
NAK	D4 - Broadcast = 0
Packet	D5 - Dest. logical ID
	D6 - Source logical ID
	D7 - EOP
	D8 - LPC

Another very short control packet is the write token (WT) that consists of only two characters:

WT	D1 - EOP
	D2 - LPC

A valid WT LPC will equal the address word to detect the occurrence of erroneous WT's generated by noise on the loop.

The write token is used to achieve a rapid type of implicit polling which will be described below. DN-1 is the end-of-packet word which is equal to eight consecutive "ones". This bit pattern was chosen because it is a unique word that does not exist as a transmitted character in any of the usual transmission codes and because it is an existing B7* condition test (i.e., the all bits true test, ABT) which is used to implement variable length packet sizes for ESM. The final informaton word is used for a longitudinal parity check which is used to determine whether an ACK or NAK type response should be sent to the packet originator.

Address Directed Protocol

An address directed protocol was found to provide an attractive foundation for implementing ESM in a rapid, efficient, and reliable manner. Each node on a loop will have a register set to a unique read or functional address within the loop; each node will have

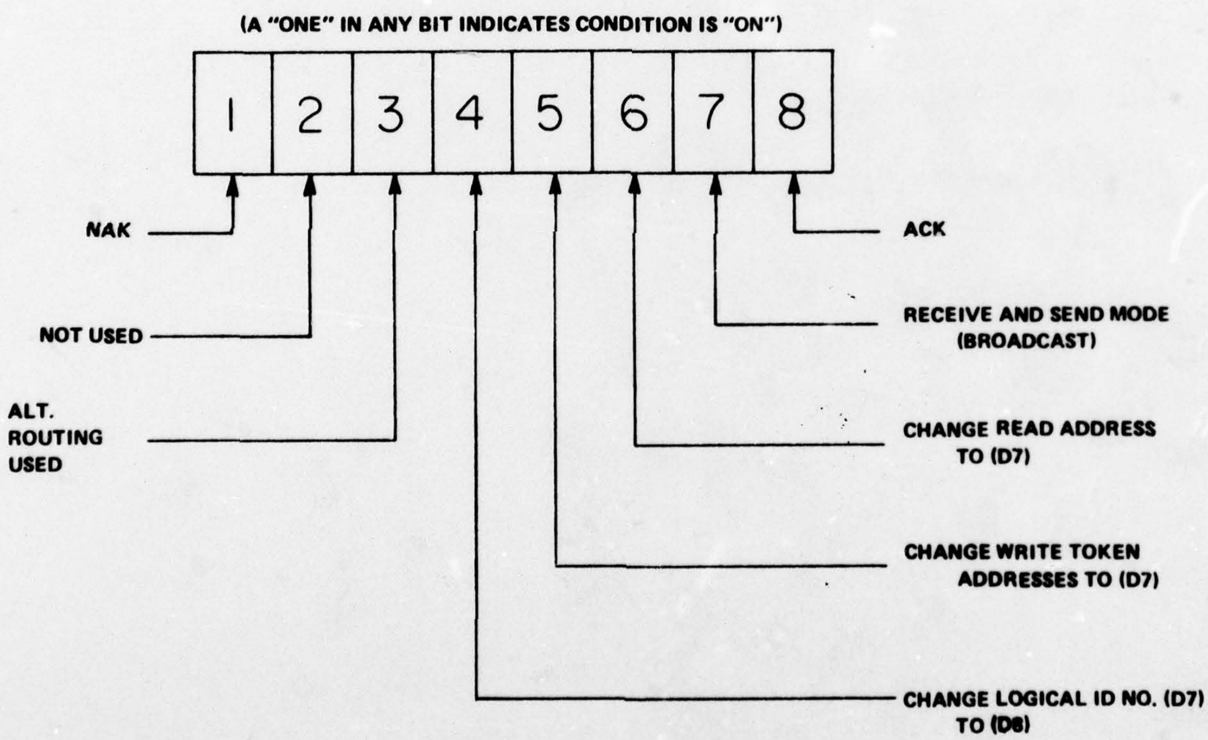


Figure B-8. Control Word Bit Identification the ability to sense address fields, ignoring those fields that are not equal to its read address, and reading into its memory the information word following an address field that is equal to its read address. A node will have permission to write a packet onto the loop only when it has received the write token (WT) which has a logical ID equal to 255, i.e., an all ONEs bit pattern. The WT will be sent from node to node around the loop. That is, a node reads the WT addressed to it, writes a packet if it has anything to write, and then sends the WT on to the next node in the loop. The orbiting WT defines an implicit polling scheme which allows a group of M nodes on a loop to write information directly to a destination without interfering with each other. This implicit polling scheme is much faster than an explicit polling scheme in which handshaking messages are passed back and forth causing a large overhead setup time. If worst-case conditions are assumed (in which everyone on the loop desires to send a packet at once) the time it takes for a write token to travel completely around the loop or the maximum time a node must wait before another packet can be written is given by:

$$T_{WT} = \frac{MP}{C_L} \qquad (1)$$

where M is the number of nodes on the loop, P is the maximum packet size given in characters, and C_L is the loop capacity given in characters/sec. Considering that the average WT cycle time will be less than the maximum obtained, assuming worst case conditions, the WT cycle time will be between the limits,

$$\frac{MK}{C_L} \leq T_{WT} \leq \frac{MP}{C_L} \qquad (2)$$

where K is the number of characters comprising a WT adjusted to reflect any processing time that the node takes to recognize that it has received a WT.

For the case of ESM, if we assume that M = 4, P = 256 characters, and C_L = 24,000 characters/second, then under worst-case conditions, the WT cycle time will equal approximately 43 milliseconds.

Since the worst-case WT orbit time for a loop is known, nodal software may provide for the creation of a new WT if one is not received within MP/C_L seconds. Furthermore, each node that has the WT has the ability to destructively write onto any address and information field thus erasing any invalid characters that may circulate the loop due to bit inversions or packets sent to down nodes. Thus, the protocol guarantees that the loop can never become clogged due to unreceived packets or a lost WT.

The address directed protocol provides near instantaneous communication between two nodes on a loop. Since intermediate nodes ignore packets that do not have address fields corresponding to their read addresses, a direct line connection is made between a node possessing the WT and its destination node on the same loop.

The nodes also provide for a delay when a packet is destined to the same node as the WT. ACK and NAK type packets are sent before a regular packet transmission.

Method of Addressing

The address directed protocol is implemented in the nodes by means of a simple table look-up. The table is stored in a 256-word page in each nodal data memory, and it maps logical ID's to nodal functional addresses. For each data memory location on the conversion page corresponding to a particular logical ID, there is an 8-bit representation of the functional address of the node associated with that logical ID. A node wishing to send a message to logical ID of value X sends each informaton word of the message preceded by an address word having the value contaned in location X of the node's conversion table page. Rapid reconfiguration of the network is possible using this scheme merely by modifying this page in each node's memory.

An example of this method of addressing is illustrated in Figure B-9. The read addresses of the nodes are given for each node. Note that gateway node read addresses equal the loop number of the loop to which they interface. Suppose that host B wishes to send a packet to logical ID 138 which resides on host C. Host B uses its own logical ID 17 as the source logical ID which will be used as the destination logical ID for the return ACK or NAK type packet.

Host B supplies the information words to the CIE which determines the functional write address for logical ID 138, and it sends a packet onto the loop having the form of packet A when it receives a WT. Gateway Node 2 on Loop 1 reads the packet destined to it and sends the information words across the interface to Loop 2. Gateway Node 1 of Loop 2 then looks in its conversion table and sends packet B onto the loop. Node 12 of Loop 2 reads the packet and determines whether the LPC character checks or not. If we assume the LPC does check, the CIE delivers information words to Host C and sends an ACK type packet having the form of packet C to logical ID 17. The packet is read by Gateway Node 1 of Loop 2 which transfers the information words to Gateway Node 2 of Loop 1. Finally packet D is sent on Loop 1 which is read by Node 11 which pairs the ACK to a packet on its outstanding packet list. Note that if the connection between Loop 1 and Loop 2 was inoperable, alternate routing could be used if the CIE connected to Host B sent its packet to Gateway Node 3 of Loop 1 and set D3 = 32 to indicate alternate routing. The packet would thus reach Loop 2 via the Gateway nodes of Loop 3. An originating node can determine whether or not a packet ever reached its destination by waiting for an ACK or NAK within a certain predetermined amount of time. If a NAK is received or there is no response, the originating node may try again to send the packet, possibly by an alternate route. Alternate routing is implemented merely by changing the address words to the functional address of the other gateway node on the loop.

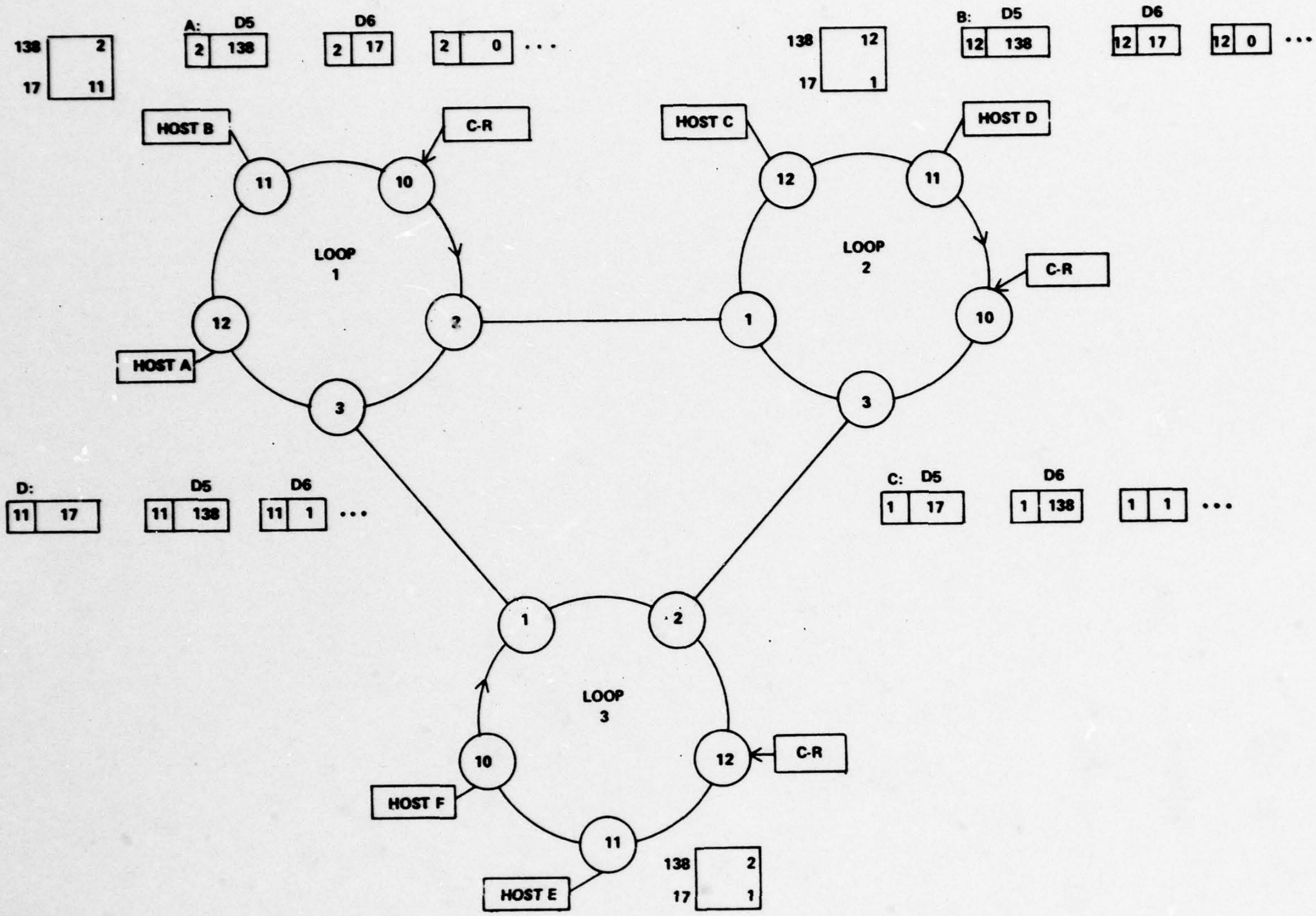


Figure B-9. Method of Addressing

The address directed protocol possesses attractive features which provide a simple implementation of certain kinds of control messages. For example, various types of broadcast messages may be implemented by assigning a special broadcast logical ID and modifying the control information word (D3) so that the message is placed in the receive and send mode (c.f. Figure B-8). A node which receives a message that is in the receive and send mode will retransmit the message to the functional address that is specified in its logical ID to functional address conversion page in the location given by the special logical ID located in information word D5 (c.f. Table B-1). Different types of broadcasts may be implemented using this scheme, e.g., network broadcasts, local loop broadcasts, selected host only broadcasts, etc. In a broadcast type packet, information word D4 is used to guarantee that nodes do not receive a message twice and that broadcasts are correctly quenched. The originator of a broadcast will write its functional address in D4 and then quench the broadcast when the packet travels completely around its loop at which time the originator node will recognize its functional address in D4 and not resend the packet. Whenever broadcasts travel from loop to loop via a gateway node, the left-most bit of D4 will be set by that gateway node to indicate to other gateway nodes on the receiving loop not to send the packet across the interface so that nodes do not receive a packet more than once. A gateway node that acts as the originator of a broadcast for its loop will place its functional address in D4 as well as setting the left-most bit and will then quench the broadcast for its loop when a complete circuit of the loop has occurred.

A broadcast type packet may also be used in conjunction with a special node interpreted control message (e.g., modification of logical ID to functional address page, c.f. Figure B-8) to implement rapid network reconfigurations or for creating, destroying and moving logical ID's.

B.8.2.4 Nodal Hardware

The nodal hardware illustrated in Figure B-10 is configured around two Burroughs B7* microprocessors and hence, can be described in terms of two processor-centered segments. The first segment consists of the Nodal Control Unit (NCU) microprocessor and its associated control memory, data memory, ancillary logic and loop interface logic. The primary purpose of this segment is to insert packets into the loop and to remove packets (containing an appropriate address) from the loop. Hence, it provides only for control and buffering relative to the communications loop.

The second segment consists of the CIE (Control and Interface Equipment) microprocessor and its associated control memory, data memory, ancillary logic, and external interface logic. This segment provides for overall node control, packet and message handling, traffic control and external device interfacing.

In additon to the nodal hardware of Figure B-10 a Clock Generator, a Clock-Retimer and Loading Logic are required for each loop. The specific functions and characteristics of these units and of the individual elements of the NCU and CIE segments are described in detail in the following paragraphs.

NCU Segment

The Loop Interface element contains the necessary cable drivers and receivers for direct loop interface. It includes the circuitry for deriving clock from the data stream and for maintaining frame synchronization relative to the data stream. It contains an address register, loaded by the B7*, and associated comparison circuitry to permit recognition of a specific address in an address field on the loop. Upon address recognition, the information word is streamed directly into the NCU data memory, while being monitored by the B7* for an end-of-packet (EOP) character.

The Loop Interface logic operates from one of three selectable clock rates: (1) 960 kHz, (2) 280 kHz, and (3) 12 kHz. The logic is contained on a single printed circuit board (PCB).

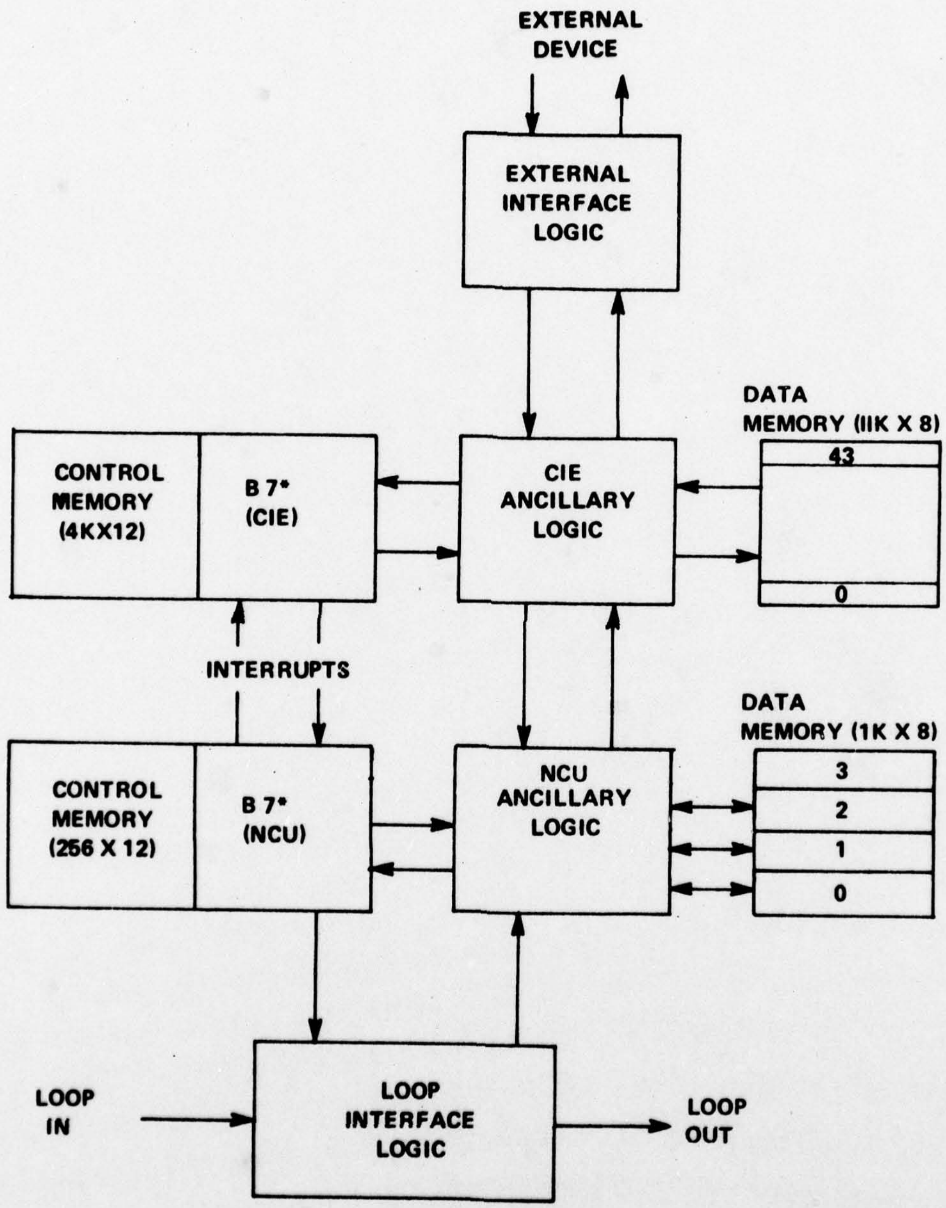


Figure B-10. Node Configuration

The NCU Microprocessor provides for control of the Loop Interface logic and the NCU Data Memory. That is, it establishes the Read or Write mode of operation (relative to the loop), sets the Loop Interface address register for a Read operation or initiates output for a Write operation, controls addressing of the Data Memory input and output locations and monitors the input/output stream for the EOP character. It interrupts the CIE microprocessor upon completion of the write/read cycle and responds to an interrupt from the CIE microprocessor to begin its next write/read cycle.

The NCU Microprocessor operates from the clock derived by the Loop Interface logic; hence, it operates in synchronism with the loop bit stream. Processor operation is bit-serial with 10 clocks (10.4 usec) per instruction or per input/output byte (8 bits). The NCU microprocessor has 8-bit data registers, a 12-bit instruction register, and employs 8-bit memory addressing thereby permitting up to 256 words of control memory. This memory has 12-bit words and is provided in PROM form. The NCU microprocessor together with its control memory is contained on two PCB's.

The NCU Data Memory functions as I/O buffering relative to the loop and, in additon, provides a mailbox page for communication with the CIE microprocessor and for storing other loop control information. This RAM consists of 4 pages, each accommodating 256 8-bit words. It employs n-MOS semiconductor technology with a 350-nanosecond read or write cycle. It occupies one PCB.

The NCU Ancillary Logic provides for memory addressing and read/write control of the NCU Data Memory. That is, it provides NCU data memory access and control by both the NCU microprocessor and (when used with the CIE Ancillary Logic) the CIE microprocessor. It provides for serial/parallel data conversion to permit data transfer among the B7* (serial), Data Memory (parallel) and the communications loop (serial). It permits the routing of data to/from the microprocessor and several destinations (e.g., Data Memory or Loop Interface Logic). Finally, it permits direct memory-to-memory transfers between NCU and CIE Data Memories without processor handling, but under processor initiation. The NCU Ancillary Logic is contained on one PCB.

CIE Segment

The CIE Microprocessor provides for control of the entire node. It communicates with the NCU Microprocessor via interrupts and via the mailbox page of the NCU data memory. In this manner, it initiates NCU microprocessor operations relating to loop interfacing and it accesses NCU data memory I/O pages to transfer data between those pages and the I/O queues of its own data memory. As mentioned earlier, these inter-memory transfers are accomplished directly (memory-to-memory) in a parallel transfer mode. The CIE B7* determines message type (e.g., single address, multi-address, acknowledgement, etc.), does parity checking, generates ACK/NAK messages, determines alternate routing, controls I/O queues, does message assembly, loads/unloads buffers of the External Interface Logic, and maintains status of these buffers.

The CIE Microprocessor is very similar to the NCU microprocessor except that it operates from a 8.96 MHz clock with 9 clocks per instruction and employs 12-bit memory addressing, thereby permitting up to 4K words of control memory. This memory has 12-bit words and is in the form of external RAM on two PCB's. The CIE microprocessor (like the B7* NCU) is contained on two PCB's.

The CIE Data Memory primarily provides storage for assembling and queueing messages (in the form of packets) to/from the communications loop as well as to/from the external device. It also provides for storing user address and routing information, and includes work page capability. This RAM consists of 44 pages each accommodating 256 eight-bit words (i.e., a total of 11K words). It employs n-MOS semiconductor technology with a 350-nanosecond read or write cycle. It is contained on three PCB's.

The CIE Ancillary Logic provides for memory addressing and read/write control of the CIE Data Memory; together with the NCU Ancillary Logic it provides for access and control of the NCU Data Memory by the CIE Microprocessor. It also provides serial/parallel data conversion to permit data transfer among the CIE B7* (serial), Data Memory (parallel) and the External Interface Logic (parallel). It permits the routing of data to/from the microprocessor and several destinations (e.g., data memory, memory address register, interface logic, etc.). Finally, it permits direct memory-to-memory transfers between CIE and NCU data memories without processor handling, but under processor initiation. The CIE Ancillary Logic is contained on one PCB.

The External Interface Logic permits interface with an external host computer, an external CRT terminal, or another communications loop. It provides the necessary I/O buffers and controls to allow data transfer to/from the I/O queues of the CIE Data Memory and the external device (host computer, CRT terminal or communications loop). Data is transferred between data memory and the I/O buffers in the direct parallel transfer mode without processor handling, but upon processors initiation. Buffer status registers are set by the buffers and are read by the processor. Flags are set by the buffer and by the external device to control external data transfers in serial form. Necessary line drivers are included in the External Interface Logic.

This logic is contained on one PCB for each type of external device.

Clock Generator

The clock generator develops the various clock signals required for the proper operation of the loop and its interconnected nodes. It consists of two separate crystal oscillators and the associated divider and driver logic to derive and output the necessary clock signals. The primary clock signals developed and their uses are:

Clock Signal	Function
8.96 MHz	CIE clock
1.92 MHz 560 KHz 24 KHz	NCU and Loop clock (one rate per loop, selected by card-mounted switches, and divided by two by CR)
560 KHz	Host Interface clock and Gateway Interface Clock
96 KHz 9600 HZ	CRT Interface clock
96 KHz 2.8 KHz 1.2 KHz	Real time clock for CIE (one rate per loop selected by card-mounted switches).

Other logic clocks are also generated and distributed to the PCB's of each node.

Clock-Retimer

A clock-retimer is provided for each communications loop. It accepts the loop clock signal from the clock generator and establishes the previously described loop frame format. It also accepts the data signal from the loop and provides data regeneration and data resynchronization, thereby compensating for effects relative to signal degradation and propagation time. This logic is contained on one PCB.

Loading Logic

The Loader Board and the Loader ancillary board together provide the capability to load the CIE control memories of each of the ESM nodes. These boards accept serial data (and associated clock) from the Host PDP-11/40 that is connected to ESM Loop #2. This data, at 560 KBps, is routed to the appropriate control memory as a result of proper setting of the panel-mounted switches (on each cabinet) that are used for loading.

B.8.2.5 Nodal Software

Data Flow

This section summarizes the nodal software required to implement the address-directed protocol for the ESM. A node consists of two Burroughs B7* Microprocessors operating in parallel. One of the microprocessors, the Nodal Control Unit (NCU), is used to read and write information onto the loop via a line interface unit (LIU). The second processor, the Control and Interface Equipment (CIE), is responsible for intelligent control of the node, and acts as an interface for external equipment which may be a host computer, a CRT terminal or another CIE. The NCU has an associated 256 twelve-bit word control memory, and the CIE has an associated 4K words of control memory. The CIE has access to a data memory consisting of 12K words (bytes or characters of eight bits). The NCU has access to 1K of this same data memory.

The B7* machines are programmed in microcode (i.e., MDMPL). The CIE microprocessor is able to handle data from both the NCU and host computer or CRT or gateway. The NCU may interrupt the CIE and vice-versa via the B7*'s External (EXT) control line which may be tested by an IF EXT type condition test instruction. The type and source of data is communicated to the CIE by means of external registers to which the originating processor has access. The nodal software was developed using a top-down modular approach that conforms to structured programming techniques.

The system data flow is illustrated in Figure B-11. The NCU interrupts the CIE after it has read a packet. The host computer (or another Gateway CIE) informs the CIE when it has a message to send. The CIE interrupts the NCU and instructs it either to go into the Read state to read a packet addressed to it, or to go into the Write state to write a broadcast type packet onto the loop or to write a singly addressed output packet onto the loop. The CIE interrupts the host whenever it receives a message destined for the host.

The interrupts labeled "read" or "write" between the NCU and CIE are shown with numerals "0", "1", or "2". These numerals refer to page addresses in data memory that are shared by the NCU and CIE. The functions assigned to these pages are explained below.

NCU - CIE Shared Memory

The total nodal data memory consists of 12K 8-bit words divided into 48 pages of 256 words each. The first four pages are addressable by both the NCU and the CIE, but disjointly in time. When the NCU operates as a nodal controller, the shared memory is the NCU memory; when the NCU is waiting for an EXT interrupt, the CIE may control the shared memory.

These four pages are shown in Figure B-12 and are labelled as pages 0, 1, 2 and 3. Page 0 is used as an input buffer for packets received by the node. Page 2 is the output buffer for packets to be sent by the node. Page 1 is the mailbox. Page 3 is not currently used. Page 0 may also be used as a read-write buffer for packets that are received by the node in a receive/send mode of operation such as that used for broadcast type packets.

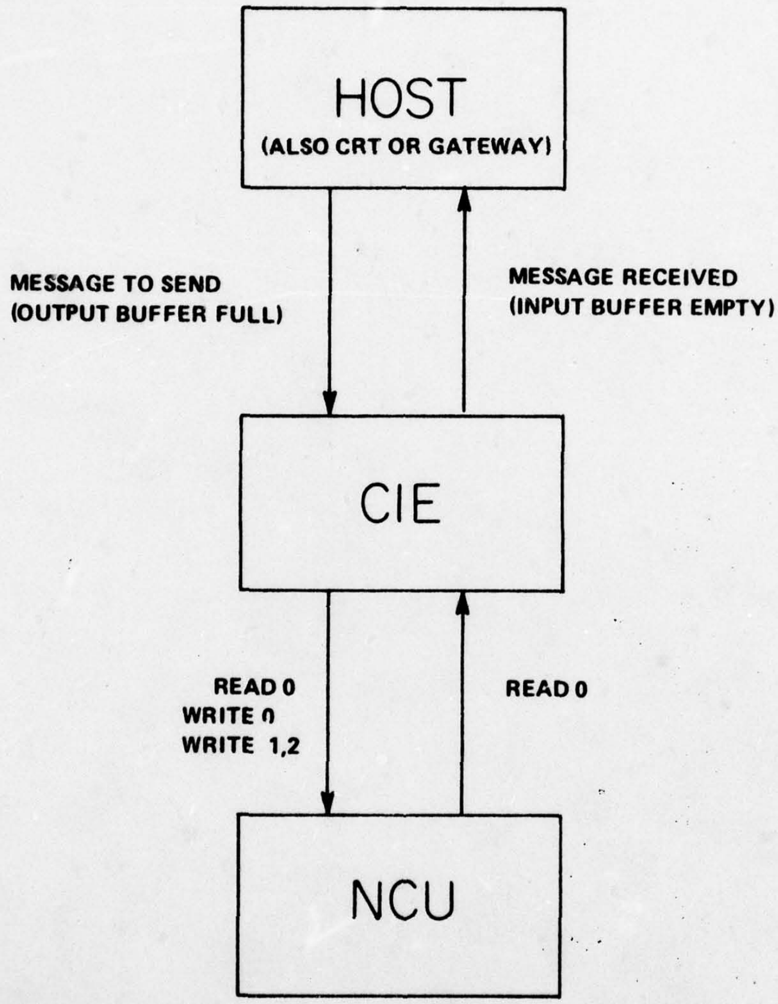


Figure B-11. System Data Flow

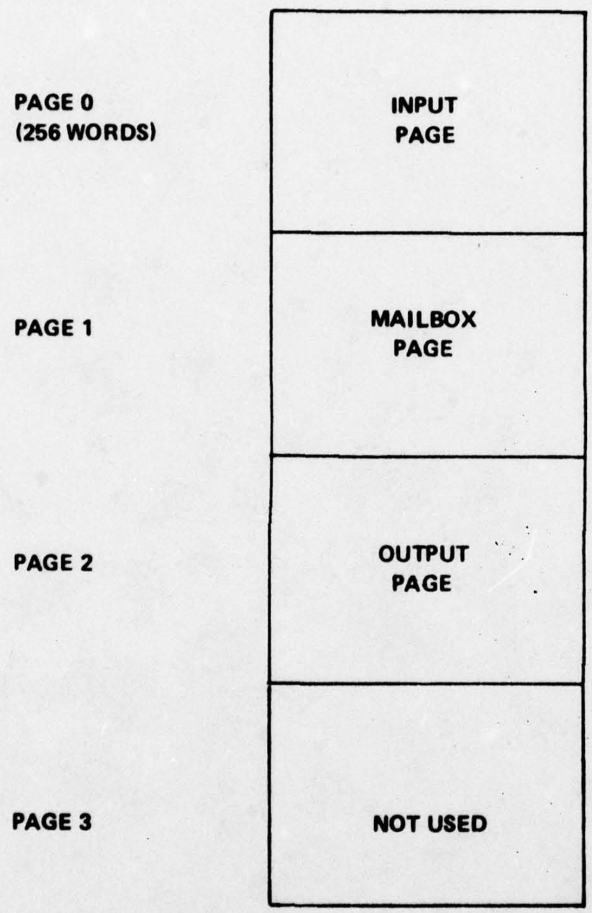


Figure B-12. Common NCU-CIE Access Pages in Data Memory

Page 1 (the mailbox) has multiple uses. It stores interrupt information to be used by the NCU, it stores parameters such as the node's read address, and ACK-NAK messages which are to be written to the loop upon receipt of the write token (WT). Figure B-13 shows the content of the mailbox.

When a WT is received, the ACK-NAK packets are sent followed by the content of the output page. The WT is then sent to the next hardware address which is obtained from page 1.

The remaining 44 pages of data memory are accessed only by the CIE. Page 0 of the CIE memory is a workpage which is used to store commonly used variables, queue status indicators, and scratch-pad areas for storing temporary variables. Page 1 is used as the logical-ID to functional address page which is illustrated in Figure B-14. This page is used to translate rapidly a logical ID to a write or functional address. The write address is then used by the NCU to set its address register to generate the proper address words. The other pages in data memory are used for storing packets in the input to host queue and the output to loop queue. The maximum size of these queues will be determined by variables stored on the work page. The queues are described by four variables; two of which are used as pointers to the page at which the packet on the top of queue is located and the first free page, and the other two will be used to count the total number of packets currently in the queue and the maximum number in order to indicate queue overflow. There is space in the node to store a maximum of 41 packets. Page 2 of the CIE memory is used to build ACK/NAK packets which are moved to the mailbox page when the WT is received.

NCU Software Module Transitions

The operation of the NCU may be described by the three-state diagram shown in Figure B-15. The NCU is always in one of three states; namely: Read, Wait or Write. The state transitions and their causes follow:

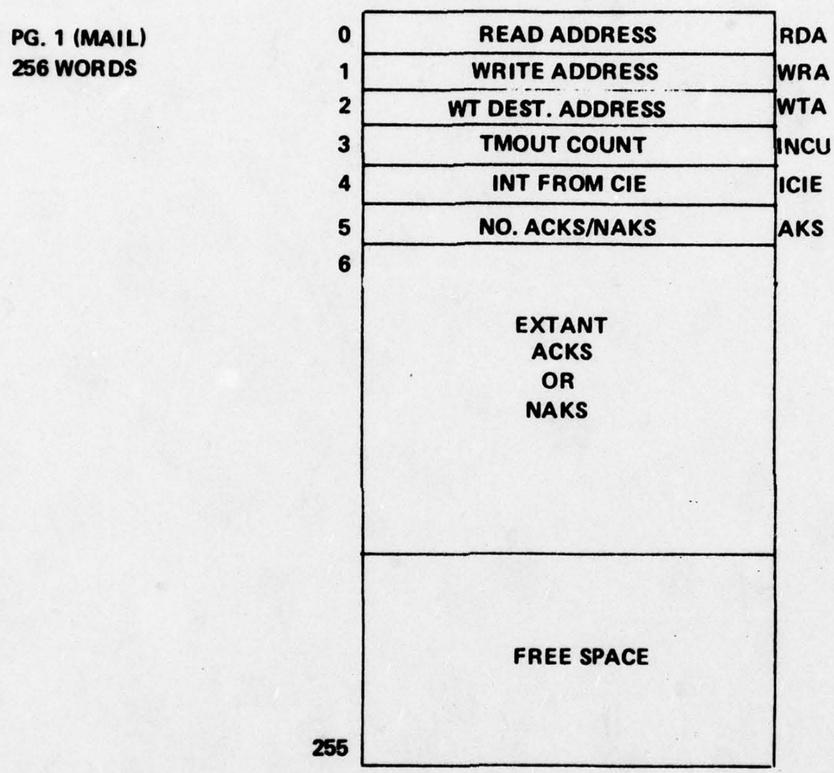
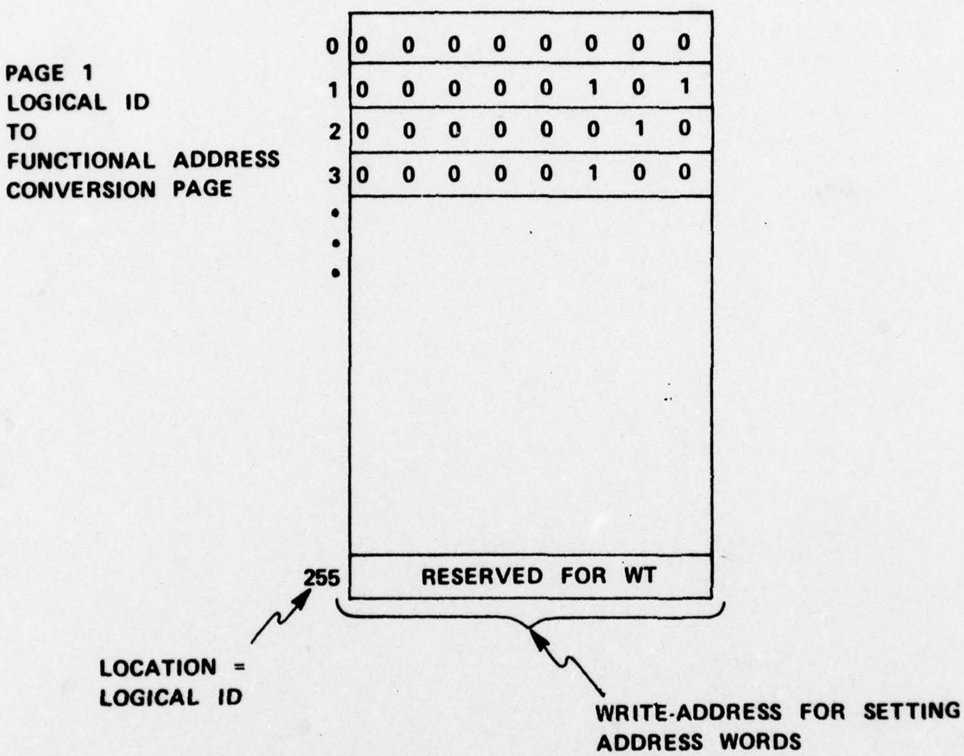


Figure B-13. Mailbox Page Description



IF TABLE ENTRY = 0 THEN FREE LOGICAL-ID
(I.E., NOT USED IN SYSTEM)
IF TABLE ENTRY = THAT NODE'S FUNCTIONAL ADDRESS THEN LOGICAL-ID
IS PRESENT AT THAT NODE.
FOR RECEIVE/SEND MODE, TABLE ENTRY IS FUNCTIONAL ADDRESS OF
NEXT DESTINATION NODE.

Figure B-14. Logical-ID to Functional-Address Conversion Page

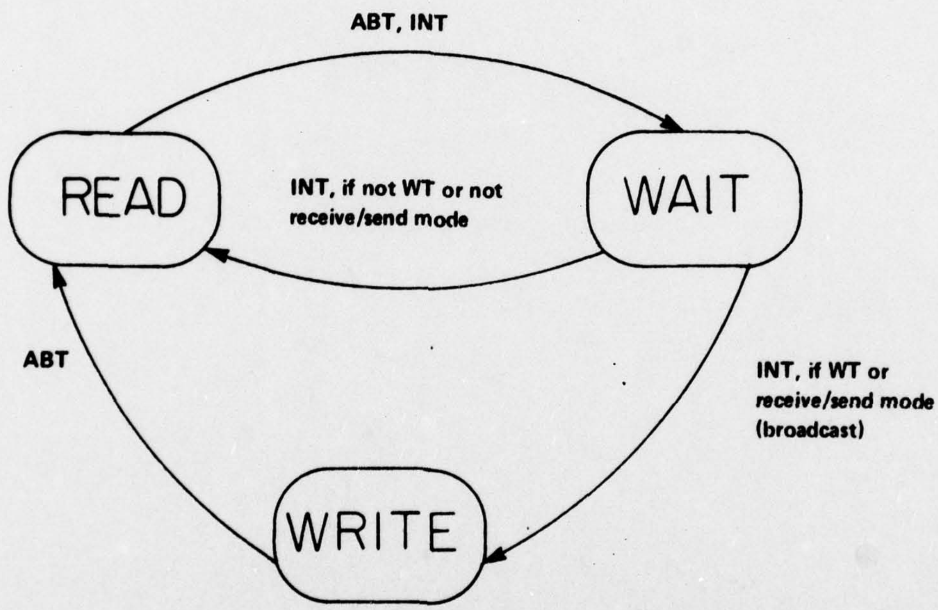


Figure B-15. NCU State Diagram and Software Modules

1. Read-to-wait. This state transition occurs when a packet has been read into the input page of the NCU as indicated by the end-of-packet word (EOP). The NCU informs the CIE of this condition setting the EXT of the CIE. The NCU then suspends operation by waiting for its EXT to be set. The read-to-wait transition is unconditonal.

2. Wait-to-read. The CIE determines the type of packet in the input page. If the packet is neither a WT nor a receive/send type, the CIE sets the mailbox for read and sets the EXT of the NCU. The NCU then comes out of the Wait state and goes into its Read mode.

3. Wait-to-write. The CIE determines the type of packet in the input page. If the packet is a WT or a receive/send type, the CIE sets the mailbox for the type of write and sets the EXT of the NCU. The NCU then comes out of the Wait state and goes into the Write state.

4. Write-to-read. This transition occurs unconditionally after write is complete.

NCU Software Modules

The software modules of the NCU are written to correspond to the three states; a functional description follows:

1. Read. The LIU address register is set to the read address given in the mailbox page (Figure B-13). When the nodal logic senses an address word that is equal to the read address, the information word that follows is read into the input page and the B-register of the NCU. The data words are read into sequential locations of the input page until

the EOP (all ONEs) is sensed in the B-register by an IF ABT command in the read loop of the NCU program. The information word following the EOP is also read. This is the longitudinal parity check (LPC) word. Exit to the read-to-wait routine is then performed wherein the EXT of the CIE is set and the Wait state is entered by a looping IF EXT instruction.

2. Wait. This module allows the CIE and NCU to access the same data pages. The NCU dwells in this state until its EXT is set. When an interrupt does occur, the NCU examines the mailbox page to determine what type of interrupt has occurred. The possible interrupts are Read, Write 0, or Write 1,2.

3. Write. If a Write 0 interrupt from the CIE has occurred, the NCU writes the data words of page 0 with the proper address field indicated on its mailbox page until an EOP character is found. For a Write 1,2 interrupt, the NCU first writes any ACK type packets that may reside on page 1 and then writes the output packet residing on page 2, if any, followed by a write token sent to the next node on the loop.

CIE Software Modules

The CIE software that implements address-directed protocols is definable as a set of nine modules sequenced as shown in Figure B-16. Modules on the left have higher selection priority than those on the right. This provides the quickest NCU wait-to-read transitions which must be performed rapidly to ensure that no message destined for a node is missed owing to late transition to the Read state. A short functional description for each module follows.

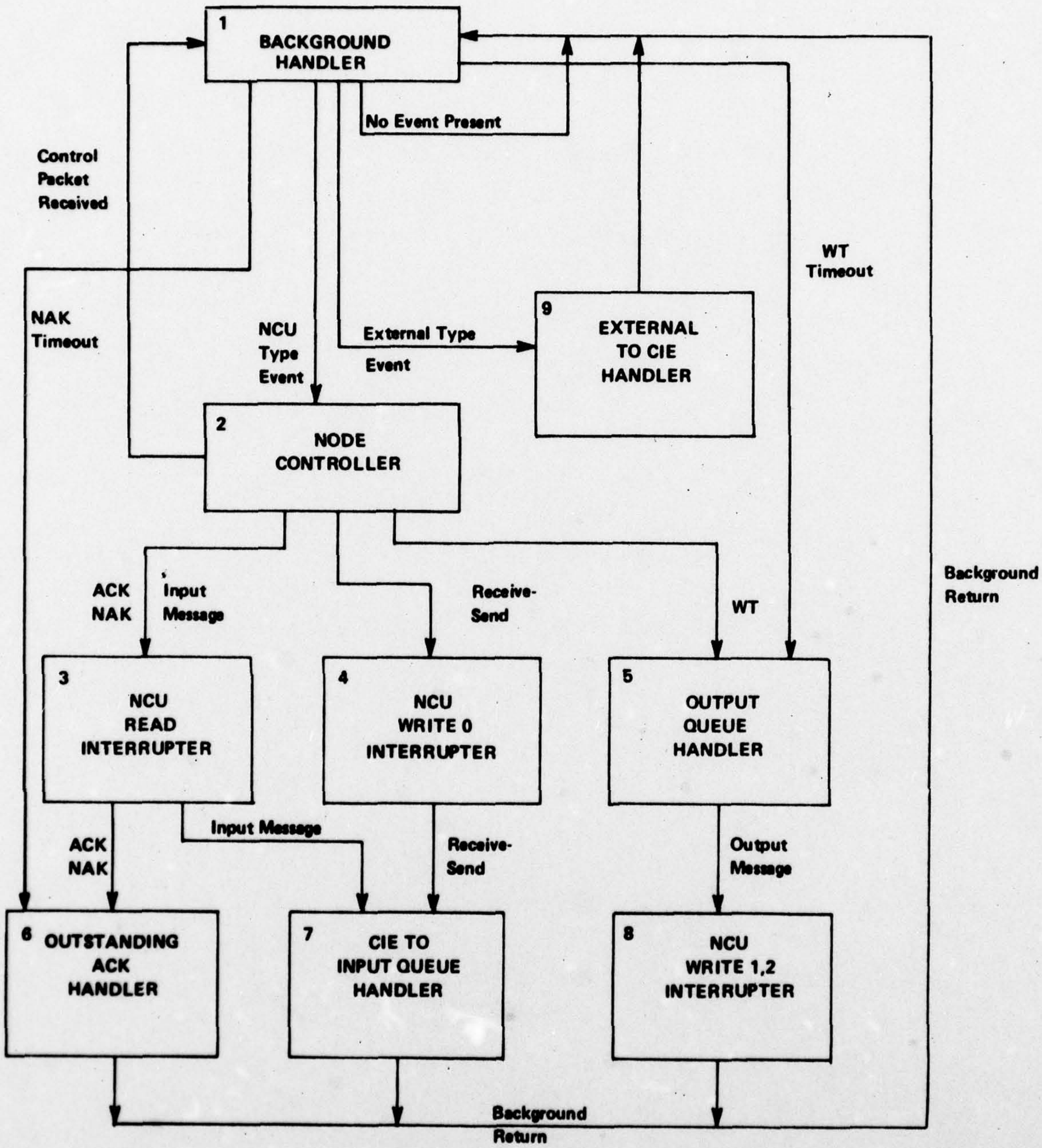


Figure B-16. CIE Software Modules

1. Background Module. The CIE scans the events that are to be processed. If none is present, the CIE looks for an empty external input buffer (for transfer of data to external equipment - such as host or user terminal, or in the case of gateway nodes another CIE). It loads the external buffer form input queue if a packet is present. It looks for an EXT interrupt from the interface buffer. It also handles the generation of new WT's and checks packets in the output queue for retransmission timeout.

2. Node Controller. An NCU event occurs only upon completion of an NCU read-to-wait transition. The NODE CONTROLLER moves the packet on page 0 to an empty page in CIE memory. The header is then examined. For ACK, NAK or input messages the NCU READ INTERRUPTER is started immediately with one exception; namely: the message is a nodal control message. In that case, one of the following is performed first.

   - Write mailbox to change hardware address;
   - Change logical-ID/functional address table;
   - Write mailbox to change WT address.

   If the input packet is of the receive/send type then the NCU WRITE 0 INTERRUPTER is started. If the input packet is a WT then the output queue handler is started.

3. NCU Read Interrupter. The read mailbox is set and the EXT of the NCU is set to cause a wait-to-read transition. For ACK/NAK inputs, the OUTSTANDING ACK HANDLER is called; otherwise the CIE TO INPUT QUEUE HANDLER is called. If the node is a gateway node, ACK/NAK inputs are treated as regular input messages destined for another loop.

4. NCU Write 0 Interrupter. The Write 0 mailbox is set and the EXT of the NCU is set to cause a wait-to-write transition. The CIE TO INPUT QUEUE HANDLER is then called. Thus a receive/send message is treated as both an input and an output message.

5. Output Queue Handler. After a WT has been received, all extant output ACK/NAK messages are moved to the mailbox. An output message (if any) is then moved to the NCU page 2. The NCU WRITE 1, 2 INTERRUPTER is then called.

6. Outstanding ACK handler. An ACK received is paired to a packet previously written to the line and the packet page is marked available. A NAK received is paired to a previously written page and the page is relinked to the Output Queue for retransmission. At the end of the Outstanding ACK module, return to the Background module is performed.

7. CIE to Input Queue Handler. All input packets are handled by this module except ACK/NAK packets received at local nodes and WT packets. Input message and receive/send packets are checked for parity. If parity checks, the packet is linked to Input Queue and an ACK is added to the extant output ACK/NAK list. If parity does not check, the packet is marked null and a NAK is added to the extant ACK/NAK list. The Background module is then called.

8. NCU Write 1, 2 Interrupter. The Write 1, 2 mailbox is set. The destination for WT and the output message write address are set into the mailbox. The EXT of the NCU is then set, and the Background module is called.

9. External to CIE Handler. If an external to CIE event exists, the CIE transfers the content of the CIE buffer to the Output Queue for messages and the CIE buffer is marked empty. In gateway nodes ACK/NAK packets may also be sent across the external interface. When received, such ACK/NAK messages are placed in the extant ACK/NAK list for transfer to the NCU at the next used Output Queue Handler. The Background module is then called.

B.8.3 ESMD Loop

B.8.3.1 Introduction

The ESMD loop is presently in construction. Each individual node comprises an LIU, a Control and Interface Processor (CIP) which is a BDS and may also have an external interface peculiar to an external device attached to the node. The nodes are the fully up-to-date nodes that are proposed for use herein except that an nBDS will be used. The LIU is completely redesigned with features remarkably improved over the LIU of the ESM. The BDS is a full microcomputer that operates from instructions derived from a higher level language (Extended ALGOL) and is particularly well suited to the processing of character strings.

A comparison between the ESM and ESMD nodes is given below. Note that the ESMD loop operates at only one megabit/second instead of the proposed two megabits/second. This was done because only one megabit/second was required. Actually the bit frequency can be varied from push-button rates up to several megabits/second.

Line Discipline: The ESM node handles 25,000 bytes/second, the ESMD handles 125,000 bytes/second.

Addressability: The ESM node can be set to only one address at a time, the ESMD node can be set to accept any combination of 256 addresses changable on BDS command.

Recovery from LIU or Line Failure: Manual in the ESM, automatic through loop-back in the ESMD.

Buffering: Single packet in and out in the ESM, double packet in and out in the ESMD.

B.8.3.4. ESMD Node Construction

The salient features of the ESMD node construction are shown in figure B-18. The LIU is composed (from bottom to top in the diagram) of a secondary data stream delay, clock loss detectors and logic for automatic loop-back; line interface and control logic for read and write logic including address recognition; double input and double output buffers with buffer status registers; and the BDS interface and control. All of the LIU logic is in the form of TTL chips and MOS memory chips in DIP form mounted on a single card. The Burroughs BDS is in the form of two cards containing nine LSI chips and a number of other chips. The memory is in the form of a single card containing 64 memory chips and address logic. The BDS controls the LIU and the external interface and control.

Thus, the single module of LIU and BDS can be used for a wide variety of processing purposes where only the external interface changes according to the needs of the system.

The node proposed for the BCA system differs mainly in the line frequency of two megabits/second and the use of an nBDS which uses only one card and runs twice as fast as the BDS.

B.8.3.5. Features of the ESMD Loop

The ESMD loop is composed of eight nodes as described above (Figure B-19). One of the nodes (E) interfaces with a B776 computer equipped with a hard copy unit (HCU) a visual display unit (VDU) in the form of a TD830 CRT terminal and a dual disk cartridge unit. Not shown is the tape cassette unit that is also supplied. All of this equipment provides the program development unit for the loop.

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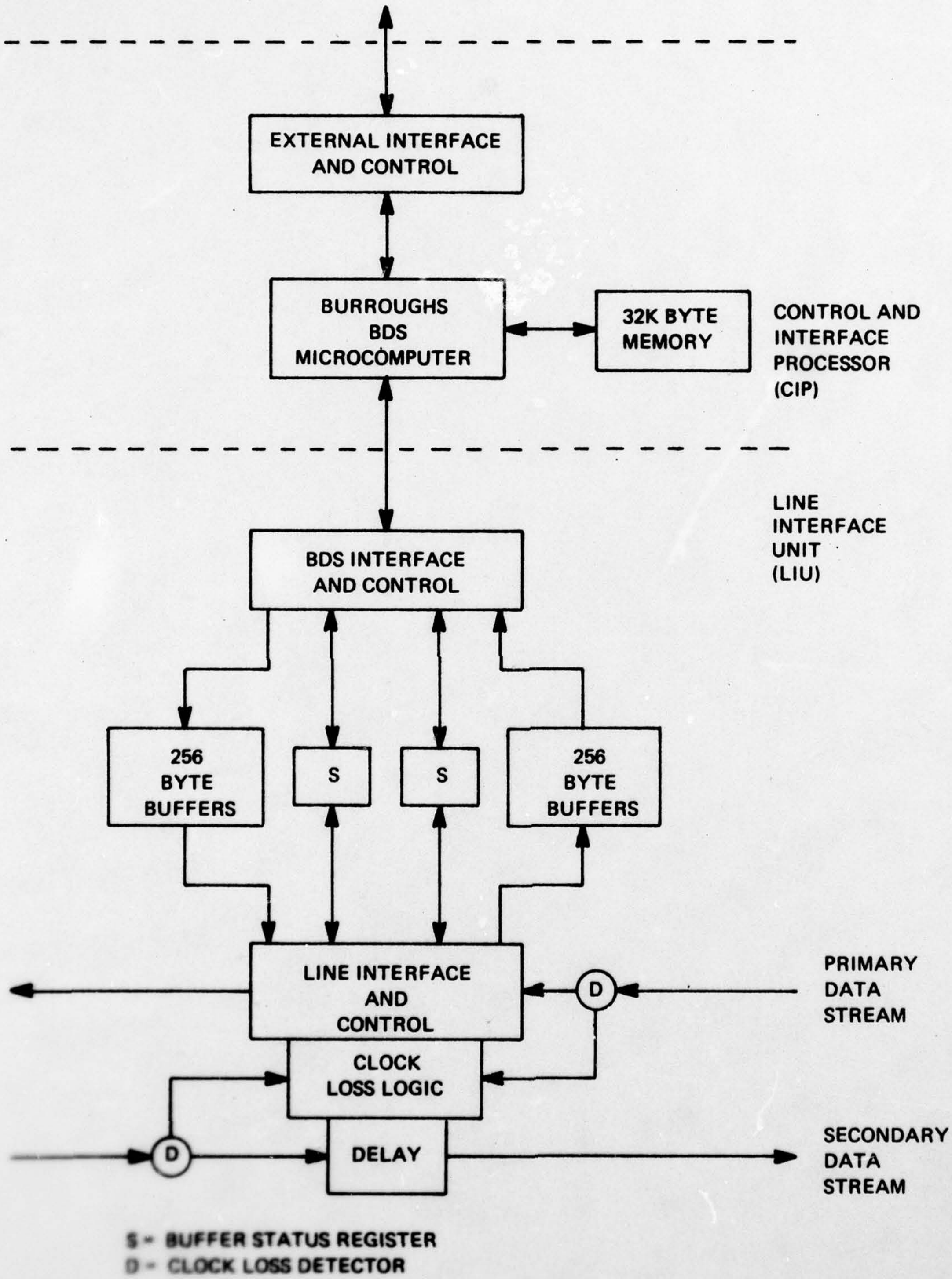

Figure B-18. ESMD Node

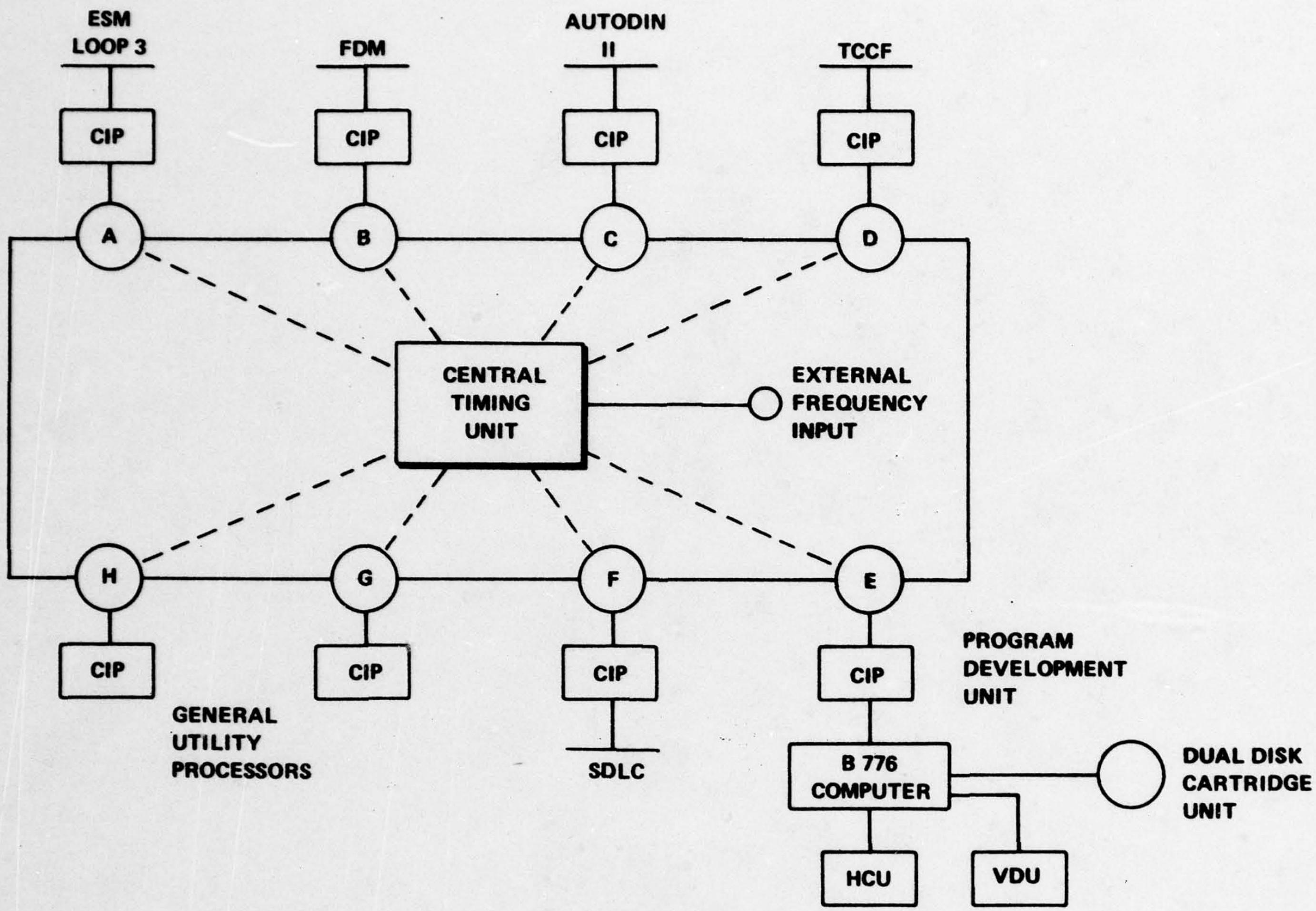

Figure B-19. Multiple Interface Loop

The remainder of the nodes on the loop are primarily for interfacing the ESM and a future equipment (FDM) with several different systems using different line protocols. One such protocol is the Autodin II, phase I mode VI protocol which is similar to BDLC except for the 32 bit CRC check (C). Another protocol is the Tactical Communication and Control Facility (TCCF) protocol for Army TRI-TAC communications (D). Node F handles the SDLC protocol that may interface with an Automatic Tech Control (ATEC) facility. In addition, one of the general utility processors may operate a Hewlett-Packard instrumentation interface.

Reames [1] Cecil B. Reames and Ming T. Liu "Design and Simulation of Distributed Loop Computer Network (DLCN)", Proceedings of 3rd Annual Symposium of Computer Architecture, Jan. 1976.

APPENDIX C.

Simulation Outputs

The Burroughs Operational Systems Simulator (BOSS) run on a B6700 was used to perform the simulation study. BOSS is a general-purpose, discrete-events simulator program that constitutes a computerized tool for simulating the operation of a system or process. Block-diagram oriented and data-base driven, BOSS is particularly easy for the systems analyst to use. Its attractive features include:

- No formal language programming is needed for BOSS modeling. Modeling is simplified because of certain inherent biases and default characteristics in logical flow and queue servicing.

- Model parameters mapped on a BOSS block diagram may be transferred directly to input data files.

- A large library of data base error messages and notes facilitate model debugging.

- BOSS generates pertinent output reports without the need for input commands.

Unlike other general purpose simulation languages (e.g., GPSS, (SIMSCRIPT), the time required for BOSS coding is insignificant. In practice, the modeler maps BOSS parameters onto a logical flow chart which is transcribed to a file-oriented data base directly from the flow chart to the file. The series of input files comprises data input to be executed with BOSS object machine codes.

BOSS SIMULATOR
MARK VI
MARCH 22, 1977

BOSS SIMULATION

8/31/77

SERIES BUSS SIMULATION

NUMBER OF STATIONS	10	
PACKET SIZE (CHARACTERS)	50	
ACK-NAK SIZE	10	
TOTAL CHARACTERS PER PACKET	260	
TIME UNIT (10 BIT TIMES)	1	
TIME UNITS FOR BUSS PROCESSING	2	PER PACKET
TIME UNITS TOTAL	210	PER PACKET
TIME UNITS FOR CRASH RESTART	2	PER CRASH
TIME UNITS INTERARRIVAL	250	POISSON

FINAL PRINTOUT

"NOW" IS   2500000 TIME UNITS.

PROCESS NUMBER 1 WAS COMPLETED 1070 TIME(S).

MEAN IS 947 TIME UNITS.
RMS. DEV. IS 1285 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
209	0
214	2
214	5
214	10
214	15
286	25
357	35
512	50
750	65
1000	75
1560	85
1992	90
3473	95
5199	98
12402	100

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
1013767	365888	0.00	100.00

PROCESS NUMBER 2 WAS COMPLETED 1030 TIME(S).

MEAN IS 959 TIME UNITS.
RMS. DEV. IS 1352 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
209	0
215	2
215	5
215	10
215	15
288	25
349	35
519	50
750	65
1031	75
1526	85
1895	90
3130	95
6198	98
12679	100

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
987405	330226	0.00	100.00

PROCESS NUMBER 3 WAS COMPLETED 970 TIME(S).

MEAN IS 1013 TIME UNITS.
RMS. DEV. IS 1625 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
209	0
215	2
215	5
215	10
215	15
287	25
348	35
505	50
735	65
1037	75
1521	85
2006	90
3324	95
7690	98
12593	100

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
982306	368292	0.00	100.00

PROCESS NUMBER 4 WAS COMPLETED 1057 TIME(S).

MEAN IS 798 TIME UNITS.
RMS. DEV. IS 1135 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
209	0
214	2
214	5
214	10
214	15
274	25
333	35
440	50
641	65
854	75
1221	85
1593	90
2432	95
3707	98
12340	100

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
843165	219819	0.00	100.00

PROCESS NUMBER 5 WAS COMPLETED 1011 TIME(S).

MEAN IS 963 TIME UNITS.
RMS. DEV. IS 1256 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
208	0
213	2
213	5
213	10
223	15
295	25
357	35
492	50
781	65
1086	75
1664	85
2124	90
3348	95
4849	98
10785	100

.........TOTAL ACTIVE.........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
973339	322737	0.00	100.00

PROCESS NUMBER 6 WAS COMPLETED 1026 TIME(S).

MEAN IS 1023 TIME UNITS.
RMS. DEV. IS 1688 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
209	0
216	2
216	5
216	10
216	15
280	25
358	35
500	50
816	65
1116	75
1609	85
1992	90
3132	95
5401	98
16370	100

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
1049243	385292	0.00	100.00

PROCESS NUMBER 7 WAS COMPLETED 990 TIME(S).

MEAN IS 842 TIME UNITS.
RMS. DEV. IS 1078 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
209	0
214	2
214	5
214	10
214	15
274	25
345	35
488	50
714	65
1011	75
1451	85
1748	90
2446	95
3924	98
12383	100

PROCESS NUMBER 7 WAS NOT COMPLETED 2 TIME(S).

MEAN IS 416 TIME UNITS.
RMS. DEV. IS 377 TIME UNITS.

ELAPSED TIME
793
39

.........TOTAL ACTIVE.........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
834129	207362	0.00	100.00

AD-A063 703 BURROUGHS CORP PAOLI PA FEDERAL AND SPECIAL SYSTEMS GROUP F/G 17/2
MODULAR SYSTEM CONTROL DEVELOPMENT MODEL (MSCDM). APPENDICES A --ETC(U)
SEP 77 DCA100-76-C-0083
UNCLASSIFIED 64280-APP-A-E SBIE-AD-E100 146 NL

3 OF 4
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PROCESS NUMBER 8 WAS COMPLETED 1013 TIME(S).

MEAN IS 791 TIME UNITS.
RMS. DEV. IS 864 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
209	0
212	2
212	5
212	10
212	15
264	25
337	35
455	50
658	65
903	75
1416	85
1896	90
2642	95
3709	98
6945	100

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
801446	202635	0.00	100.00

PROCESS NUMBER 9 WAS COMPLETED 996 TIME(S).

MEAN IS 1003 TIME UNITS.
RMS. DEV. IS 1649 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
209	0
216	2
216	5
216	10
216	15
273	25
346	35
461	50
721	65
970	75
1602	85
2179	90
3316	95
5611	98
14991	100

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
999438	384074	0.00	100.00

PROCESS NUMBER 10 WAS COMPLETED 989 TIME(S).

MEAN IS 933 TIME UNITS.
RMS. DEV. IS 1288 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
208	0
213	2
213	5
213	10
213	15
284	25
355	35
485	50
709	65
956	75
1451	85
2131	90
3529	95
5301	98
12281	100

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
922596	301954	0.00	100.00

PROCESS NUMBER 11 WAS COMPLETED 1070 TIME(S).

MEAN IS 605 TIME UNITS.
RMS. DEV. IS 624 TIME UNITS.

COMPLETION TIMES AT 2 PERCENTILE INTERVALS

%	0	2	4	6	8
0	209	211	211	211	211
10	211	211	211	211	211
20	211	211	211	211	228
30	239	256	272	283	306
40	317	339	344	361	378
50	389	405	422	422	422
60	463	494	527	566	599
70	633	633	671	729	803
80	838	852	948	1048	1113
90	1259	1461	1662	1891	2700
100	5884				

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
647879	0		

PROCESS NUMBER 12 WAS COMPLETED 1030 TIME(S).

MEAN IS 638 TIME UNITS.
RMS. DEV. IS 690 TIME UNITS.

COMPLETION TIMES AT 2 PERCENTILE INTERVALS

%	0	2	4	6	8
0	209	212	212	212	212
10	212	212	212	212	212
20	212	212	212	219	234
30	262	277	291	305	320
40	334	349	363	377	392
50	413	420	420	428	485
60	517	543	571	601	629
70	629	650	722	780	837
80	867	981	1053	1117	1261
90	1313	1469	1685	1893	2521
100	7564				

.........TOTAL ACTIVE.........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
657179	0		

PROCESS NUMBER 13 WAS COMPLETED 970 TIME(S).

MEAN IS 633 TIME UNITS.
RMS. DEV. IS 663 TIME UNITS.

COMPLETION TIMES AT 2 PERCENTILE INTERVALS

%	0	2	4	6	8
0	209	212	212	212	212
10	212	212	212	212	212
20	212	212	212	212	231
30	250	263	282	294	313
40	326	339	354	364	377
50	396	409	422	422	428
60	460	504	549	574	618
70	632	655	721	810	842
80	899	1001	1052	1128	1262
90	1365	1548	1687	2092	2545
100	6724				

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
614014	0		

PROCESS NUMBER 14 WAS COMPLETED 1057 TIME(S).

MEAN IS 590 TIME UNITS.
RMS. DEV. IS 649 TIME UNITS.

COMPLETION TIMES AT 2 PERCENTILE INTERVALS

%	0	2	4	6	8
0	209	212	212	212	212
10	212	212	212	212	212
20	212	212	212	212	227
30	241	263	271	285	292
40	307	322	344	358	380
50	395	402	417	417	417
60	436	460	497	526	563
70	586	628	628	687	750
80	811	840	877	996	1052
90	1201	1351	1509	1890	2709
100	7684				

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
623346	0		

PROCESS NUMBER 15 WAS COMPLETED 1011 TIME(S).

MEAN IS 644 TIME UNITS.
RMS. DEV. IS 683 TIME UNITS.

COMPLETION TIMES AT 2 PERCENTILE INTERVALS

%	0	2	4	6	8
0	208	211	211	211	211
10	211	211	211	211	211
20	211	211	211	221	244
30	257	270	283	303	316
40	329	342	356	369	388
50	402	415	421	421	435
60	467	502	533	566	617
70	632	633	737	798	843
80	843	956	1053	1157	1257
90	1441	1613	1756	2113	2942
100	6946				

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
650602	0		

PROCESS NUMBER 16 WAS COMPLETED 1026 TIME(S).

MEAN IS 647 TIME UNITS.
RMS. DEV. IS 719 TIME UNITS.

COMPLETION TIMES AT 2 PERCENTILE INTERVALS

%	0	2	4	6	8
0	209	213	213	213	213
10	213	213	213	213	213
20	213	213	213	213	223
30	243	253	273	282	302
40	322	332	351	361	381
50	401	410	420	420	450
60	479	519	558	602	627
70	637	696	775	844	844
80	913	1011	1060	1188	1267
90	1415	1572	1750	2104	2518
100	10292				

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
663951	0		

PROCESS NUMBER 17 WAS COMPLETED 990 TIME(S).

MEAN IS 633 TIME UNITS.
RMS. DEV. IS 751 TIME UNITS.

COMPLETION TIMES AT 2 PERCENTILE INTERVALS

%	0	2	4	6	8
0	209	214	214	214	214
10	214	214	214	214	214
20	214	214	214	214	225
30	236	247	269	279	299
40	312	323	345	366	378
50	389	410	421	421	421
60	454	489	530	563	596
70	621	629	682	760	830
80	849	989	1052	1098	1229
90	1329	1457	1669	2071	2782
100	11387				

PROCESS NUMBER 17 WAS NOT COMPLETED 1 TIME(S).

ELAPSED TIME IS 122 TIME UNITS

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
626767	0		

PROCESS NUMBER 18 WAS COMPLETED 1013 TIME(S).

MEAN IS 591 TIME UNITS.
RMS. DEV. IS 596 TIME UNITS.

COMPLETION TIMES AT 2 PERCENTILE INTERVALS

%	0	2	4	6	8
0	209	212	212	212	212
10	212	212	212	212	212
20	212	212	212	218	230
30	242	260	273	285	304
40	322	335	353	372	384
50	396	410	421	421	421
60	446	483	519	544	575
70	612	630	630	693	766
80	827	840	932	1049	1121
90	1236	1413	1579	1946	2361
100	6514				

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
598811	0		

PROCESS NUMBER 19 WAS COMPLETED 996 TIME(S).

MEAN IS 618 TIME UNITS.
RMS. DEV. IS 684 TIME UNITS.

COMPLETION TIMES AT 2 PERCENTILE INTERVALS

%	0	2	4	6	8
0	209	212	212	212	212
10	212	212	212	212	212
20	212	212	212	218	231
30	243	256	269	288	307
40	313	333	345	358	377
50	390	409	422	422	422
60	441	460	492	523	565
70	600	632	665	728	791
80	842	912	991	1052	1157
90	1262	1472	1684	2109	2746
100	6724				

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
615364	0		

PROCESS NUMBER 20 WAS COMPLETED 989 TIME(S).

MEAN IS 628 TIME UNITS.
RMS. DEV. IS 680 TIME UNITS.

COMPLETION TIMES AT 2 PERCENTILE INTERVALS

%	0	2	4	6	8
0	208	210	210	210	210
10	210	210	210	210	210
20	210	210	210	222	237
30	251	268	285	297	314
40	331	343	354	366	377
50	394	412	417	417	423
60	452	492	532	562	596
70	630	630	654	705	764
80	843	907	981	1050	1193
90	1262	1469	1810	2315	2972
100	6094				

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
620642	0		

PROCESS NUMBER 22 WAS COMPLETED 10152 TIME(S).

MEAN IS 208 TIME UNITS.
RMS. DEV. IS 0 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
208	0
208	2
208	5
208	10
208	15
208	25
208	35
208	50
208	65
208	75
208	85
208	90
208	95
208	98
208	100

PROCESS NUMBER 22 WAS NOT COMPLETED 1 TIME(S).

ELAPSED TIME IS 120 TIME UNITS

.........TOTAL ACTIVE.........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
2111736	2111736	100.00	0.00

PROCESS NUMBER 23 WAS COMPLETED 10152 TIME(S).

MEAN IS 927 TIME UNITS.
RMS. DEV. IS 1347 TIME UNITS.

COMPLETION TIMES AT 2 PERCENTILE INTERVALS

%	0	2	4	6	8
0	208	215	215	215	215
10	215	215	215	215	231
20	247	263	279	294	310
30	310	326	342	357	373
40	373	389	405	421	452
50	484	515	531	563	594
60	626	657	705	752	799
70	847	910	973	1036	1115
80	1210	1305	1431	1589	1731
90	1952	2252	2741	3466	5092
100	16370				

PROCESS NUMBER 23 WAS NOT COMPLETED 2 TIME(S).

MEAN IS 416 TIME UNITS.
RMS. DEV. IS 377 TIME UNITS.

ELAPSED TIMES

793 39

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
9406834	3088279	0.00	100.00

REGISTER STATUS

REGISTER NUMBER	TIMES CALLED	OLD VALUE	NEW VALUE
1	2140	0	0
2	2060	0	0
3	1940	0	0
4	2114	0	0
5	2022	0	0
6	2052	6	0
7	1981	7	7
8	2026	0	0
9	1992	0	0
10	1978	0	0
11	1	1	1
12	1	10	10
13	26150	6	7
100	20305	2	1
101	415	397	415

QUEUE STATISTICS BY UNIT TYPE BASED ON ACTIVE TIME.

UNIT TYPE	......TIME PERCENTAGE BY NUMBER IN QUEUE...... 1	2	3	4	5	6	7	>7	TOTAL	..LENGTH.. AVG	MAX
					OVERALL						
11	4.4	1.4	0.9	0.5	0.4	0.1	0.0	0.0	7.74	0.15	7
12	4.5	1.5	0.6	0.7	0.2	0.0	0.0	0.0	7.53	0.13	6
13	4.4	1.3	0.6	0.4	0.2	0.1	0.3	0.1	7.36	0.15	8
14	4.2	0.9	0.3	0.4	0.1	0.0	0.0	0.0	5.83	0.09	6
15	4.8	1.4	0.7	0.4	0.4	0.0	0.0	0.0	7.61	0.13	5
16	5.4	1.2	0.4	0.2	0.4	0.3	0.3	0.0	8.16	0.15	8
17	4.6	1.2	0.4	0.0	0.0	0.0	0.0	0.0	6.21	0.08	4
18	4.2	1.3	0.4	0.0	0.0	0.0	0.0	0.0	5.92	0.08	3
19	3.6	1.1	1.0	0.5	0.3	0.5	0.1	0.0	7.02	0.15	7
20	4.3	1.2	0.5	0.4	0.2	0.2	0.0	0.0	6.83	0.12	6
42	14.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.69	0.15	1
					REPORT INTERVAL						
11	2.6	0.8	0.0	0.0	0.0	0.0	0.0	0.0	3.40	0.04	2
12	2.4	0.7	4.1	12.7	4.2	0.2	0.0	0.0	24.29	0.89	6
13	10.4	5.2	4.9	1.1	0.0	0.0	0.0	0.0	21.55	0.40	4
14	5.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	6.88	0.08	2
15	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.12	0.02	1
16	6.5	1.9	0.0	0.0	0.0	0.0	0.0	0.0	8.44	0.10	2
17	5.7	1.3	0.0	0.0	0.0	0.0	0.0	0.0	6.98	0.08	2
18	6.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	7.06	0.08	2
19	4.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	4.28	0.04	2
20	3.2	2.6	0.0	0.0	0.0	0.0	0.0	0.0	5.83	0.08	2
42	20.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.22	0.20	1

UNIT UTILIZATION STATISTICS

UNIT TYPE	UNIT ID NUMB	TOTAL TIMES USED	......PERCENT OF ACTIVE TIME...... ...IN-USE... DELTA	TOTAL	.DEPENDENT.. DELTA	TOTAL	FREE TOTAL
3	3	20720	79.39	84.89	0.00	0.00	15.11
11	11	1070	23.34	25.92	0.00	0.00	74.08
12	12	1030	33.44	26.29	0.00	0.00	73.71
13	13	970	32.06	24.56	0.00	0.00	75.44
14	14	1057	26.17	24.93	0.00	0.00	75.07
15	15	1011	20.08	26.02	0.00	0.00	73.98
16	16	1026	20.22	26.56	0.00	0.00	73.44
17	17	991	22.78	25.07	0.00	0.00	74.93
18	18	1013	21.42	23.95	0.00	0.00	76.05
19	19	996	22.69	24.61	0.00	0.00	75.39
20	20	989	25.46	24.83	0.00	0.00	75.17
* 41	21	3091	0.04	0.04	0.00	0.00	99.96
* 41	22	3088	0.04	0.04	0.00	0.00	99.96
* 41	23	3087	0.04	0.04	0.00	0.00	99.96
* 41	24	3082	0.04	0.04	0.00	0.00	99.96
* 41	25	3091	0.04	0.04	0.00	0.00	99.96
* 41	26	3082	0.04	0.04	0.00	0.00	99.96
* 41	27	3097	0.04	0.04	0.00	0.00	99.96
* 41	28	3087	0.04	0.04	0.00	0.00	99.96
* 41	29	3081	0.04	0.04	0.00	0.00	99.96
* 41	30	3088	0.04	0.04	0.00	0.00	99.96

* UNIT TYPE HAS BEEN CHANGED BY TRANSFER

UNIT TYPES TRANSFERRED:

UNIT TYPE	AVERAGE NUMBER IN TYPE ..DURING ACTIVE TIME.. DELTA	OVERALL
41	8.313	8.317
42	1.687	1.683

BOSS SIMULATOR
MARK VI
MARCH 22, 1977

BOSS SIMULATION

8/25/77

LOOP SIMULATION TYPE WT-2

NUMBER OF NODES	10	
PACKET SIZE (CHARACTERS)	250	
ACK-NAK SIZE	10	
WRITE TOKEN SIZE	4	
WRITE TOKEN SIZE	4	
TOTAL CHARACTERS PER PACKET (PACKET +ACK +WT-IN +WT-OUT)	268	
TIME UNIT (10 BIT TIMES)	1	WT DELAY/NODE
TIME UNITS FOR TOTAL PACKET	214	FIXED
TIME UNITS INTERARRIVAL	250	POISSON

FINAL PRINTOUT

"NOW" IS 2500000 TIME UNITS.

PROCESS NUMBER 1 WAS COMPLETED 950 TIME(S).

MEAN IS	822 TIME UNITS.
RMS. DEV. IS	761 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
214	0
216	2
216	5
221	10
227	15
295	25
379	35
548	50
827	65
1068	75
1432	85
1745	90
2435	95
3125	98
5609	100

PROCESS NUMBER 1 WAS NOT COMPLETED 2 TIME(S).

MEAN IS	949 TIME UNITS.
RMS. DEV. IS	196 TIME UNITS.

ELAPSED TIME
1145
753

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
782427	782427	0.00	100.00

PROCESS NUMBER 2 WAS COMPLETED 1021 TIME(S).

MEAN IS 896 TIME UNITS.
RMS. DEV. IS 839 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
214	0
217	2
217	5
224	10
250	15
337	25
417	35
591	50
844	65
1112	75
1579	85
1946	90
2634	95
3538	98
7050	100

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
914914	914914	0.00	100.00

PROCESS NUMBER 3 WAS COMPLETED 1035 TIME(S).

MEAN IS 910 TIME UNITS.
RMS. DEV. IS 806 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
214	0
216	2
216	5
222	10
257	15
349	25
435	35
647	50
941	65
1153	75
1612	85
1999	90
2492	95
3331	98
6097	100

PROCESS NUMBER 3 WAS NOT COMPLETED 1 TIME(S).

ELAPSED TIME IS 171 TIME UNITS

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
942018	942018	0.00	100.00

PROCESS NUMBER 4 WAS COMPLETED 1000 TIME(S).

MEAN IS 937 TIME UNITS.
RMS. DEV. IS 937 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
214	0
217	2
217	5
223	10
250	15
334	25
421	35
638	50
882	65
1165	75
1582	85
2075	90
2734	95
3787	98
6957	100

PROCESS NUMBER 4 WAS NOT COMPLETED 2 TIME(S).

MEAN IS 2565 TIME UNITS.
RMS. DEV. IS 1248 TIME UNITS.

ELAPSED TIME
3813
1317

.........TOTAL ACTIVE.........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
942425	942425	0.00	100.00

PROCESS NUMBER 5 WAS COMPLETED 1007 TIME(S).

MEAN IS 847 TIME UNITS.
RMS. DEV. IS 781 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
214	0
216	2
216	5
221	10
246	15
331	25
397	35
552	50
813	65
1066	75
1536	85
1829	90
2624	95
3261	98
5351	100

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
852819	852819	0.00	100.00

PROCESS NUMBER 6 WAS COMPLETED 1061 TIME(S).

MEAN IS 955 TIME UNITS.
RMS. DEV. IS 1042 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
214	0
217	2
217	5
217	10
240	15
323	25
407	35
581	50
861	65
1172	75
1633	85
2073	90
3042	95
4219	98
7968	100

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
1013643	1013643	0.00	100.00

PROCESS NUMBER 7 WAS COMPLETED 1011 TIME(S).

MEAN IS 956 TIME UNITS.
RMS. DEV. IS 1004 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
214	0
218	2
218	5
226	10
242	15
349	25
423	35
603	50
886	65
1164	75
1628	85
2070	90
3009	95
4256	98
8608	100

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
966961	966961	0.00	100.00

PROCESS NUMBER 8 WAS COMPLETED 1034 TIME(S).

MEAN IS 958 TIME UNITS.
RMS. DEV. IS 1024 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
214	0
217	2
217	5
224	10
231	15
320	25
409	35
594	50
895	65
1169	75
1650	85
2090	90
3001	95
4690	98
7229	100

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
990670	990670	0.00	100.00

PROCESS NUMBER 9 WAS COMPLETED 1007 TIME(S).

MEAN IS 980 TIME UNITS.
RMS. DEV. IS 1174 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
214	0
219	2
219	5
219	10
249	15
319	25
409	35
569	50
840	65
1106	75
1642	85
2124	90
3328	95
4950	98
10480	100

PROCESS NUMBER 9 WAS NOT COMPLETED 1 TIME(S).

ELAPSED TIME IS 943 TIME UNITS

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
987829	987829	0.00	100.00

PROCESS NUMBER 10 WAS COMPLETED 999 TIME(S).

MEAN IS 885 TIME UNITS.
RMS. DEV. IS 796 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
214	0
216	2
216	5
221	10
226	15
329	25
421	35
610	50
901	65
1133	75
1561	85
1893	90
2543	95
3300	98
5458	100

PROCESS NUMBER 10 WAS NOT COMPLETED 2 TIME(S).

MEAN IS 703 TIME UNITS.
RMS. DEV. IS 118 TIME UNITS.

ELAPSED TIME
820
585

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
885241	885241	0.00	100.00

PROCESS NUMBER 11 WAS COMPLETED 950 TIME(S).

MEAN IS 656 TIME UNITS.
RMS. DEV. IS 425 TIME UNITS.

COMPLETION TIMES AT 2 PERCENTILE INTERVALS

%	0	2	4	6	8
0	214	214	216	218	218
10	220	222	224	226	237
20	248	267	282	295	312
30	325	341	361	382	396
40	415	435	436	456	476
50	528	551	583	613	649
60	649	681	736	792	845
70	862	862	888	960	1026
80	1074	1074	1079	1219	1287
90	1287	1302	1502	1502	1714
100	2140				

PROCESS NUMBER 11 WAS NOT COMPLETED 1 TIME(S).

ELAPSED TIME IS 738 TIME UNITS

.........TOTAL ACTIVE.........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
623517	623517	0.00	100.00

PROCESS NUMBER 12 WAS COMPLETED 1021 TIME(S).

MEAN IS 674 TIME UNITS.
RMS. DEV. IS 423 TIME UNITS.

COMPLETION TIMES AT 2 PERCENTILE INTERVALS

%	0	2	4	6	8
0	214	214	216	218	220
10	220	224	224	239	256
20	271	288	309	328	341
30	361	377	399	410	424
40	436	436	466	502	529
50	553	574	612	634	649
60	666	735	768	817	852
70	862	862	944	1011	1064
80	1074	1074	1077	1201	1287
90	1287	1393	1502	1502	1714
100	2140				

.........TOTAL ACTIVE.........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
688548	688548	0.00	100.00

PROCESS NUMBER 13 WAS COMPLETED 1035 TIME(S).

MEAN IS 675 TIME UNITS.
RMS. DEV. IS 413 TIME UNITS.

COMPLETION TIMES AT 2 PERCENTILE INTERVALS

%	0	2	4	6	8
0	214	216	216	218	220
10	223	224	224	235	254
20	271	294	322	338	352
30	369	389	403	420	436
40	436	455	483	512	554
50	585	624	648	649	649
60	677	725	780	830	862
70	862	869	957	1012	1045
80	1074	1074	1074	1125	1251
90	1287	1298	1502	1502	1714
100	2140				

PROCESS NUMBER 13 WAS NOT COMPLETED 1 TIME(S).

ELAPSED TIME IS 171 TIME UNITS

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
699053	699053	0.00	100.00

PROCESS NUMBER 14 WAS COMPLETED 1000 TIME(S).

MEAN IS 688 TIME UNITS.
RMS. DEV. IS 427 TIME UNITS.

COMPLETION TIMES AT 2 PERCENTILE INTERVALS

%	0	2	4	6	8
0	214	216	216	218	220
10	220	224	224	233	257
20	277	303	316	331	353
30	372	388	406	421	435
40	436	458	507	539	576
50	610	630	649	649	656
60	697	742	774	810	859
70	862	883	950	1017	1074
80	1074	1074	1175	1287	1287
90	1287	1423	1502	1502	1714
100	2140				

PROCESS NUMBER 14 WAS NOT COMPLETED 1 TIME(S).

ELAPSED TIME IS 309 TIME UNITS

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
688157	688157	0.00	100.00

PROCESS NUMBER 15 WAS COMPLETED 1007 TIME(S).

MEAN IS 658 TIME UNITS.
RMS. DEV. IS 413 TIME UNITS.

COMPLETION TIMES AT 2 PERCENTILE INTERVALS

%	0	2	4	6	8
0	214	214	216	218	220
10	220	224	224	235	256
20	273	293	307	324	339
30	353	371	382	394	408
40	424	436	452	472	500
50	529	554	586	622	643
60	649	675	731	777	825
70	862	862	873	944	1033
80	1074	1074	1074	1187	1287
90	1287	1357	1502	1502	1704
100	2140				

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
662295	662295	0.00	100.00

PROCESS NUMBER 16 WAS COMPLETED 1061 TIME(S).

MEAN IS 672 TIME UNITS.
RMS. DEV. IS 431 TIME UNITS.

COMPLETION TIMES AT 2 PERCENTILE INTERVALS

%	0	2	4	6	8
0	214	214	216	218	220
10	220	224	224	236	250
20	265	284	307	323	340
30	356	371	388	405	418
40	431	436	445	471	510
50	531	565	606	633	649
60	649	696	745	783	837
70	862	862	922	987	1059
80	1074	1074	1185	1287	1287
90	1287	1469	1502	1502	1714
100	2140				

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
712781	712781	0.00	100.00

PROCESS NUMBER 17 WAS COMPLETED 1011 TIME(S).

MEAN IS 672 TIME UNITS.
RMS. DEV. IS 418 TIME UNITS.

COMPLETION TIMES AT 2 PERCENTILE INTERVALS

%	0	2	4	6	8
0	214	214	216	218	220
10	222	224	224	233	261
20	284	309	322	341	356
30	369	388	401	418	429
40	436	459	482	506	546
50	566	593	614	633	649
60	657	708	762	819	862
70	862	862	870	943	1009
80	1074	1074	1074	1180	1287
90	1287	1354	1502	1502	1714
100	2140				

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
679704	679704	0.00	100.00

PROCESS NUMBER 18 WAS COMPLETED 1034 TIME(S).

MEAN IS 674 TIME UNITS.
RMS. DEV. IS 434 TIME UNITS.

COMPLETION TIMES AT 2 PERCENTILE INTERVALS

%	0	2	4	6	8
0	214	214	216	218	220
10	222	224	224	228	239
20	260	277	290	312	332
30	350	371	388	404	420
40	436	436	458	488	521
50	545	591	621	649	649
60	666	729	776	820	861
70	862	862	882	958	1048
80	1074	1074	1152	1252	1287
90	1287	1409	1502	1544	1714
100	2140				

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
697199	697199	0.00	100.00

PROCESS NUMBER 19 WAS COMPLETED 1007 TIME(S).

MEAN IS 666 TIME UNITS.
RMS. DEV. IS 425 TIME UNITS.

COMPLETION TIMES AT 2 PERCENTILE INTERVALS

%	0	2	4	6	8
0	214	214	216	216	218
10	220	224	224	233	248
20	260	279	297	312	335
30	346	361	382	405	420
40	431	436	456	489	517
50	542	572	597	629	649
60	650	709	755	802	857
70	862	862	875	944	1002
80	1074	1074	1112	1221	1287
90	1287	1339	1502	1502	1714
100	2140				

PROCESS NUMBER 19 WAS NOT COMPLETED 1 TIME(S).

ELAPSED TIME IS 943 TIME UNITS

.........TOTAL ACTIVE.........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
671719	671719	0.00	100.00

PROCESS NUMBER 20 WAS COMPLETED 999 TIME(S).

MEAN IS 679 TIME UNITS.
RMS. DEV. IS 427 TIME UNITS.

COMPLETION TIMES AT 2 PERCENTILE INTERVALS

%	0	2	4	6	8
0	214	214	216	218	220
10	220	222	224	224	234
20	258	277	298	324	346
30	363	386	405	420	435
40	436	455	488	512	555
50	578	600	623	649	649
60	654	722	759	822	862
70	862	862	917	996	1062
80	1074	1074	1181	1278	1287
90	1287	1462	1502	1502	1696
100	2140				

PROCESS NUMBER 20 WAS NOT COMPLETED 1 TIME(S).

ELAPSED TIME IS 820 TIME UNITS

.........TOTAL ACTIVE.........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
678750	678750	0.00	100.00

PROCESS NUMBER 21 WAS NOT COMPLETED 1 TIME(S).

ELAPSED TIME IS 2499999 TIME UNITS

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
2499999	2499999	87.57	12.43

PROCESS NUMBER 22 WAS COMPLETED 10125 TIME(S).

MEAN IS 915 TIME UNITS.
RMS. DEV. IS 929 TIME UNITS.

TIME FOR COMPLETION	PERCENTILE POINTS
214	0
219	2
219	5
219	10
239	15
329	25
409	35
589	50
866	65
1141	75
1592	85
1993	90
2765	95
3843	98
10480	100

PROCESS NUMBER 22 WAS NOT COMPLETED 8 TIME(S).

MEAN IS 1193 TIME UNITS.
RMS. DEV. IS 1042 TIME UNITS.

ELAPSED TIME
3813
1317
1145
943
820
753
585
171

........TOTAL ACTIVE........		PERCENT OF TASK TIME	
PROCESS TIME	TASK TIME	NORMAL	IN QUEUE
9278947	9278947	0.00	100.00

QUEUE STATISTICS BY UNIT TYPE BASED ON ACTIVE TIME.

UNIT TYPE	......TIME PERCENTAGE BY NUMBER IN QUEUE...... 1	2	3	4	5	6	7	>7	TOTAL	..LENGTH.. AVG	MAX
					OVERALL						
11	4.4	0.8	0.1	0.0	0.0	0.0	0.0	0.0	5.29	0.06	3
12	4.9	1.6	0.3	0.0	0.0	0.0	0.0	0.0	6.82	0.09	4
13	5.3	1.4	0.3	0.2	0.0	0.0	0.0	0.0	7.20	0.10	4
14	4.8	1.6	0.5	0.1	0.0	0.0	0.0	0.0	7.08	0.10	5
15	4.9	1.1	0.2	0.0	0.0	0.0	0.0	0.0	6.18	0.08	3
16	5.4	1.7	0.5	0.3	0.1	0.0	0.0	0.0	8.00	0.12	5
17	4.7	1.8	0.7	0.2	0.1	0.0	0.0	0.0	7.44	0.11	5
18	4.6	1.7	0.8	0.3	0.0	0.0	0.0	0.0	7.46	0.12	5
19	4.9	1.4	0.7	0.3	0.1	0.1	0.0	0.0	7.62	0.13	6
20	4.8	1.4	0.2	0.0	0.0	0.0	0.0	0.0	6.42	0.08	3
21	24.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.94	0.25	1
22	27.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.54	0.28	1
23	28.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.96	0.28	1
24	27.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.53	0.28	1
25	26.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.49	0.26	1
26	28.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.51	0.29	1
27	27.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.19	0.27	1
28	27.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.89	0.28	1
29	26.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.87	0.27	1
30	27.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.15	0.27	1
41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	1
42	12.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.43	0.12	1
					REPORT INTERVAL						
11	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.86	0.04	2
12	3.0	2.8	1.4	0.0	0.0	0.0	0.0	0.0	7.14	0.13	3
13	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.48	0.01	1
14	3.1	2.7	1.5	0.3	0.0	0.0	0.0	0.0	7.66	0.14	4
15	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.81	0.02	1
16	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.82	0.03	1
17	5.2	3.2	0.3	0.0	0.0	0.0	0.0	0.0	8.69	0.12	3
18	7.9	4.0	4.8	3.3	0.1	0.0	0.0	0.0	20.11	0.44	5
19	7.0	1.9	0.9	0.0	0.0	0.0	0.0	0.0	9.82	0.14	3
20	5.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0	5.78	0.06	2
21	29.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.71	0.30	1
22	29.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.55	0.30	1
23	16.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.30	0.16	1
24	24.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.77	0.25	1
25	26.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.27	0.26	1
26	34.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	34.07	0.34	1
27	34.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	34.64	0.35	1
28	43.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.20	0.43	1
29	32.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.82	0.33	1
30	29.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.62	0.30	1
42	8.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.50	0.08	1

UNIT UTILIZATION STATISTICS

UNIT TYPE	UNIT ID NUMB	TOTAL TIMES USED	.....PERCENT OF ACTIVE TIME...... ...IN-USE... DELTA	TOTAL	.DEPENDENT.. DELTA	TOTAL	FREE TOTAL
11	11	3255	29.80	25.03	0.00	0.00	74.97
12	12	3254	29.64	27.63	0.00	0.00	72.37
13	13	3255	16.41	28.05	0.00	0.00	71.95
14	14	3255	24.86	27.62	0.00	0.00	72.38
15	15	3254	26.36	26.58	0.00	0.00	73.42
16	16	3254	34.15	28.60	0.00	0.00	71.40
17	17	3254	34.72	27.28	0.00	0.00	72.72
18	18	3254	43.27	27.98	0.00	0.00	72.02
19	19	3254	32.91	26.96	0.00	0.00	73.04
20	20	3254	29.71	27.24	0.00	0.00	72.76
* 31	21	1900	9.24	8.13	0.00	0.00	91.87
* 32	22	2042	8.56	8.74	0.00	0.00	91.26
* 33	23	2070	5.14	8.86	0.00	0.00	91.14
* 34	24	2000	7.70	8.56	0.00	0.00	91.44
* 35	25	2014	8.35	8.62	0.00	0.00	91.38
* 36	26	2122	9.84	9.08	0.00	0.00	90.92
* 37	27	2022	10.27	8.65	0.00	0.00	91.35
* 38	28	2068	12.63	8.85	0.00	0.00	91.15
* 39	29	2015	9.94	8.62	0.00	0.00	91.38
* 40	30	1998	8.99	8.55	0.00	0.00	91.45
* 42	41	5530	0.00	0.00	0.00	0.00	100.00
* 41	42	5425	0.00	0.00	0.00	0.00	100.00
* 41	43	5123	0.00	0.00	0.00	0.00	100.00
* 41	44	5071	0.00	0.00	0.00	0.00	100.00
* 42	45	5453	0.00	0.00	0.00	0.00	100.00
* 41	46	4937	0.00	0.00	0.00	0.00	100.00
* 41	47	5428	0.00	0.00	0.00	0.00	100.00
* 42	48	5239	0.00	0.00	0.00	0.00	100.00
* 42	49	5202	0.00	0.00	0.00	0.00	100.00
* 42	50	5385	0.00	0.00	0.00	0.00	100.00

* UNIT TYPE HAS BEEN CHANGED BY TRANSFER

UNIT TYPES TRANSFERRED:

UNIT TYPE	AVERAGE NUMBER IN TYPE ..DURING ACTIVE TIME.. DELTA	OVERALL
21	0.000	0.000
22	0.000	0.000
23	0.000	0.000
24	0.000	0.000
25	0.000	0.000
26	0.000	0.000
27	0.000	0.000
28	0.000	0.000
29	0.000	0.000
30	0.000	0.000
31	1.000	1.000
32	1.000	1.000
33	1.000	1.000
34	1.000	1.000
35	1.000	1.000
36	1.000	1.000
37	1.000	1.000
38	1.000	1.000
39	1.000	1.000
40	1.000	1.000
41	6.990	7.279
42	3.010	2.721

APPENDIX D

GLOSSARY OF ACRONYMS

The interdisciplinary nature of the present study is emphasized by the large number of different acronyms, from diverse sources, that appear in the discussion. The following is a partial list of some of the relevant acronyms that have been identified. It also serves as a glossary.

ACAS	AUTOVON Centralized Alarm System
ACOC	Area Communications Operations Center
ADM	Adaptive Delta Modulation
ADO	Burroughs Advanced Development Organization
ASC	Automatic Switching Center (AUTODIN)
ASCII	American Standard Code for Information Interchange
ASCC	AUTODIN Station Control Console
ASSC	AUTODIN Station Supervisory Console
ASU	Alarm Scanner Unit
ATEC	Atuomated Tech Control
AVIE	AUTOVON Information and Evaluation Network
BARS	Buffered Automatic Reporting System
BBSA	Baseband Signal Analysis

BDLC	Burroughs Data Link Control
BDS	Basic Data Set
BER	Bit Error Rate
BITE	Built-In Test Equipment
BIU	Bus Interface Unit
BOSS	Burroughs Operational System Simulator. A simulator, written at FSSG, of processes that can be described by graphs whose arcs are tasks and whose nodes are events.
CACAES	Computer Assisted Circuit Engineering Allocation System
CCI	Command and Control Interpreter
CCSD	Communications Circuit Service Designator
CESE	Communications Equipment Support Element
CI	Communications Interface
CIE	ESM Control and Interface Equipment
CNCE	Communications Nodal Control Equipment
CPMAS	Communications Performance Monitoring and Assessment
CPU	Central Processor Unit
CRT	Cathode Ray Tube
CNCE	Communications Nodal Control Element

CSCE	Communications System Control Element
DAU	Digital Applique Unit
DB	Decibel; also Data Base Organization
DC	Data Collection
DCA	Defense Communications Agency
DCAOC	Defense Communications Agency Operations Center
DCEC	Defense Communications Engineering Center
DCS	Defense Communications System
DBMS	Data Base Management Service
DDMS	Digital Distortion Monitoring Subsystem
DEB	Digital European Backbone
DOD	Department of Defense
DPMAS	Digital Performance Monitoring Assessment
DRAMA	Digital Radio And Multiplex Acquisition
DR/DA	Data Reduction/Data Assessment
DSCS	Defense Satellite Communication System
DSPL	Display System Program Language
DSQC	Digital Service Quality Control

ESM	Exploratory System Control Model
ESMD	Exploratory System Control Model Development
FAC	Feldsberg-Augsburg-Coltano
FDM	Feasibility Development Model
FDM	Frequency Division Multiplex
FDX	Full Duplex
FIAC	Fault Isolation and Analysis Coordination
FKV	Frankfurt-Koenigstuhl-Vaihingen Digital Transmission System
FSK	Frequency Shift Keying
HSF	Hybrid Simulation Facility
IDN	Integrated Data Network
IEMATS	Improved Emergency Message Automatic Transmisssion System
IO	Input/Output
IOQCS	In-service Out-of-service Quality Control Subsystem
IQCS	In-service Quality Control Subsystem
ITS	Institute for Telecommunications Science
KHz	KiloHertz

MAS	Measurement Acquisition Station
MAU	Measurement Acquisition Unit; Also Monitor Alarm Unit
MCC	Major Control Center
MMAC	Major Monitor Alarm and Control Center
MSCDM	Modular System Control Development Model
MSMS	Modem Signal Monitoring Subsystem
MTBF	Mean Time Between Failure
MTTR	Mean Time to Repair
MTU	Monitor Telemetering Unit
MW	Microwave
NCS	Nodal Control Station
NCU	ESM Nodal Control Unit
NEC	Nippon Electric Company
NICS	NATO Integrated Communication System
NPR	Noise Power Ratio
NSF	National Science Foundation
NSS	Nucleus Subsystem
OCRI	Operator Control and Report Interface

OQCS	Out-of-service Quality Control Subsystem
OT&E	Operational Test and Evaluation
PA	Performance Assessment
PATE	Programmable ATEC Terminal Equipment
PCM	Pulse Code Modulation
PDU	Program Development Unit
PM	Phase Modulation
PM	Preventive Maintenance
PROM	Programmable Read Only Memory
PTF	Patch and Test Facility
QPSK	Quadrature Phase Shift Keying
R	Reporting
RAM	Random Access Memory
RCOC	Regional Communications Operations Center
RF	Radio Frequency
RFQ	Request for Quotation
RMS	Root Mean Square
RPS	Reflected Power Sensor

RSL	Received Signal Level
SAE	Stand Alone Element
SETA	System Engineering Technical Assistance Contract
SC	Scheduling of Functions
SCC	System Control Center
SCN	Specification Change Notice
SCS	Sector Control Station
SDCA	Switch Data Collection/Analysis
SMAC	Station Monitor Alarm and Control Center
SSCI	Station to Station Communications Interface
TCCF	Tactical Communications Control Facility
TCF	Tech Control Facility
TCIP	Tech Control Improvement Program
TDCS	Traffic Data Collection System
TDM	Time Division Multiplex
TTL	Transistor Transistor Logic
TTY	Teletype

VF	Voice Frequency
VFCT	Voice Frequency Carrier Telegraphy
VSQC	Voice Service Quality Control
WBSA	Wideband Signal Analysis
WT	Write Token
WWOLS	World-Wide On-Line System

APPENDIX E

BENCHMARK PROGRAM LISTINGS

E.1 TI 990/10

The benchmark program (PATH) was run for 100 loops on the TI 990/10 minicomputer with a resulting time of 5 seconds. Since the processor had a one second clock tick interval, the result could be as low as 4 seconds and as high as 6 seconds. Thus the 10 loop time listed above is within $\pm$ 100 msec. of accuracy. Listed below are the program listing and resulting printout.

```
C***********************************************************************M
C*************************** S T A R T U P *****************************M
C******* STATISTICAL ANALYSIS AND ROUTING TABLE UPDATING PROGRAM *******M
C***********************************************************************M
C************************ JULY 1976 VERSION ****************************M
C***********************************************************************M
C***********************************************************************M
C     PROGRAM MAIN(INPUT,OUTPUT,PUNCH,TAPE5=INPUT,TAPE6=OUTPUT,TAPE7=PUNM
C    1CH)                                                               M
C***********************************************************************M
C     *                                                                *M
C******  THIS SUB-PROGRAM PERFORMS THE FOLLOWING FUNCTION(S)'          *M
C     *         1. READ AND WRITE DATA                                 *M
C     *         2. WRITE PERFORMANCE BASED UPON THE ORIGINAL AND REVISED *M
C     *           ROUTING TABLES(IF REVISION WAS DONE)                 *M
C     *                                                                *M
C******  THIS SUB-PROGRAM USES THE FOLLOWING SUBROUTINE(S)'            *M
C     *         1. DECOD1(ONLY FOR EUROPEAN AUTOVON NETWORK)           *M
C     *         2. DECOD2(ONLY FOR EUROPEAN AUTOVON NETWORK)           *M
C     *         3. PATH                                                *M
C     *         4. ATGOS                                               *M
C     *         5. SORT                                                *M
C     *         6. REVRT3(IF REVISION IS NEEDED)                       *M
C     *         7. SECOND(SYSTEM DEPENDENT SUBROUTINE                  *M
C     *                                                                *M
C***********************************************************************M
      INTEGER*4 LUNIT,ERG,CCS,NPRINT,YES,NO
      DIMENSION NTIME(3)
      DIMENSION IRT( 5,15,4), FLTG(105), CLSD( 5,15), IRRT( 5,15,4), GOSM
     1(105),NODE(11),STR(15),CLS(15),PR( 5,15,5),PL( 5,15,5)            M
      COMMON LNUM( 5,15),WT( 5,15),NTRK(105),TR( 5,15),LOCATI( 5,15,5),LM
     1OCATF( 5,15,5),NPATH( 200),ILLSDR( 5,15),NS,NL,BPMAX,NPPO,NDPO,INLM
     2RT,NAUTVN,NCONRT,STEP,IFIRST
      DATA ERG,CCS,YES,NO /4HERG ,4HCCS ,4HYES ,4HNO  /
C
C                                                                       M
C*****READ AND WRITE TITLE                                              M
C                                                                       M
      READ(5,200)(GOS(I),I=1,20)                                        M
      WRITE(6,201)(GOS(I),I=1,20)                                       M
C                                                                       M
C*****READ AND WRITE OPTION CARD INFORMATION                            M
C                                                                       M
      READ(5,202)NPPO,NDPO,INLRT,NAUTVN,NCONRT,LUNIT                    M
      WRITE(6,203)NPPO,NDPO,INLRT,NAUTVN,NCONRT,LUNIT                   M
C                                                                       M
C*****CHECK IF THE TRAFFIC UNITS ARE CORRECTLY SPECIFIED                M
C                                                                       M
      IF((LUNIT.NE.CCS).AND.(LUNIT.NE.ERG)) GO TO 152                   M
C                                                                       M
C*****READ AND WRITE PROGRAM PARAMETERS                                 M
C                                                                       M
      READ(5,204)NS,NL,BPMAX,DUM,DUM1                                   M
      OVLD=1.                                                           M
```

```
      IF (DUM.NE.0.) OVLD=DUM                                        M
      STEP=0.01                                                      M
      IF(DUM1.NE.0.)STEP=DUM1                                        M
      WRITE(6,205)NS,NL,BPMAX,DUM,DUM1                               M
C                                                                    M
C*****INITIALIZE SPARSE MATRICES                                     M
C                                                                    M
      DO 101 I=1,NS                                                  M
      CLS(I)=0.                                                      M
      STR(I)=0.                                                      M
      DO 101 J=1,NS                                                  M
         LNUM(I,J)=0                                                 M
         WT(I,J)=1.                                                  M
  101 CONTINUE                                                       M
C                                                                    M
C*****READ AND WRITE TRUNK GROUP INFORMATION                         M
C                                                                    M
      DO 102 I=1,NL                                                  M
      READ(5,206)IS,ID,LN,IDUM                                       M
      WRITE(6,207)IS,ID,LN,IDUM                                      M
         LNUM(IS,ID)=LN                                              M
         LNUM(LD,IS)=LN                                              M
         NTRK(LN)=IDUM                                               M
      NPATH(LN)=IS                                                   M
      K=105+LN                                                       M
      NPATH(K)=ID                                                    M
         GOS(I)=.9                                                   M
  102 CONTINUE                                                       M
C                                                                    M
C*****READ AND WRITE ROUTING TABLE,TRAFFIC,AND NNGOS WEIGHT INFORMATION M
C                                                                    M
      IDUM=NS*(NS-1)                                                 M
      DO 103 I=1,IDUM                                                M
      READ(5,208)IS,ID,IDUM1,IDUM2,IDUM3,DUM,W                       M
      WRITE(6,209)IS,ID,IDUM1,IDUM2,IDUM3,DUM,W                      M
         IRT(IS,ID,1)=IDUM1                                          M
         IRT(IS,ID,2)=IDUM2
         IRT(IS,ID,3)=IDUM3                                          M
         IRT(IS,ID,4)=0                                              M
      IF(LUNIT.EQ.ERG)DUM=DUM*36.                                    M
         TR(IS,ID)=DUM*OVLD                                          M
         IF (W.NE.0.) WT(IS,ID)=W                                    M
  103 CONTINUE                                                       M
C                                                                    M
C*****IF THE NETWORK IS EUROPEAN AUTOVON, READ AND WRITE THE ACRONYMS M
C*****FOR ITS OFFICES                                                M
C                                                                    M
      IF(NAUTVN.EQ.1)READ(5,268)(NODE(I),I=1,11)                     M
      IF(NAUTVN.EQ.1)WRITE(6,269)(NODE(I),I=1,11)                    M
C                                                                    M
C*****WRITE USER SPECIFIED OPTIONS                                   M
C                                                                    M
      WRITE(6,257)                                                   M
      NPRINT=3HYES                                                   M
```

```
        IF(NPPO.EQ.0)NPRINT=3HNO                                              M
        WRITE(6,258)NPRINT                                                    M
        NPRINT=3HYES                                                          M
        IF(NDPO.EQ.0)NPRINT=3HNO                                              M
        WRITE(6,259)NPRINT                                                    M
        WRITE(6,260)INLRT                                                     M
        IF(INLRT.EQ.1) WRITE(6,261)                                           M
        IF(INLRT.EQ.2) WRITE(6,262)                                           M
        IF(INLRT.EQ.3) WRITE(6,263)                                           M
        WRITE(6,231)BPMAX                                                     M
        WRITE(6,267)STEP                                                      M
        IF(NAUTVN.EQ.1) WRITE(6,264)                                          M
        IF((NAUTVN.EQ.1).AND.(NCONRT.EQ.1)) WRITE(6,265)                      M
        IF((NAUTVN.EQ.1).AND.(NCONRT.EQ.0)) WRITE(6,266)                      M
C                                                                             M
C*****WRITE NETWORK DESCRIPTION                                               M
C                                                                             M
        WRITE(6,210)NS,NL                                                     M
C                                                                             M
C*****CHECK IF THE NETWORK IS EUROPEAN AUTOVON                                M
C                                                                             M
        IF(NAUTVN.EQ.1) GO TO 106                                             M
C                                                                             M
C*****WRITE TRUNK GROUP INFORMATION                                           M
C                                                                             M
        DO 104 I=1,NL                                                         M
        K=I+105                                                               M
        WRITE(6,211)I,NPATH(I),NPATH(K),NTRK(I)
        NPATH(I)=0                                                            M
        NPATH(K)=0                                                            M
  104   CONTINUE                                                              M
        WRITE(6,212)                                                          M
C                                                                             M
C*****WRITE ORIGINAL ROUTING TABLE, TRAFFIC MATRIX AND WEIGHT                 M
C       INFORMATION                                                           M
C                                                                             M
        DO 105 I=1,NS                                                         M
        DO 105 J=1,NS                                                         M
           IF (I.EQ.J) GO TO 105                                              M
        WRITE(6,213)I,J,TR(I,J),IRT(I,J,1),IRT(I,J,2),IRT(I,J,3),WT(I,J)      M
    105 CONTINUE                                                              M
        WRITE(6,273)                                                          M
        GO TO 107                                                             M
C                                                                             M
C*****WRITE TRUNK GROUP,ORIGINAL ROUTING TABLE,TRAFFIC AND WEIGHT             M
C*****INFORMATION FOR THE EUROPEAN AUTOVON NETWORK                            M
C                                                                             M
  106   ITRG=0                                                                M
        CALL DECOD1(IRT,ITRG,NODE)                                            M
C                                                                             M
C*****CHECK IF THE PATH ARE TO BE PRINTED                                     M
C                                                                             M
  107   IF(NPPO.EQ.0) GO TO 108                                               M
        WRITE(6,214)                                                          M
```

```
C                                                                       M
C*****CHECK FOR ILLEGAL PATHS IN THE ORIGINAL ROUTING TABLE              M
C                                                                       M
108    CALL TIME (NTIME)
       WRITE(6,8000)NTIME
       DO 20 I=1,100
       ISOLD=IS
       IDOLD=ID
       ICONOL=ICON
       IFIRST=1
       CALL PATH(IRT,NPPO,IS,ID,ICON)                                   M
       IS=ISOLD
       ID=IDOLD
 20    ICON=ICONOL
147    CALL TIME(NTIME)
       IFIRST=0
       CALL PATH(IRT,NPPO,IS,ID,ICON)
       WRITE(6,8010)NTIME
       WRITE(6,251)                                                     M
       STOP                                                             M
152    WRITE(6,270)
       WRITE(6,271)
       STOP
C                                                                       M
C*****FORMAT STATEMENTS                                                 M
C                                                                       M
200    FORMAT (20A4)                                                    M
201    FORMAT (1H1,20A4/1H0,30HVERBATIM ACCOUNT OF INPUT DATA)          M
202    FORMAT(5(I1,1X),A3)                                              M
203    FORMAT(1H0,5(I1,1X),A3)                                          M
204    FORMAT(I2,I3,3F6.3)                                              M
205    FORMAT(1H0,I2,I3,3F6.3)                                          M
206    FORMAT (2I2,I3,6X,I2)                                            M
207    FORMAT (1H,2I2,I3,6X,I2)                                         M
208    FORMAT(2I2,3I3,F6.2,F6.2)                                        M
209    FORMAT(1H ,2I2,3I3,2F6.2)                                        M
210    FORMAT (1H0,19HNETWORK DESCRIPTION,/1H0,29HNUMBER OF SWITCHES IN NM
      1ETWORK,1X,I2/1H ,33HNUMBER OF TRUNK GROUPS IN NETWORK,1X,I3/1H0,42M
      2X,15HEXISTING NUMBER,/1H ,11HLINK NUMBER,10X,11HSWITCH PAIR,13X,9HM
      3OF TRUNKS)                                                       M
211    FORMAT (1H ,4X,I3,15X,I2,5X,I2,17X,I3)                           M
212    FORMAT (1H0,24HSWITCH-TO-SWITCH TRAFFIC,37X,22HORIGINAL ROUTING TAM
      1BLE,/1H0,4HFROM,10X,2HTO,10X,14HTRAFFIC IN CCS,10X,8HCHOICE 1,10X,M
      28HCHOICE 2,10X,8HCHOICE 3,10X,6HWEIGHT,/1H ,46X,16H(PRIMARY ROUTESM
      3))                                                               M
213    FORMAT (1H ,1X,I2,11X,I2,14X,F6.1,16X,I3,15X,I3,15X,I3,13X,F6.2) M
214    FORMAT (1H0,43HPATH DEFINED BY THE ORIGINAL ROUTING TABLE )
230    FORMAT(1H0,27HNETWORK GRADE OF SERVICE IS, F10.5,/1H ,36HWEIGHTED M
      1NETWORK GRADE OF SERVICE IS,F10.5)                               M
231    FORMAT(1H0,45HMAXIMUM ALLOWABLE BLOCKING PROBABILITY(BPMAX),1X,F6.M
      13)                                                               M
250    FORMAT (1H ,39HTIME REQUIRED TO EXECUTE ENTIRE PROGRAM,1X,F9.3,1X,M
      17HSECONDS)                                                       M
```

```
251   FORMAT(1H0,50X,19H***S T A R T U P***,/1H ,51X,17HJULY 1976 VERSIOM
      1N)                                                                  M
252   FORMAT(1H0,90HMAXIMUM ALLOWABLE SOURCE TO DESTINATION BLOCKING PROM
      1BABILITY COULD NOT BE MET IN ALL CASES)                             M
253   FORMAT (1H ,37HTIME REQUIRED TO REVISE ROUTING TABLE,1X,F9.3,1X,7HM
      1SECONDS)                                                            M
254   FORMAT (1H0,55HTHE ORIGINAL ROUTING TABLE HAS AT LEAST ONE LOOP INM
      1 IT.,/1H ,40HA LOOP WAS ENCOUNTERED ON THE PATHS FROM,1X,I2,1X,2HTM
      2O,1X,I2,/1H ,45HEXECUTION OF THE PROGRAM HAS BEEN TERMINATED.)    M
255   FORMAT (1H0,64HTHE ORIGINAL ROUTING TABLE HAS AT LEAST TWO DISTINCM
      1T SPILL NODES/1H ,17HON THE PATHS FROM,1X,I2,1X,2HTO,1X,I2/1H ,20HM
      2EXECUTION TERMINATED)                                               M
256   FORMAT (1H0,61HTHE ORIGINAL ROUTING TABLE HAS AT LEAST TWO DISTINCM
      1T PATHS TO/1H ,29HSPILL NODES ON THE PATHS FROM,1X,I2,2HTO,1X,I2/1M
      2H ,20HEXECUTION TERMINATED)                                         M
257   FORMAT(1H1,23HUSER SPECIFIED OPTIONS')                               M
258   FORMAT(1H0,23HLIST OF PATHS REQUIRED',2X,A3)                         M
259   FORMAT(1H ,59HDETAILS OF PATH RELIABILITY AND PATH CARRIED LOAD REM
      1QUIRED',2X,A3)                                                      M
260   FORMAT(1H0,58HOPTION NUMBER FOR INITIALIZING ROUTING TABLE FOR REVM
      1ISION=,2X,I2,/1H ,27H(NOTES ON THE OPTIONS USED')                   M
261   FORMAT(1H ,61HALL SPILL SWITCHES OF THE ORIGNAL ROUTING TABLE ARE M
      1CONVERTED,/1H ,40HINTO NON-SPILL SWITCHES BEFORE REVISION))         M
262   FORMAT(1H ,61HNO CHANGES TO THE ORIGNAL ROUTING TABLE MADE BEFORE M
      1REVISION))                                                          M
263   FORMAT(1H ,61HALL NON-SPILL SECOND AND THIRD CHOICES IN THE ORIGNAM
      1L ROUTING,/1H ,34HTABLE ARE DELETED BEFORE REVISION))               M
264   FORMAT(1H0,24HGIVEN NETWORK IS AUTOVON)                              M
265   FORMAT(1H0,47HAN ATTEMPT TO IMPROVE CONUS TRAFFIC IS REQUIRED)
266   FORMAT(1H0,51HAN ATTEMPT TO IMPROVE CONUS TRAFFIC IS NOT REQUIRED)M
267   FORMAT(1H0,31HSTEP SIZE OF PBMAX REDUCTIONS=,F6.3)                   M
268   FORMAT(11(A3,1X))                                                    M
269   FORMAT(1H0,11(A3,1X))                                                M
270   FORMAT(1H0,40HTRAFFIC LOAD UNITS INCORRECTLY SPECIFIED)              M
271   FORMAT(1H ,20HEXECUTION TERMINATED)                                  M
272   FORMAT(1H ,5X,I2,2H (,A3,1H),17X,F6.1,19X,F9.6,17X,F9.6)             M
273   FORMAT(1H0,53H(CHOICE LEVEL WITH MINUS SIGN DENOTES A SPILL SWITCHM
      1))                                                                  M
274   FORMAT(1H0,54H(NUMBER OF ROWS ALTERED IN THE ORIGNAL ROUTING TABLEM
      1= ,I3,1X,1H))                                                       M
8000  FORMAT(' STARTING TIME=',I3,':',I3,':',I3)
8010  FORMAT(' ENDING TIME=',I3,':',I3,':',I3)
      END                                                                  M
```

COMMON BLOCK/$BLANK/ ALLOCATION 0BDA BYTES

LOCN	NAME	MODE	BYTES	TYPE	LOCN	NAME	MODE	BYTES	TYPE
0000	LNUM	INTEGER*2	150	ARRAY	0096	WT	REAL	300	ARRAY
01C2	NTRK	INTEGER*2	210	ARRAY	0294	TR	REAL	300	ARRAY
03C0	LOCATI	INTEGER*2	750	ARRAY	06AE	LOCATF	INTEGER*2	750	ARRAY
099C	NPATH	INTEGER*2	400	ARRAY	0B2C	ILLSDR	INTEGER*2	150	ARRAY
0BC2	NS	INTEGER*2	2	SCALAR	0BC4	NL	INTEGER*2	2	SCALAR
0BC6	BPMAX	REAL	4	SCALAR	0BCA	NPPO	INTEGER*2	2	SCALAR
0BCC	NDPO	INTEGER*2	2	SCALAR	0BCE	INLRT	INTEGER*2	2	SCALAR
0BD0	NAUTVN	INTEGER*2	2	SCALAR	0BD2	NCONRT	INTEGER*2	2	SCALAR
0BD4	STEP	REAL	4	SCALAR	0BD8	IFIRST	INTEGER*2	2	SCALAR

ARRAY ALLOCATION

LOCN	NAME	MODE	BYTES	TYPE	LOCN	NAME	MODE	BYTES	TYPE
0030	NTIME	INTEGER*2	6	ARRAY	0036	IRT	INTEGER*2	600	ARRAY
028E	FLTG	REAL	420	ARRAY	0432	CLSD	REAL	300	ARRAY
055E	IRRT	INTEGER*2	600	ARRAY	07B6	GOS	REAL	420	ARRAY
095A	NODE	INTEGER*2	22	ARRAY	0970	STR	REAL	60	ARRAY
09AC	CLS	REAL	60	ARRAY	09E8	PR	REAL	1500	ARRAY
0FC4	PL	REAL	1500	ARRAY					

SCALAR ALLOCATION

LOCN	NAME	MODE	BYTES	TYPE	LOCN	NAME	MODE	BYTES	TYPE
15A0	ERG	INTEGER*4	4	SCALAR	15A4	CCS	INTEGER*4	4	SCALAR
15A8	YES	INTEGER*4	4	SCALAR	15AC	NO	INTEGER*4	4	SCALAR
15B0	I	INTEGER*2	2	SCALAR	15B2	LUNIT	INTEGER*4	4	SCALAR
15B6	DUM	REAL	4	SCALAR	15BA	DUM1	REAL	4	SCALAR
15BE	OVLD	REAL	4	SCALAR	15C2	J	INTEGER*2	2	SCALAR
15C4	IS	INTEGER*2	2	SCALAR	15C6	ID	INTEGER*2	2	SCALAR
15C8	LN	INTEGER*2	2	SCALAR	15CA	IDUM	INTEGER*2	2	SCALAR
15CC	LD	INTEGER*2	2	SCALAR	15CE	K	INTEGER*2	2	SCALAR
15D0	IDUM1	INTEGER*2	2	SCALAR	15D2	IDUM2	INTEGER*2	2	SCALAR
15D4	IDUM3	INTEGER*2	2	SCALAR	15D6	W	REAL	4	SCALAR
15DA	NPRINT	INTEGER*4	4	SCALAR	15DE	ITRG	INTEGER*2	2	SCALAR
15E0	ISOLD	INTEGER*2	2	SCALAR	15E2	IDOLD	INTEGER*2	2	SCALAR
15E4	ICONOL	INTEGER*2	2	SCALAR	15E6	ICON	INTEGER*2	2	SCALAR

```
SUBPROGRAMS CALLED

NAME     TYPE       ARGS   NAME     TYPE       ARGS   NAME     TYPE       ARGS

F$RRF    RUNTIME           F$RROL   RUNTIME           F$RSIO   RUNTIME
F$RWF    RUNTIME           F$RIOL   RUNTIME           F$REOL   RUNTIME
DECOD1   REAL       3      TIME     REAL       1      F$RIUS   RUNTIME
PATH     REAL       5      F$RSTO   RUNTIME           F$RFZ    RUNTIME
F$RFIR   RUNTIME           F$RREL   RUNTIME           F$REVP   RUNTIME
F$XPRE   RUNTIME           F$REL    RUNTIME           F$RES    RUNTIME
F$RET    RUNTIME           F$RITP   RUNTIME

STATEMENT LABELS

LOCN  LABEL USE          LOCN  LABEL USE           LOCN  LABEL USE

0006  200   FORMAT       000C  201   FORMAT        003C  202   FORMAT
004A  203   FORMAT       12BE  152                 005C  204   FORMAT
006A  205   FORMAT       0CDA  101   DO END        0DA6  102   DO END
007C  206   FORMAT       008A  207   FORMAT        0EC2  103   DO END
009C  208   FORMAT       00B0  209   FORMAT        097C  268   FORMAT
0988  269   FORMAT       068C  257   FORMAT        06AC  258   FORMAT
06D2  259   FORMAT       071C  260   FORMAT        078A  261   FORMAT
0802  262   FORMAT       0848  263   FORMAT        033C  231   FORMAT
0950  267   FORMAT       08BA  264   FORMAT        08DC  265   FORMAT
0914  266   FORMAT       00C4  210   FORMAT        11F2  106
1104  104   DO END       018E  211   FORMAT        01AE  212   FORMAT
11CC  105                0270  213   FORMAT        0A1A  273   FORMAT
1202  107                1214  108                 02AA  214   FORMAT
0AA2  8000  FORMAT       126A  20    DO END        127C  147   UNUSED
0AC6  8010  FORMAT       03C0  251   FORMAT        0998  270   FORMAT
09CA  271   FORMAT       02DE  230   FORMAT        037A  250   FORMAT
03FE  252   FORMAT       0462  253   FORMAT        04A6  254   FORMAT
0562  255   FORMAT       05F4  256   FORMAT        09E8  272   FORMAT
0A58  274   FORMAT       0B00  M55                 0B32  M56
0C2A  M57                0C50  M58                 0E7C  M59
0EC2  M60                0F08  M61                 0F42  M62
0F6C  M63                0F9C  M64                 0FDA  M65
0FEE  M66                1002  M67                 103A  M68
1056  M69                1070  M70                 0BDA  M71
12BE  M72                0C2A  M73                 0C50  M74
0C80  M75                0CA4  M76                 0CD4  M77
0CF8  M78                0DC6  M79                 0E7C  M80
0EC2  M81                0F08  M82                 0EE4  M83
0F42  M84                0F1E  M85                 0F6C  M86
0F9C  M87                0FC6  M88                 0FDA  M89
0FEE  M90                1002  M91                 103A  M92
1056  M93                1056  M94                 1070  M95
1070  M96                11F2  M97                 1096  M98
1122  M99                1128  M100                11CC  M101
118C  M102               1214  M103                1236  M104
```

STATEMENT LOCATIONS

LINE	LOCN	LINE	LOCN	LINE	LOCN	LINE	LOCN	LINE	LOCN	LINE	LOCN
27	0AF2	28	0AF2	29	0AF2	31	0AF2	34	0AF2	39	0AF2
40	0B24	44	0B56	45	0B86	49	0BB6	53	0BDA	54	0C04
55	0C10	56	0C2A	57	0C36	58	0C50	62	0C7A	63	0C80
64	0C92	65	0C9E	66	0CA4	67	0CB8	68	0CDA	72	0CF2
73	0CF8	74	0D1C	75	0D40	76	0D56	77	0D6C	78	0D78
79	0D7E	80	0D8A	81	0D94	82	0DA6	86	0DB2	87	0DC0
88	0DC6	89	0DFC	90	0E32	91	0E48	92	0E4E	93	0E54
94	0E58	95	0E7C	96	0E9C	97	0EC2	102	0ECE	103	0F08
107	0F42	108	0F4E	109	0F5A	110	0F6C	111	0F7E	112	0F8A
113	0F9C	114	0FAE	115	0FC0	116	0FDA	117	0FEE	118	1002
119	1014	120	1026	121	103A	122	1056	126	1070	130	1088
134	1090	135	1096	136	10A2	137	10F4	138	10FC	139	1104
140	1110	145	111C	146	1122	147	1128	148	1130	149	11CC
150	11E4	151	11F0	156	11F2	157	11F6	161	1202	162	1208
166	1214	167	121C	168	1230	169	1236	170	123C	171	1242
172	1248	173	124E	174	125E	175	1264	176	126A	177	127C
178	1284	179	1288	180	1298	181	12AC	182	12B8	183	12BE
184	12CA	185	12D6	189	12DC	190	12DC	191	12DC	192	12DC
193	12DC	194	12DC	195	12DC	196	12DC	197	12DC	198	12DC
199	12DC	203	12DC	204	12DC	208	12DC	209	12DC	210	12DC
212	12DC	214	12DC	216	12DC	218	12DC	220	12DC	222	12DC
225	12DC	228	12DC	231	12DC	232	12DC	233	12DC	235	12DC
237	12DC	239	12DC	241	12DC	243	12DC	244	12DC	245	12DC
246	12DC	247	12DC	248	12DC	249	12DC	250	12DC	251	12DC
252	12DC	254	12DC	256	12DC	257	12DC	258	12DC		

ENTRY=0AE8
PROGRAM SIZE=130E BYTES
DATA SIZE=1604 BYTES
COMPILATION COMPLETE
0 WARNINGS
0 ERRORS

```
      SUBROUTINE PATH (IRT, IWR, IS, ID, ICON)                          P
C*****************************************************************************P
C     *                                                                *P
C******  THIS SUB-PROGRAM PERFORMS THE FOLLOWING FUNCTION(S)/          *P
C     *         1. ENUMERATE AND STORE ALL PATHS BETWEEN EVERY NODE PAIR *P
C     *         2. WRITE ALL THE PATHS, IF REQUIRED                    *P
C     *         3. CHECK IF ANY ILLEGAL PATHS ARE FORMED               *P
C     *                                                                *P
C*****************************************************************************P
      DIMENSION IRT( 5,15,4), IPATH(15), ITSS(2), ITDS(2), LS(2), MS(2) P
      COMMON LNUM( 5,15),WT( 5,15),NTRK(105),TR( 5,15),LOCATI( 5,15,5),LP
     1OCATF( 5,15,5),NPATH( 200),ILLSDR( 5,15),NS,NL,BPMAX,NPPO,NDPO,INLP
     2RT,NAUTVN,NCONRT,STEP,IFIRST
      ICON=0                                                            P
C                                                                       P
C*****INITIALIZE SPARSE MATRICES                                        P
C                                                                       P
      DO 101 I=1,NS                                                     P
      DO 101 J=1,NS                                                     P
      DO 101 K=1,5                                                      P
         LOCATI(I,J,K)=0                                                P
         LOCATF(I,J,K)=0                                                P
  101 CONTINUE                                                          P
C                                                                       P
C*****INITIALIZE PARAMETERS                                             P
C                                                                       P
      KOUNT=1                                                           P
      ISC=0                                                             P
      IS=1                                                              P
      IPATH(1)=-1                                                       P
      ID=1                                                              P
C                                                                       P
C*****INCREMENT DESTINATION                                             P
C                                                                       P
  102 ID=ID+1                                                           P
      IF (ID.GT.NS) GO TO 111                                           P
      IF (ID.EQ.IS) GO TO 102                                           P
C                                                                       P
C*****BEGIN PATH IDENTIFICATION                                         P
C                                                                       P
  103 NUMBER=1                                                          P
      IAFTER=0                                                          P
      IPSP=0                                                            P
      ISPS=0                                                            P
C                                                                       P
C*****WRITE SOURCE AND DESTINATION NODE NUMBERS WHOSE PATH IS TO BE     P
C*****FOUND                                                             P
C                                                                       P
      IF (IWR.NE.0.AND.IFIRST.EQ.0) WRITE (6,200) IS,ID                 P
      L=1                                                               P
      M=1                                                               P
      ITS=IS                                                            P
C                                                                       P
C*****DETERMINE NEXT NODE ON PATH                                       P
```

```
      C                                                                  P
        104 ITD=IRT(ITS,ID,L)                                            P
      C                                                                  P
      C*****CHECK TO SEE IF THIS NODE HAS BEEN PREVIOUSLY ENCOUNTERED    P
      C       THEREBY FORMING A LOOP                                     P
      C                                                                  P
        105 DO 106 I=1,M                                                 P
            IF (IABS(ITD).EQ.IABS(IPATH(I))) GO TO 115                   P
        106 CONTINUE                                                     P
      C                                                                  P
      C*****PUT NODE ON PATH                                             P
      C                                                                  P
            M=M+1                                                        P
            IPATH(M)=ITD                                                 P
            ITD=IABS(ITD)                                                P
      C                                                                  P
      C*****CHECK IF TEMPORARY SOURCE IS A SPILL NODE                    P
      C                                                                  P
            IDUM=M-1                                                     P
            IF (ITS.EQ.IPATH(IDUM)) GO TO 109                            P
      C                                                                  P
      C*****STORE THE SPILL NODE IN THE STACK                            P
      C                                                                  P
            ISPS=ITS                                                     P
            IF (ISPS.EQ.IS) GO TO 107                                    P
      C                                                                  P
      C*****CHECK TO SEE IF THERE ARE TWO DISTINCT ROUTES TO SPILL NODES P
      C       OR IF TWO SPILL NODES OCCUR ON SAME PATH                   P
      C                                                                  P
            IF (IAFTER.EQ.1) GO TO 116                                   P
            IF (IPSP.EQ.0) IPSP=ISPS                                     P
            IF (IPSP.EQ.ISPS) GO TO 107                                  P
      C                                                                  P
      C*****RETURN FOR TWO DISTINCT SPILL NODES                          P
      C                                                                  P
            ICON=2                                                       P
            RETURN                                                       P
      C                                                                  P
      C*****FIND AND STORE THE NEXT ALTERNATE DESTINATION FROM THE SPILL NODE P
      C                                                                  P
        107 L=L+1                                                        P
            IAD=IRT(ITS,ID,L)                                            P
            IF (IAD.EQ.0) GO TO 108                                      P
            ISC=ISC+1                                                    P
            ITSS(ISC)=ITS                                                P
            ITDS(ISC)=IAD                                                P
            LS(ISC)=L                                                    P
            MS(ISC)=M-1                                                  P
            GO TO 109                                                    P
      C                                                                  P
      C*****CHECK TO SEE IF THE NEXT PATH IS THE FIRST ONE AFTER THE LAST PATHP
      C       OF A SPILL NODE                                            P
      C                                                                  P
        108 IF (IPSP.NE.0) IAFTER=1                                      P
```

```
C
C*****CHECK TO SEE IF THE DESTINATION NODE HAS BEEN REACHED
C
  109 IF (ITD.EQ.ID) GO TO 112
C
C*****ADVANCE TO THE NEXT LINK OF PATH
C
      ITS=ITD
      L=1
      GO TO 104
C
C*****WITHDRAW THE LAST STORED ALTERNATE DESTINATION IN THE STACK
C
  110 ITS=ITSS(ISC)
      ITD=ITDS(ISC)
      L=LS(ISC)
      M=MS(ISC)
      ISC=ISC-1
      GO TO 105
C
C*****INCREMENT THE SOURCE AND REINITIALIZE THE DESTINATION OR RETURN
C
  111 IS=IS+1
      IF (IS.GT.NS) RETURN
      IPATH(1)=-IS
      ID=1
      GO TO 103
C
C*****PUT THE COMPLETED PATH INTO SPARSE ARRAY AND NOTE ITS INITIAL AND
C     FINAL ADDRESSES
C
  112 LOCATI(IS,ID,NUMBER)=KOUNT
      LOCATF(IS,ID,NUMBER)=KOUNT+M-1
      NUMBER=NUMBER+1
C
C*****WRITE THE SEQUENCE OF NODES ON THE PATH FROM SOURCE TO DESTINATION
C
      IF (IWR.NE.0.AND.IFIRST.EQ.0) WRITE (6,201) (IPATH(I),I=1,M)
      DO 113 I=1,M
         NPATH(KOUNT)=IPATH(I)
         KOUNT=KOUNT+1
         IF (KOUNT.GT.3000) GO TO 114
  113 CONTINUE
      IF (ISC.EQ.0) GO TO 102
      GO TO 110
C
C*****MESSAGE FOR PATH ARRAY OVERFLOW
C
  114 WRITE (6,202)
      STOP
C
C*****RETURN FOR LOOP IN PATH
C
  115 ICON=1
```

```
      RETURN                                                                P
C                                                                           P
C*****RETURN FOR TWO PATHS TO SAME OR DISTINCT SPILL NODES                   P
C                                                                           P
  116 ICON=3                                                                P
      RETURN                                                                P
200   FORMAT (1H0,4HFROM,1X,I2,1X,2HTO,1X,I2)                               P
201   FORMAT (1H ,15(1H(,I3,1H)))                                           P
202   FORMAT (1H0,20HPATH MEMORY OVERFLOW,/1H ,20HEXECUTION TERMINATED)     P
      END                                                                   P
```

COMMON BLOCK/$BLANK/ ALLOCATION 0BDA BYTES

LOCN	NAME	MODE	BYTES	TYPE	LOCN	NAME	MODE	BYTES	TYPE
0000	LNUM	INTEGER*2	150	ARRAY	0096	WT	REAL	300	ARRAY
01C2	NTRK	INTEGER*2	210	ARRAY	0294	TR	REAL	300	ARRAY
03C0	LOCATI	INTEGER*2	750	ARRAY	06AE	LOCATF	INTEGER*2	750	ARRAY
099C	NPATH	INTEGER*2	400	ARRAY	0B2C	ILLSDR	INTEGER*2	150	ARRAY
0BC2	NS	INTEGER*2	2	SCALAR	0BC4	NL	INTEGER*2	2	SCALAR
0BC6	BPMAX	REAL	4	SCALAR	0BCA	NPPO	INTEGER*2	2	SCALAR
0BCC	NDPO	INTEGER*2	2	SCALAR	0BCE	INLRT	INTEGER*2	2	SCALAR
0BD0	NAUTVN	INTEGER*2	2	SCALAR	0BD2	NCONRT	INTEGER*2	2	SCALAR
0BD4	STEP	REAL	4	SCALAR	0BD8	IFIRST	INTEGER*2	2	SCALAR

ARRAY ALLOCATION

LOCN	NAME	MODE	BYTES	TYPE	LOCN	NAME	MODE	BYTES	TYPE
0030	IPATH	INTEGER*2	30	ARRAY	004E	ITSS	INTEGER*2	4	ARRAY
0052	ITDS	INTEGER*2	4	ARRAY	0056	LS	INTEGER*2	4	ARRAY
005A	MS	INTEGER*2	4	ARRAY					

SCALAR ALLOCATION

LOCN	NAME	MODE	BYTES	TYPE	LOCN	NAME	MODE	BYTES	TYPE
005E	I	INTEGER*2	2	SCALAR	0060	J	INTEGER*2	2	SCALAR
0062	K	INTEGER*2	2	SCALAR	0064	KOUNT	INTEGER*2	2	SCALAR
0066	ISC	INTEGER*2	2	SCALAR	0068	NUMBER	INTEGER*2	2	SCALAR
006A	IAFTER	INTEGER*2	2	SCALAR	006C	IPSP	INTEGER*2	2	SCALAR
006E	ISPS	INTEGER*2	2	SCALAR	0070	L	INTEGER*2	2	SCALAR
0072	M	INTEGER*2	2	SCALAR	0074	ITS	INTEGER*2	2	SCALAR
0076	ITD	INTEGER*2	2	SCALAR	0078	IDUM	INTEGER*2	2	SCALAR
007A	IAD	INTEGER*2	2	SCALAR					

DUMMY ARGUMENT ALLOCATION

LOCN	NAME	MODE	BYTES	TYPE	LOCN	NAME	MODE	BYTES	TYPE
007C	IRT	INTEGER*2	2	ARRAY	007E	IWR	INTEGER*2	2	SCALAR
0080	IS	INTEGER*2	2	SCALAR	0082	ID	INTEGER*2	2	SCALAR
0084	ICON	INTEGER*2	2	SCALAR					

SUBPROGRAMS CALLED

NAME	TYPE	ARGS	NAME	TYPE	ARGS	NAME	TYPE	ARGS
F$RWF	RUNTIME		F$RIOL	RUNTIME		F$RSIO	RUNTIME	
IABS	INTEGER*2	1	F$RSTO	RUNTIME		F$RFZ	RUNTIME	
F$RGMY	RUNTIME							

STATEMENT LABELS

LOCN	LABEL	USE	LOCN	LABEL	USE	LOCN	LABEL	USE
00BA	101	DO END	00FC	102		02C6	111	
0110	103		0004	200	FORMAT	015C	104	
0182	105		019E	106	DO END	03C6	115	
0286	109		0224	107		03D0	116	
027A	108		02EE	112		02A0	110	
0024	201	FORMAT	039E	113	DO END	03B4	114	
0038	202	FORMAT	008C	M19		0092	M20	
0098	M21		02C6	M22		00FC	M23	
0148	M24		0148	M25		0148	M26	
01FC	M27		0188	M28		03C6	M29	
0286	M30		0224	M31		03D0	M32	
01FC	M33		0212	M34		0224	M35	
027A	M36		0286	M37		0286	M38	
02EE	M39		02D6	M40		02D6	M41	
037A	M42		037A	M43		037A	M44	
0356	M45		0380	M46		03B4	M47	
00FC	M48							

STATEMENT LOCATIONS

LINE	LOCN	LINE	LOCN	LINE	LOCN	LINE	LOCN	LINE	LOCN	LINE	LOCN
259	0000	268	0080	269	0080	272	0080	276	0086	277	008C
278	0092	279	0098	280	00B6	281	00BA	285	00DE	286	00E4
287	00E8	288	00F0	289	00F4	293	00FC	294	0102	295	0108
299	0110	300	0116	301	011A	302	011E	307	0122	308	0148
309	014E	310	0154	314	015C	319	0182	320	0188	321	019E
325	01AA	326	01AE	327	01BA	331	01C4	332	01CE	336	01D8
337	01DE	342	01E8	343	01F0	344	01FC	348	021A	349	0222
353	0224	354	0228	355	024E	356	0254	357	0258	358	0264
359	0268	360	026E	361	0278	366	027A	370	0286	374	0290
375	0296	376	029C	380	02A0	381	02AC	382	02B2	383	02B8
384	02BE	385	02C2	389	02C6	390	02CC	391	02D6	392	02E2
393	02EA	398	02EE	399	0312	400	0336	404	033A	405	037A
406	0380	407	0392	408	0396	409	039E	410	03AA	411	03B0
415	03B4	416	03C0	420	03C6	421	03CE	425	03D0	426	03D8
427	03DA	428	03DA	429	03DA	430	03DA				

```
ENTRY=0072
PROGRAM SIZE=03EC BYTES
DATA SIZE=0088 BYTES
COMPILATION COMPLETE
0 WARNINGS
0 ERRORS
```

COMMAND LIST

```
NOSYMT
LIBRARY FILES.FORTRN.OSLOBJ
LIBRARY FILES.FORTRN.STLOBJ
PHASE 0, FORT
INCLUDE FILES.FTNOBJ
END
```

LINK MAP

```
CONTROL FILE = FILES.LARRY.FTNLINK

LINKED OUTPUT FILE = FILES.FTNRUN

LIST FILE = FILES.LISTLNF2

OUTPUT FORMAT = ASCII
```

PHASE 0, FORT   ORIGIN = 0000 LENGTH = 7830

MODULE	NO	ORIGIN	LENGTH	TYPE	DATE	TIME	CREATOR
$MAIN	1	0000	130E	INCLUDE	07/11/77	11:05:28	FTN990
$DATA	1	5020	1604				
PATH	2	130E	03EC	INCLUDE	07/11/77	11:05:28	FTN990
$DATA	2	6624	0088				
F$RFZ	3	16FA	0354	LIBRARY	04/11/77	16:06:40	SDSMAC
F$RFIR	4	1A4E	08B4	LIBRARY	04/11/77	15:47:28	SDSMAC
F$RINP	5	2302	0074	LIBRARY	04/26/77	18:25:10	SDSMAC
TIME	6	2376	0030	LIBRARY	05/22/76	11:32:55	FTN990
$DATA	6	66AC	0032				
F$RPAU	7	23A6	00B0	LIBRARY	12/16/76	16:42:02	SDSMAC
F$XPRE	8	2456	004A	LIBRARY	12/03/76	17:42:52	SDSMAC
F$ERRC	9	24A0	013C	LIBRARY	12/16/76	16:13:13	SDSMAC
F$RFTS	10	25DC	006A	LIBRARY	05/21/76	17:49:04	SDSMAC
F$FINP	11	2646	0B52	LIBRARY	05/12/77	09:47:21	SDSMAC
F$RBUF	12	3198	008C	LIBRARY	02/18/77	07:52:42	SDSMAC
F$RWRK	13	3224	0172	LIBRARY	05/10/77	16:41:44	SDSMAC
F$XFCB	14	3396	00C8	LIBRARY	11/18/76	16:10:05	SDSMAC
F$XVFB	15	345E	02B4	LIBRARY	05/27/77	14:42:44	SDSMAC
DATIME	16	3712	0038	LIBRARY	05/22/76	12:51:13	FTN990
$DATA	16	66DE	0038				
F$XCLS	17	374A	0086	LIBRARY	05/05/77	16:33:43	SDSMAC
F$RPRE	18	37D0	008E	LIBRARY	05/11/77	08:34:35	SDSMAC
F$XFTL	19	385E	0012	LIBRARY	05/11/77	15:44:17	SDSMAC
F$XLOG	20	3870	0083	LIBRARY	05/05/77	10:06:54	SDSMAC
F$XLWS	21	38F4	0027	LIBRARY	05/06/77	14:29:31	SDSMAC
F$XTBL	22	391C	038D	LIBRARY	11/18/76	15:55:59	SDSMAC
F$XERR	23	3CAA	000A	LIBRARY	12/03/76	17:43:39	SDSMAC
F$XIOF	24	3CB4	0123	LIBRARY	11/17/76	15:20:09	SDSMAC
F$XLIO	25	3DD8	001A	LIBRARY	05/05/77	16:41:51	SDSMAC
F$RMSG	26	3DF2	015B	LIBRARY	01/07/77	10:05:43	SDSMAC
F$RSVC	27	3F4E	0074	LIBRARY	04/25/77	18:02:30	SDSMAC
F$XBUT	28	3FC2	002D	LIBRARY	11/10/76	15:08:50	SDSMAC
F$XREL	29	3FF0	001A	LIBRARY	05/28/76	19:19:28	SDSMAC
F$REVP	30	400A	000C	LIBRARY	12/16/76	16:49:53	SDSMAC
EXINT	31	4016	0172	LIBRARY	04/11/77	16:14:00	SDSMAC
F$RITP	32	4188	0010	LIBRARY	04/26/77	18:24:35	SDSMAC
F$RGMY	33	4198	007E	LIBRARY	06/02/76	10:18:28	SDSMAC
F$XRST	34	4216	0002	LIBRARY	12/17/76	17:13:42	SDSMAC
F$RLOC	35	4218	0040	LIBRARY	05/22/76	12:09:20	SDSMAC
S$GTCA	36	4258	060C	LIBRARY	06/01/77	08:19:17	SDSLNK
$DATA	36	6716	04F0				
F$FLT	37	4864	00A4	LIBRARY	05/22/76	14:51:03	SDSMAC
F$PASR	38	4908	0164	LIBRARY	05/20/76	13:27:42	SDSMAC
F$XMR	39	4A6C	00A4	LIBRARY	05/20/76	13:50:32	SDSMAC
F$XDR	40	4B10	0158	LIBRARY	05/20/76	14:03:58	SDSMAC
F$FIX	41	4C68	00C4	LIBRARY	05/22/76	14:47:37	SDSMAC
F$RWSP	42	4D2C	00FC	LIBRARY	12/17/76	17:16:02	SDSMAC
F$FITP	43	4E28	01B6	LIBRARY	07/23/76	11:59:39	SDSMAC
F$RAER	44	4FDE	0041	LIBRARY	04/26/77	18:26:02	SDSMAC

COMMON	NO	ORIGIN	LENGTH
$BLANK	2	6C06	0BDA
TIMXXX	6	77E0	0028
REGSXX	16	7808	0028

D E F I N I T I O N S

NAME	VALUE	NO	NAME	VALUE	NO	NAME	VALUE	NO	NAME	VALUE	NO
*$MAIN	0000	1	A$BBUF	0106*	13	A$BFCB	00FA*	13	A$BPRB	0102*	13
A$BTCA	00FE*	13	A$BWK1	3224	13	A$BWK2	4D2C	42	A$EFCB	00FC*	13
A$EPRB	0104*	13	A$ETCA	0100*	13	*CIFLAG	6BE6	36	*CODE	6BE8	36
DATIME	3712	16	*EXPIRE	6B78	36	F$ALN1	012D*	13	F$ALN2	012C*	13
F$ASAD	0006*	18	F$ASLU	016E*	13	F$ERRC	24A0	9	F$ERRS	24A6	9
*F$ERST	252A	9	*F$FACC	265E	11	*F$FACD	2662	11	F$FCBE	000A*	18
F$FCOL	28DC	11	F$FCUS	2870	11	F$FDEN	2678	11	*F$FDIS	2646	11
*F$FDIT	264A	11	F$FDOL	28CE	11	F$FDUS	2862	11	F$FENN	266E	11
F$FEOL	28A0	11	F$FEUS	2834	11	F$FFOL	28AE	11	F$FFUS	2842	11
F$FIOL	2892	11	F$FITP	4E28	43	F$FIUS	2826	11	F$FLAG	0005*	18
F$FLOL	28F0	11	F$FLUS	2884	11	F$FRE	26A8	11	F$FREB	26A2	11
F$FRED	269C	11	F$FRER	2696	11	F$FRF	26C0	11	F$FRFB	26BA	11
F$FRFD	26B4	11	F$FRFR	26AE	11	F$FROL	28C0	11	F$FRUS	2854	11
F$FSIO	295E	11	F$FWE	2684	11	F$FWER	267E	11	F$FWF	2690	11
F$FWFR	268A	11	F$ILOG	334E	13	F$INAS	0168*	13	F$LSTA	0001*	18
F$LUNO	0000*	18	F$LUNT	0166*	13	F$NAME	0008*	18	*F$OPEN	366E	15
F$PRB	0002*	18	F$R10A	0014*	13	F$R10B	011C*	13	F$RAER	4FDE	44
*F$RASN	0376*	22	F$RBUF	319C	12	*F$RCAL	0375*	22	*F$RCOL	236E	5
*F$RCUS	2352	5	*F$RDEN	2306	5	*F$RDOL	2366	5	*F$RDUS	234A	5
*F$REA	4036	31	*F$RECB	411C	31	*F$REDV	406A	31	F$REL	4016	31
*F$REMP	4048	31	*F$RENG	4138	31	*F$RENN	2302	5	F$REOL	235A	5
F$RES	4024	31	*F$RESQ	4108	31	F$RET	414C	31	*F$REUS	233E	5
F$REVP	400A	30	F$RFD	1B32	4	F$RFE	1B20	4	F$RFF	1AF8	4
F$RFFD	2FBC	11	F$RFFQ	260A	10	F$RFG	1A4E	4	F$RFI	16FA	3
F$RFIR	1ADC	4	F$RFL	181E	3	*F$RFOL	235E	5	F$RFRW	2F44	11
F$RFSI	296E	11	F$RFSR	3056	11	F$RFSW	2FF2	11	F$RFTS	25DC	10
*F$RFUS	2342	5	F$RFWB	2632	10	F$RFWD	2F34	11	F$RFZ	1884	3
F$RGMY	4198	33	F$RIOL	2356	5	F$RITP	4188	32	F$RIUS	233A	5
F$RLOG	0128*	13	*F$RLOL	236A	5	F$RLP2	012A*	13	*F$RLUS	234E	5
*F$RMON	038C*	22	*F$RNUM	036F*	22	*F$ROP	0362*	22	*F$RPAU	23A6	7
*F$RPRB	0360*	22	F$RPRE	37D0	18	*F$RPRM	0370*	22	*F$RRE	2326	5
*F$RREB	2322	5	*F$RRED	231E	5	*F$RREL	3FF0	29	*F$RRER	231A	5
F$RRF	2336	5	*F$RRFB	2332	5	*F$RRFD	232E	5	*F$RRFR	232A	5
F$RROL	2362	5	*F$RRUS	2346	5	F$RSIO	2372	5	F$RSTO	23B8	7
*F$RTCA	0366*	22	F$RTFG	324C	13	*F$RTID	0373*	22	F$RVFB	0028*	13
F$RVP2	002A*	13	*F$RWE	230E	5	*F$RWER	230A	5	F$RWF	2316	5
*F$RWFR	2312	5	F$RWRK	3226	13	F$RWSP	4D2E	42	F$STAT	0004*	18
F$UNIT	0161*	13	F$XAR	4912	38	F$XBCH	0020*	21	F$XBFS	0088*	12
*F$XBUI	3D84	24	*F$XBUO	3D70	24	F$XBUT	3FC2	28	*F$XCAL	3C91	22
F$XCDE	4C74	41	F$XCDI	4C70	41	F$XCED	4870	37	F$XCER	486C	37
F$XCID	4868	37	F$XCIR	4864	37	F$XCLS	374A	17	F$XCPX	0022*	21
F$XCPY	0023*	21	F$XCRE	4C6C	41	F$XCRI	4C68	41	F$XDR	4B12	40
*F$XEOF	3D66	24	F$XERR	3CAA	23	F$XFCB	3396	14	F$XFCE	345E	14
*F$XFND	3D6C	24	F$XFTL	385E	19	F$XLIO	3DD8	25	F$XLOG	3870	20
F$XLR	3FF0	29	F$XLWS	38F4	21	*F$XMON	3CA8	22	F$XMR	4A6E	39

NAME	VALUE	NO	NAME	VALUE	NO	NAME	VALUE	NO	NAME	VALUE	NO
F$XNGR	3FFC	29	F$XPRE	2456	8	F$XPSE	384C	18	F$XRED	3CB4	24
F$XRST	4216	34	*F$XRWD	3D4E	24	F$XSR	490A	38	F$XSTP	3854	18
F$XSTR	3FF6	29	F$XTBE	3C7C	22	F$XTBL	391C	22	*F$XTID	3C8F	22
*F$XTRA	3D46	24	F$XVFB	346A	15	F$XVWS	332E	13	F$XWRT	3CD2	24
G$XE01	3DF2	26	*G$XE02	3E05	26	*G$XE03	3E1A	26	*G$XE04	3E2C	26
*G$XE05	3E3D	26	*G$XE06	3E4E	26	G$XE08	3E60	26	G$XE09	3E82	26
G$XE10	3EAF	26	*G$XE11	3ECA	26	G$XE12	3EE5	26	G$XE13	3EFD	26
G$XE14	3F3B	26	*IO$CLS	45E0	36	*IO$DOV	45E2	36	*IO$LUV	45E4	36
*IO$OPN	45E6	36	LOC	4218	35	*MYTASK	6BEC	36	*OPCASG	45E8	36
*OPCBKS	45E9	36	*OPCCLS	45EA	36	*OPCFWS	45EB	36	*OPCOPN	45EC	36
*OPCOPX	45ED	36	*OPCRAS	45EE	36	*OPCRDR	45EF	36	*OPCREW	45F0	36
*OPCWAS	45F1	36	*OPCWEF	45F2	36	*OVYSAV	6B7A	36	P$ABUF	0006*	18
*P$AKEY	000C*	18	P$CCNT	000A*	18	P$ERR	0001*	18	*P$IFA	001C*	18
P$LACN	0016*	18	P$LUN	0003*	18	P$OP	0002*	18	*P$PASS	0018*	18
P$PFCB	0024*	18	*P$PRB	0000*	18	P$PRBE	0026*	18	*P$REC1	000D*	18
*P$REC2	000E*	18	P$RECL	0008*	18	*P$RES1	000C*	18	*P$RES2	001A*	18
*P$SFA	0020*	18	*P$SFLG	0004*	18	*P$SVC0	0000*	18	P$UFLG	0005*	18
P$ULRL	0012*	18	P$UPRL	0014*	18	P$UTF1	0010*	18	*P$UTF2	0011*	18
*PARM1	6BF2	36	*PARM2	6BF4	36	PATH	130E	2	*PRBBAD	0006*	36
*PRBCHC	000A*	36	*PRBCUR	0012*	36	*PRBERC	0001*	36	*PRBERR	0001*	36
*PRBEVN	0011*	36	*PRBFIL	0010*	36	*PRBFLD	0014*	36	*PRBLUN	0003*	36
*PRBOPC	0002*	36	*PRBPTN	0016*	36	*PRBRCL	0008*	36	*PRBRLN	0008*	36
*PRBSFL	0004*	36	*PRBTYP	0006*	36	*PRBUFL	0005*	36	*PRBUTF	0010*	36
*PRBXFL	000E*	36	*PRMTMP	6BE2	36	*PX$CUR	0012*	18	*PX$EVC	0011*	18
*PX$FIL	0010*	18	*PX$FLG	000E*	18	*PX$FST	0014*	18	*S$$ADS	470A	36
*S$$ARB	47C2	36	*S$$COP	4680	36	*S$$GRB	47C4	36	*S$$LUP	46A4	36
*S$APRB	3632	15	S$CLOS	43C2	36	S$GTCA	4258	36	S$MAPS	4326	36
*S$NEW	47D8	36	S$OPEN	442C	36	*S$PARM	4646	36	*S$PTCA	42A0	36
S$RTCA	42DE	36	*S$SCPY	4670	36	*S$SETS	46EE	36	S$STOP	4600	36
S$WEOL	4484	36	S$WRIT	44EA	36	*STATE	6BF6	36	SVC	3F4E	27
*TCAAVL	000A*	36	*TCABUF	6716	36	*TCANCT	0008*	36	*TCAPRB	6A78	36
*TCAPTR	6A88	36	*TCATSB	0002*	36	*TCBUFF	6A7E	36	*TCCHCT	6A82	36
*TCFLAG	6A7C	36	*TCLUNO	6A7B	36	*TCOPCD	6A7A	36	*TCRECL	6A80	36
*TCRECN	6A86	36	*TCSTAT	6A79	36	*TDELAY	6A8A	36	TIME	2376	6
*TLAPRB	6A8E	36	*TLF	6AB6	36	*TLFBSZ	6AB8	36	*TLFBUF	6ABC	36
*TLFLUN	6B48	36	*TLFNAM	6BF8	36	*TLFNXT	6B4A	36	*TLFPRB	6B4C	36
*TLFREC	6B74	36	*TLFTYP	6B76	36	*TRMNUM	6C04	36	*UFLBLK	45F4	36
*UFLEXW	45F5	36	*UFLXTD	45F6	36	*UTFACR	45F8	36	*UTFGLN	45FC	36
*UTFTLC	45FE	36	*W$$A3I	6BA2	36	*W$$A4I	6B82	36	*W$BID	6BA2	36
*W$CLOS	6B82	36	*W$DPAG	6BC2	36	*W$FMT	6BC2	36	*W$GKEY	6BC2	36
*W$GTCA	6BA2	36	*W$IADD	6B82	36	*W$IASC	6B82	36	*W$IDIV	6B82	36
*W$IMUL	6B82	36	*W$INT	6BC2	36	*W$ISUB	6B82	36	*W$MAPK	6B82	36
*W$MAPS	6B82	36	*W$NEW	6B82	36	*W$OPEN	6B82	36	*W$OVLY	6B82	36
*W$PARM	6B82	36	*W$PKEY	6BC2	36	*W$PNCT	6B82	36	*W$PTCA	6B82	36
*W$QBID	6BA2	36	*W$RIT	6BA2	36	*W$RTCA	6B82	36	*W$SCOM	6B82	36
*W$SCPY	6B82	36	*W$SETK	6B82	36	*W$SETS	6B82	36	*W$SNCT	6BA2	36
*W$SPLT	6B82	36	*W$STAT	6B82	36	*W$STOP	6BC2	36	*W$WEOL	6B82	36
*W$WIT	6BA2	36	*W$WRIT	6B82	36						

UNRESOLVED REFERENCES

NAME	COUNT	NO	NAME	COUNT	NO	NAME	COUNT	NO	NAME	COUNT	NO
DECOD1	1	1									

NAME	COUNT NO	NAME	COUNT NO	NAME	COUNT NO	NAME	COUNT NO

**** LINKING COMPLETED

```
*********************** EXAMPLE 5.1: 5-NODE, 8-LINK NETWORK ***************

VERBATIM ACCOUNT OF INPUT DATA

1 1 2 0 0 ERG

 5  8   .010 1.000 0.000
 1 2  1        14
 1 3  2        12
 2 4  3        10
 4 5  4         7
 3 5  5        10
 2 3  6        12
 2 5  7        13
 3 4  8        15
 1 2  2   0   0  1.50   1.00
 1 3  3   0   0  2.00   1.00
 1 4  2   3   0  2.00   1.00
 1 5  3   2   0  4.00   1.00
 2 1  1   0   0  1.50   1.00
 2 3  3   4   0  2.80   1.00
 2 4  4   3   0  3.00   1.00
 2 5  5   3   0  1.20   1.00
 3 1  1   0   0  2.00   1.00
 3 2  2   0   0  2.50   1.00
 3 4  4   0   0  5.00   1.00
 3 5  5   4   0  4.20   1.00
 4 1  3   2   0  1.70   1.00
 4 2  2   5   0  2.20   1.00
 4 3  3   5   0  3.00   1.00
 4 5  5   3   0  1.60   1.00
 5 1  3   2   0  2.50   1.00
 5 2  2   4   0  2.50   1.00
 5 3  3   2   0  1.20   1.00
 5 4  4   3   0  1.00   1.00
```

```
USER SPECIFIED OPTIONS'

LIST OF PATHS REQUIRED'  YES
DETAILS OF PATH RELIABILITY AND PATH CARRIED LOAD REQUIRED'   YES

OPTION NUMBER FOR INITIALIZING ROUTING TABLE FOR REVISION=   2
(NOTES ON THE OPTIONS USED'
NO CHANGES TO THE ORIGNAL ROUTING TABLE MADE BEFORE REVISION)

MAXIMUM ALLOWABLE BLOCKING PROBABILITY(BPMAX)    .010

STEP SIZE OF PBMAX REDUCTIONS=,  .010

NETWORK DESCRIPTION

NUMBER OF SWITCHES IN NETWORK  5
NUMBER OF TRUNK GROUPS IN NETWORK   8
```

LINK NUMBER	SWITCH PAIR		EXISTING NUMBER OF TRUNKS
1	1	2	14
2	1	3	12
3	2	4	10
4	4	5	7
5	3	5	10
6	2	3	12
7	2	5	13
8	3	4	15

SWITCH-TO-SWITCH TRAFFIC

ORIGINAL ROUTING T

FROM	TO	TRAFFIC IN CCS	CHOICE 1 (PRIMARY ROUTES)	CHOICE 2
1	2	54.0	2	0
1	3	72.0	3	0
1	4	72.0	2	3
1	5	144.0	3	2
2	1	54.0	1	0
2	3	100.8	3	4
2	4	108.0	4	3
2	5	43.2	5	3
3	1	72.0	1	0
3	2	90.0	2	0
3	4	180.0	4	0
3	5	151.2	5	4
4	1	61.2	3	2
4	2	79.2	2	5
4	3	108.0	3	5
4	5	57.6	5	3
5	1	90.0	3	2
5	2	90.0	2	4
5	3	43.2	3	2
5	4	36.0	4	3

(CHOICE LEVEL WITH MINUS SIGN DENOTES A SPILL SWITCH)

PATH DEFINED BY THE ORIGINAL ROUTING TABLE
STARTING TIME= 11: 22: 57

FROM 1 TO 2
(-1)(2)(

FROM 1 TO 3
(-1)(3)(

FROM 1 TO 4
(-1)(2)(4)(
(-1)(3)(4)(

FROM 1 TO 5
(-1)(3)(5)(
(-1)(2)(5)(

FROM 2 TO 1
(-2)(1)(

FROM 2 TO 3
(-2)(3)(
(-2)(4)(3)(

```
FROM  2 TO  4
( -2)(  4)(
( -2)(  3)(  4)(

FROM  2 TO  5
( -2)(  5)(
( -2)(  3)(  5)(

FROM  3 TO  1
( -3)(  1)(

FROM  3 TO  2
( -3)(  2)(

FROM  3 TO  4
( -3)(  4)(

FROM  3 TO  5
( -3)(  5)(
( -3)(  4)(  5)(

FROM  4 TO  1
( -4)(  3)(  1)(
( -4)(  2)(  1)(

FROM  4 TO  2
( -4)(  2)(
( -4)(  5)(  2)(

FROM  4 TO  3
( -4)(  3)(
( -4)(  5)(  3)(

FROM  4 TO  5
( -4)(  5)(
( -4)(  3)(  5)(

FROM  5 TO  1
( -5)(  3)(  1)(
( -5)(  2)(  1)(

FROM  5 TO  2
( -5)(  2)(
( -5)(  4)(  2)(

FROM  5 TO  3
( -5)(  3)(
( -5)(  2)(  3)(

FROM  5 TO  4
( -5)(  4)(
( -5)(  3)(  4)(
ENDING TIME= 11: 23:  2
```

E.2 TI 990/4

The benchmark was run for 100 loops on the TI 990/4 microcomputer with a resulting time of 7 seconds. Since the processor had a one second clock time interval, the result could be as low as 6 seconds and as high as 8 seconds. Thus the 10 loop time listed above is within $\pm$ 100 msec. of accuracy. Listed below is the resulting printout.

```
************************ EXAMPLE 5.1: 5-NODE,8-LINK NETWORK ***************

VERBATIM ACCOUNT OF INPUT DATA

1 1 2 0 0 ERG

 5  8   .010 1.000 0.000
 1 2  1       14
 1 3  2       12
 2 4  3       10
 4 5  4        7
 3 5  5       10
 2 3  6       12
 2 5  7       13
 3 4  8       15
 1 2  2   0   0   1.50   1.00
 1 3  3   0   0   2.00   1.00
 1 4  2   3   0   2.00   1.00
 1 5  3   2   0   4.00   1.00
 2 1  1   0   0   1.50   1.00
 2 3  3   4   0   2.80   1.00
 2 4  4   3   0   3.00   1.00
 2 5  5   3   0   1.20   1.00
 3 1  1   0   0   2.00   1.00
 3 2  2   0   0   2.50   1.00
 3 4  4   0   0   5.00   1.00
 3 5  5   4   0   4.20   1.00
 4 1  3   2   0   1.70   1.00
 4 2  2   5   0   2.20   1.00
 4 3  3   5   0   3.00   1.00
 4 5  5   3   0   1.60   1.00
 5 1  3   2   0   2.50   1.00
 5 2  2   4   0   2.50   1.00
 5 3  3   2   0   1.20   1.00
 5 4  4   3   0   1.00   1.00
```

USER SPECIFIED OPTIONS'

LIST OF PATHS REQUIRED' YES
DETAILS OF PATH RELIABILITY AND PATH CARRIED LOAD REQUIRED' YES

OPTION NUMBER FOR INITIALIZING ROUTING TABLE FOR REVISION= 2
(NOTES ON THE OPTIONS USED'
NO CHANGES TO THE ORIGNAL ROUTING TABLE MADE BEFORE REVISION)

MAXIMUM ALLOWABLE BLOCKING PROBABILITY(BPMAX) .010

STEP SIZE OF PBMAX REDUCTIONS=, .010

NETWORK DESCRIPTION

NUMBER OF SWITCHES IN NETWORK 5
NUMBER OF TRUNK GROUPS IN NETWORK 8

LINK NUMBER	SWITCH PAIR		EXISTING NUMBER OF TRUNKS
1	1	2	14
2	1	3	12
3	2	4	10
4	4	5	7
5	3	5	10
6	2	3	12
7	2	5	13
8	3	4	15

SWITCH-TO-SWITCH TRAFFIC ORIGINAL ROUTING T

FROM	TO	TRAFFIC IN CCS	CHOICE 1 (PRIMARY ROUTES)	CHOICE 2
1	2	54.0	2	0
1	3	72.0	3	0
1	4	72.0	2	3
1	5	144.0	3	2
2	1	54.0	1	0
2	3	100.8	3	4
2	4	108.0	4	3
2	5	43.2	5	3
3	1	72.0	1	0
3	2	90.0	2	0
3	4	180.0	4	0
3	5	151.2	5	4
4	1	61.2	3	2
4	2	79.2	2	5
4	3	108.0	3	5
4	5	57.6	5	3
5	1	90.0	3	2
5	2	90.0	2	4
5	3	43.2	3	2
5	4	36.0	4	3

```
(CHOICE LEVEL WITH MINUS SIGN DENOTES A SPILL SWITCH)

PATH DEFINED BY THE ORIGINAL ROUTING TABLE
STARTING TIME= 13:  9: 23

FROM  1 TO  2
( -1) (  2) (

FROM  1 TO  3
( -1) (  3) (

FROM  1 TO  4
( -1) (  2) (  4) (
( -1) (  3) (  4) (

FROM  1 TO  5
( -1) (  3) (  5) (
( -1) (  2) (  5) (

FROM  2 TO  1
( -2) (  1) (

FROM  2 TO  3
( -2) (  3) (
( -2) (  4) (  3) (

FROM  2 TO  4
( -2) (  4) (
( -2) (  3) (  4) (

FROM  2 TO  5
( -2) (  5) (
( -2) (  3) (  5) (

FROM  3 TO  1
( -3) (  1) (

FROM  3 TO  2
( -3) (  2) (

FROM  3 TO  4
( -3) (  4) (

FROM  3 TO  5
( -3) (  5) (
( -3) (  4) (  5) (

FROM  4 TO  1
( -4) (  3) (  1) (
( -4) (  2) (  1) (
```

```
FROM  4 TO  2
( -4) (  2) (
( -4) (  5) (  2) (

FROM  4 TO  3
( -4) (  3) (
( -4) (  5) (  3) (

FROM  4 TO  5
( -4) (  5) (
( -4) (  3) (  5) (

FROM  5 TO  1
( -5) (  3) (  1) (
( -5) (  2) (  1) (

FROM  5 TO  2
( -5) (  2) (
( -5) (  4) (  2) (

FROM  5 TO  3
( -5) (  3) (
( -5) (  2) (  3) (

FROM  5 TO  4
( -5) (  4) (
( -5) (  3) (  4) (
ENDING TIME= 13:  9: 30

STOP 0                                        ***S T A R T U P***
                                              JULY 1976 VERSION

NORMAL PROGRAM COMPLETION
```

E.3 DEC PDP 11/40

The benchmark was run for 100 loops on the PDP 11/40 minicomputer with a resulting time of 14,344 seconds. It was also run for 10 loops resulting in a time of 1.441 seconds. The above times are accurate within ± 10 msec. Listed below are the output for 100 loops, the program listings, and the output for 10 loops.

```
>FOR MAIN.OBJ=MAIN.FOR
>FOR PATH.OBJ=PATH.FOR
>TKB
TKB>START.TKB=^U
START.TSK=MAIN,PATH
TKB>/
ENTER OPTIONS:
TKB>//
>RUN START.TSK
PDP 11 VERIFICATION CHECK 08/09/77




PDP 11 VERIFICATION CHECK 08/09/77

VERBATIM ACCOUNT OF INPUT DATA
1 1 2 9^U
1 1 2 0 0 ERG

1 1 2 0 0 ERG
 5  8 0.010 1.0    0.

 5  8 0.010 1.000 0.000
 1 2  1        14
 1 2  1        14
 1 3  2        12
 1 3  2        12
 2 4  3        10
 2 4  3        10
 4 5  4         7
 4 5  4         7
 3 5  5        10
 3 5  5        10
 2 3  6        12
 2 3  6        12
 2 5  7        13
 2 5  7        13
 3 4  8        15
 3 4  8        15
 1 2  2   0   0 1.5    1.0
 1 2  2   0   0  1.50  1.00
 1 3  3   0   0   ^U
 1 3  3   0   0 2.0    1.0
 1 3  3   0   0  2.00  1.00
 1 4  2   3   0 2.0    1.0
 1 4  2   3   0  2.00  1.00
 1 5  3   2   0 4.0    1.0
 1 5  3   2   0  4.00  1.00
```

2	1	1	0	0	1.5	1.0
2	1	1	0	0	1.50	1.00
2	3	3	4	0	2.8	1.0
2	3	3	4	0	2.80	1.00
2	4	4	3	0	3.0	1.0
2	4	4	3	0	3.00	1.00
2	5	5	3	0	1.2	1.0
2	5	5	3	0	1.20	1.00
3	1	1	0	0	2.0	1.0
3	1	1	0	0	2.00	1.00
3	2	2	0	0	2.5	1.0
3	2	2	0	0	2.50	1.00
3	4	4	0	0	5.0	1.0
3	4	4	0	0	5.00	1.00
3	5	5	4	0	4.2	4.0
3	5	5	4	0	4.20	4.00
4	1	3	2	0	1.7	1.0
4	1	3	2	0	1.70	1.00
4	2	2	5	0	2.2	1.0
4	2	2	5	0	2.20	1.00
4	3	3	5	0	3.0	1.0
4	3	3	5	0	3.00	1.00
4	5	5	3	0	1.6	1.0
4	5	5	3	0	1.60	1.00
5	1	3	2	0	2.5	1.0
5	1	3	2	0	2.50	1.00
5	2	2	4	0	2.5	1.0
5	2	2	4	0	2.50	1.00
5	3	3	2	0	1.2	1.0
5	3	3	2	0	1.20	1.00
5	4	4	3	0	1.0	1.0
5	4	4	3	0	1.00	1.00

USER SPECIFIED OPTIONS:

LIST OF PATHS REQUIRED: YES
DETAILS OF PATH RELIABILITY AND PATH CARRIED LOAD REQUIRED: YES

OPTION NUMBER FOR INITIALIZING ROUTING TABLE FORREVISION= 2
(NOTES ON THE OPTIONS USED
NO CHANGES TO THE ORIGINAL ROUTING TABLE MADEBEFORE REVISION)

MAXIMUM ALLOWABLE BLOCKING PROBABILITY (BPMAX) 0.010

STEP SIZE OF PBMAX REDUCTIONS=, 0.010

NETWORK DESCRIPTION

NUMBER OF SWITCHES INNETWORK 5
NUMBER OF TRUNK GROUPS IN NETWORK 8

LINK NUMBER	SWITCH PAIR		EXISTING NUMBER OF TRUNKS
1	1	2	14
2	1	3	12
3	2	4	10
4	4	5	7
5	3	5	10
6	2	3	12
7	2	5	13
8	3	4	15

SWITCH-TO-SWITCH TRAFFIC

ORIGINAL ROUTINGTABLE

(PRIMARYROUTES 3)

FROM	TO	TRAFFIC IN CCS	CHOICE 1	CHOICE 2	CHOICE 3	WEIGHT
1	2	54.0	2	0	0	1.00
1	3	72.0	3	0	0	1.00
1	4	72.0	2	3	0	1.00
1	5	144.0	3	2	0	1.00
2	1	54.0	1	0	0	1.00
2	3	100.8	3	4	0	1.00
2	4	108.0	4	3	0	1.00
2	5	43.2	5	3	0	1.00
3	1	72.0	1	0	0	1.00
3	2	90.0	2	0	0	1.00
3	4	180.0	4	0	0	1.00
3	5	151.2	5	4	0	4.00
4	1	61.2	3	2	0	1.00
4	2	79.2	2	5	0	1.00
4	3	108.0	3	5	0	1.00
4	5	57.6	5	3	0	1.00
5	1	90.0	3	2	0	1.00
5	2	90.0	2	4	0	1.00
5	3	43.2	3	2	0	1.00
5	4	36.0	4	3	0	1.00

```
(CHOICE LEVEL WITH MINUS SIGN DENOTES A SPILLSWITCH)

PATH DEFINED BY THE ORIGINAL ROUTING TABLE

FROM 1 TO  2
( -1) (  2) (

FROM 1 TO  3
( -1) (  3) (

FROM 1 TO  4
( -1) (  2) (  4) (
( -1) (  3) (  4) (

FROM 1 TO  5
( -1) (  3) (  5) (
( -1) (  2) (  5) (

FROM 2 TO  1
( -2) (  1) (

FROM 2 TO  3
( -2) (  3) (
( -2) (  4) (  3) (

FROM 2 TO  4
( -2) (  4) (
( -2) (  3) (  4) (

FROM 2 TO  5
( -2) (  5) (
( -2) (  3) (  5) (

FROM 3 TO  1
( -3) (  1) (

FROM 3 TO  2
( -3) (  2) (

FROM 3 TO  4
( -3) (  4) (

FROM 3 TO  5
( -3) (  5) (
( -3) (  4) (  5) (
```

```
FROM 4 TO  1
( -4) (  3) (  1) (
( -4) (  2) (  1) (

FROM 4 TO  2
( -4) (  2) (
( -4) (  5) (  2) (

FROM 4 TO  3
( -4) (  3) (
( -4) (  5) (  3) (

FROM 4 TO  5
( -4) (  5) (
( -4) (  3) (  5) (

FROM 5 TO  1
( -5) (  3) (  1) (
( -5) (  2) (  1) (

FROM 5 TO  2
( -5) (  2) (
( -5) (  4) (  2) (

FROM 5 TO  3
( -5) (  3) (
( -5) (  2) (  3) (

FROM 5 TO  4
( -5) (  4) (
( -5) (  3) (  4) (

 0
TIME REQUIRED TO EXECUTE ENTIRE PROGRAM    14.344 SECONDS
STARTUP                         JULY 1976 VERSION
TT2  --  STOP
>
```

```
PIP TT2:=MAIN.FOR
C*****************************************************************
C********************* S T A R T U P ***************************
C******STATISTICAL ANALYSIS AND ROUTING TABLE UPDATING PROGRAM*******
C*****************************************************************
C*********************** JULY 1976 VERSION ************************
C******************************************************************
C*******************************************************************
C******************************************************************
C       *
C****** THIS SUB-PROGRAM PERFORMS THE FOLLOWING FUNCTION(S):
C       *       1. READ AND WRITE DATA
C       *       2. WRITE PERFORMANCE BASED UPON THE ORIGINAL AND REVISED
C       *         .ROUTING TABLES(IF REVISION WAS DONE)
C       *
C****** THIS SUB-PROGRAM USES THE FOLLOWING SUBROUTINE(S):
C       *       1. DECOD1(ONLY FOR EUROPEAN AUTOVON NETWORK)
C       *       2. DECOD2(ONLY FOR EUROPEAN AUTOVAN NETWORK)
C       *       3. PATH
C       *       4. ATGOS
C       *       5. SORT
C       *       6. REVRT3(IF REVISION IS NEEDED)
C       *       7. SECOND(SYSTEM DEPENDENT SUBROUTINE)
C       *
C******************************************************************
      LOGICAL*1 GOS
      REAL*4 LUNIT,NPRINT,NO,YES
      DIMENSION IRT(5,15,4), FLTG(105), CLSD(5,15), IRRT(5,15,4),
     1GOS(80),NODE(11),STR(15),CLS(15),PR(5,15,5),PL(5,15,5)
      COMMON LNUM(5,15),WT(5,15),NTRK(105),TR(5,15),LOCATI(5,15,
     1 5),LOCATF(5,15,5),NPATH(200),ILLSDR(5,15),NS,NL,BPMAX,NPPO,NDPO
     1,INLRT,NAUTVN,NCONRT,STEP,TTOTAL,T0,IFIRST
      DATA     CCS,ERG/'CCS ','ERG '/
      DATA     YES/'YES '/
      DATA     NO/'NO'/
      CALL ASSIGN(1,'TI:')
      CALL ASSIGN (2,'TI:')
C
C*****READ AND WRITE TITLE
C
      READ(1,200) (GOS(I),I=1,80)
      WRITE(2,201) (GOS(I),I=1,80)
C
C*****READ AND WRITE OPTION CARD INFORMATION
C
      READ(1,202)NPPO,NDPO,INLRT,NAUTVN,NCONRT,LUNIT
      WRITE(2,203)NPPO,NDPO,INLRT,NAUTVN,NCONRT,LUNIT
C
```

```
C*****CHECK IF THE TRAFFIC UNITS ARE CORRECTLY SPECIFIED
C
      IF((LUNIT.NE.CCS).AND.(LUNIT.NE.ERG)) GO TO 152
C
C*****READ AND WRITE PROGRAM PARAMETERS
C
      READ(1,204)NS,NL,BPMAX,DUM,DUM1
      OVLD=1.
      IF (DUM.NE.0.) OVLD=DUM
      STEP=0.01
      IF (DUM1.NE.0.) STEP=DUM1
      WRITE(2,205)NS,NL,BPMAX,DUM,DUM1
C
C*****INITIALIZE SPARSE MATRICES
C
      T0=SECNDS(0.)
      DO 101 I=1,NS
      CLS(I)=0.
      STR(I)=0.
      DO 101 J=1,NS
          LNUM(I,J)=0
          WT(I,J)=1.
101   CONTINUE
C
C*****READ AND WRITE TRUNK GROUP INFORMATION
C
      DO 102 I=1,NL
      READ(1,206)IS,ID,LN,IDUM
      WRITE(2,207)IS,ID,LN,IDUM
      T0=SECNDS(0.)
          LNUM(IS,ID)=LN
          LNUM(LD,IS)=LN
          NTRK(LN)=IDUM
      NPATH(LN)=IS
      K=105+LN
      NPATH(K)=ID
102   CONTINUE
C
C*****READ AND WRITE ROUTING TABLE, TRAFFIC,AND NNGOS WEIGHT INFORMATION
C
      IDUM=NS*(NS-1)
      DO 103 I=1,IDUM
      READ(1,208)IS,ID,IDUM1,IDUM2,IDUM3,DUM,W
      WRITE(2,209)IS,ID,IDUM1,IDUM2,IDUM3,DUM,W
          IRT(IS,ID,1)=IDUM1
          IRT(IS,ID,2)=IDUM2
          IRT(IS,ID,3)=IDUM3
          IRT(IS,ID,4)=0
      IF (LUNIT .EQ. ERG) DUM=DUM*36.
          TR(IS,ID)=DUM*OVLD
          IF (W.NE.0.) WT(IS,ID)=W
103   CONTINUE
C
C*****IF THE NETWORK IS EUROPEAN AUTOVON, READ AND WRITE THE ACRONYMS
C*****FOR ITS OFFICES
C
      IF (NAUTVN.EQ.1)READ(1,268) (NODE(I),I=1,11)
      IF (NAUTVN .EQ. 1) WRITE(2,269) (NODE(I),I=1,11)
C
```

```
C◆◆◆◆◆WRITE USER SPECIFIED OPTIONS
C
        WRITE(2,257)
        NPRINT=YES
        IF (NPPO .EQ. 0) NPRINT=NO
        WRITE(2,258)NPRINT
        NPRINT=YES
        IF(NDPO.EQ.0)NPRINT=NO
        WRITE(2,259)NPRINT
        WRITE(2,260)INLRT
        IF(INLRT.EQ.1) WRITE(2,261)
        IF (INLRT.EQ.2) WRITE(2,262)
        IF (INLRT .EQ. 3) WRITE(2,263)
        WRITE(2,231)BPMAX
        WRITE(2,267)STEP
        IF (NAUTVN.EQ.1) WRITE(2,264)
        IF ((NAUTVN.EQ.1).AND.(NCONRT.EQ.1)) WRITE(2,265)
        IF ((NAUTVN.EQ.1).AND.(NCONRT.EQ.0)) WRITE(2,266)
C
C
C◆◆◆◆◆WRITE NETWORK DESCRIPTION
C
        WRITE(2,210)NS,NL
C
C◆◆◆◆◆CHECK IF THE NETWORK IS EUROPEAN AUTOVON
C
        IF (NAUTVN.EQ.1) GO TO 106
C
C◆◆◆◆◆WRITE TRUNK GROUP INFORMATION
C
        DO 104 I=1,NL
        K=I+105
        WRITE(2,211)I,NPATH(I),NPATH(K),NTRK(I)
        NPATH(I)=0
        NPATH(K)=0
104     CONTINUE
        WRITE(2,212)
C
C◆◆◆◆◆◆WRITE OPIGINAL ROUTING TABLE,TRAFFIC MATRIX AND WEIGHT
C◆◆◆◆◆◆INFORMATION
C
        DO 105 I=1,NS
        DO 105 J=1,NS
           IF (I.EQ.J) GO TO 105
        WRITE(2,213)I,J,TR(I,J),IRT(I,J,1),IRT(I,J,2),IRT(I,J,3),WT(I,J)
105     CONTINUE
        WRITE(2,273)
        GO TO 107
C
C◆◆◆◆◆WRITE TRUNK GROUP, ORIGINAL ROUTING TABLE, TRAFFIC AND WEIGHT
C◆◆◆◆◆INFORMATION FOR THE EUROPEAN AUTOVON NETWORK
C
106     ITRG=0
        CALL DECOD1(IRT,ITRG,NODE)
```

```
C*****CHECK IF THE PATH ARE TO BE PRINTED
C
107     IF (NPPO.EQ.0) GO TO 108
        WRITE(2,214)
C
C*****CHECK FOR ILLEGAL PATHS IN THE ORIGINAL ROUTING TABLE
C
108     T0=SECNDS(0.)
        DO 20 I=1,100
        ISOLD=IS
        IDOLD=ID
        ICONOL=ICON
        IFIRST=1
        CALL PATH (IRT,NPPO,IS,ID,ICON)
        IS=ISOLD
        ID=IDOLD
20      ICON=ICONOL
147     TTOTAL=SECNDS(T0)
        IFIRST=0
        CALL PATH (IRT,NPPO,IS,ID,ICON)
        WRITE(2,205)ICON
        WRITE(2,250)TTOTAL
        WRITE(2,251)
        STOP
152     WRITE(2,270)
        WRITE(2,271)
C
C*****FORMAT STATEMENTS
C
200     FORMAT (80A1)
201     FORMAT (1H1,80A1/1H0,30HVERBATIM ACCOUNT OF INPUT DATA)
202     FORMAT (5(I1,1X),A3)
203     FORMAT (1H0,5(I1,1X),A3)
204     FORMAT (I2,I3,3F6.3)
205     FORMAT (1H0,I2,I3,3F6.3)
206     FORMAT (2I2,I3,6X,I2)
207     FORMAT (1H,2I2,I3,6X,I2)
208     FORMAT (2I2,3I3,F6.2,F6.2)
209     FORMAT (1H,2I2,3I3,2F6.2)
210     FORMAT (1H0,19HNETWORK DESCRIPTION,/1H0,'NUMBER OF SWITCHES IN
        1NETWORK',1X,I2/1H ,33HNUMBER OF TRUNK GROUPS IN NETWORK,1X,I3/1H0,
        142X,15HEXISTING NUMBER,/1H,11HLINK NUMBER,10X,11HSWITCH PAIR,13X,
        19HOF TRUNKS)
211     FORMAT (1H,4X,I3,15X,I2,5X,I2,17X,I3)
212     FORMAT (1H0,'SWITCH-TO-SWITCH TRAFFIC',18X,'ORIGINAL ROUTING
        1TABLE',/1H0,4HFROM,5X,2HTO,5X,14HTRAFFIC IN CCS,5X,8HCHOICE 1,
        15X,8HCHOICE 2,5X,8HCHOICE 3,5X,6HWEIGHT,/1H ,23X,'(PRIMARY
        1ROUTES 3)')
213     FORMAT (1H,1X,I2,6X,I2,9X,F6.1,11X,I3,10X,I3,10X,I3,8X,F6.2)
214     FORMAT (1H0,'PATH DEFINED BY THE ORIGINAL ROUTING TABLE')
230     FORMAT (1H0,27HNETWORK GRADE OF SERVICE IS, F10.5,/1H,36HWEI
        1GHTED NETWORK GRADE OF SERVICE IS, F10.5)
231     FORMAT (1H0,'MAXIMUM ALLOWABLE BLOCKING PROBABILITY (BPMAX)',1X,
        1F6.3)
250     FORMAT (1H,39HTIME REQUIRED TO EXECUTE ENTIRE PROGRAM, 1X,F9.3,
        11X,7HSECONDS)
```

```
 251 FORMAT(1X,'STARTUP',20X,'JULY 1976 VERSION')
 252    FORMAT (1H0,90HMAXIMUM ALLOWABLE SOURCE TO DESTINATION BLOCKING
       1PROBABILITY COULD NOT BE MET IN ALL CASES)
 253    FORMAT (1H ,'TIME REQUIRED TO REVISE ROUTING TABLE',1X,F9.3,1X,7
       1HSECONDS)
 256    FORMAT (1H0,61HTHE ORIGINAL ROUTING TABLE HAS AT LEAST TWO DISTINCT
       1PATHS TO/1H ,29HSPILL NODES ON THE PATHS FROM,1X,I2,2HTO,1X,I2/
       11H,20HEXECUTION TERMINATED)
 257    FORMAT (1H1,23HUSER SPECIFIED OPTIONS:)
 258    FORMAT (1H0,23HLIST OF PATHS REQUIRED:,2X,A3)
 259    FORMAT (1H,59HDETAILS OF PATH RELIABILITY AND PATH CARRIED LOAD RE
       1QUIRED:,2X,A3)
 260    FORMAT (1H0,'OPTION NUMBER FOR INITIALIZING ROUTING TABLE FOR
       1REVISION=',2X,I2,/1H ,26H(NOTES ON THE OPTIONS USED:)
 261    FORMAT (1H,61HALL SPILL SWITCHES OF THE ORIGINALL ROUTING TABLE
       1ARE CONVERTED,/1H ,40HINTO NON-SPILL SWITCHES BEFORE REVISION))
 262    FORMAT (1H ,61HNO CHANGES TO THE ORIGINAL ROUTING TABLE MADE
       1BEFORE REVISION))
 263    FORMAT (1H ,'ALL NON-SPILL SECOND AND THIRD CHOICES IN THE ORIG
     1INAL ROUTING',/1H ,'TABLE ARE DELETED BEFORE REVISION)')
 264    FORMAT (1H0,24HGIVEN NETWORK IS AUTOVON)
 265    FORMAT (1H0,47HAN ATTEMPT TO IMPROVE CONUS TRAFFIC IS REQUIRED)
 266    FORMAT (1H0,'AN ATTEMPT TO IMPROVE CONUS TRAFFIS NOT REQUIRED')
 267    FORMAT (1H0,31HSTEP SIZE OF PBMAX REDUCTIONS=,F6.3)
 268    FORMAT (11(A3,1X))
 269    FORMAT (1H0,11(A3,1X))
 270    FORMAT (1H0,40HTRAFFIC LOAD UNITS INCORRECTLY SPECIFIED)
 271    FORMAT (1H ,20HEXECUTION TERMINATED)
 272    FORMAT (1H ,5X,I2,2H (,A3,1H),17X,F6.1,19X,F9.6,17X,F9.6)
 273    FORMAT (1H0,'(CHOICE LEVEL WITH MINUS SIGN DENOTES A SPILL
       1SWITCH)')
 274    FORMAT (1H0,54H(NUMBER OF ROWS ALTERED IN THE ORIGINAL ROUTING
       1TABLE= ,I3,1X,1H))
        END
>PIP TT2:=PATH.FOR
        SUBROUTINE PATH(IRT,IWR,IS,ID,ICON)
C****************************************************************
C          THIS SUBROUTINE PERFORMS THE FOLLOWING:
C       1. ENUMERATE & STORE ALL PATHS BETWEEN EVERY NODE PAIR
C       2. WRITE ALL THE PATHS, IF REQUIRED
C       3. CHECK IF ANY ILLEGAL PATHS ARE FORMED
C*******************************************************************
        DIMENSION IRT(5,15,4),IPATH(15),ITSS(2),ITDS(2),LS(2),MS(2)
        COMMON LNUM(5,15),WT(5,15),NTRK(105),TR(5,15),LOCATI(5,15,5),L
       1OCATF(5,15,5),NPATH(200),ILLSDR(5,15),NS,NL,BPMAX,NPPO,NDPO,INL
       2RT,NAUTVN,NCONRT,STEP,TTOTAL,T0,IFIRST
        ICON=0
C
C*****INITIALIZE SPARSE MATRICES
C
        DO 101 I=1,NS
        DO 101 J=1,NS
        DO 101 K=1,5
           LOCATI(I,J,K)=0
           LOCATF(I,J,K)=0
 101    CONTINUE
```

```
C
C*****INITIALIZE PARAMETERS
C
      KOUNT=1
      ISC=0
      IS=1
      IPATH(1)=-1
      ID=1
C
C*****INCREMENT DESTINATION
C
102   ID=ID + 1
      IF (ID.GT.NS) GO TO 111
      IF (ID.EQ.IS) GO TO 102
C
C*****BEGIN PATH IDENTIFICATION
C
103   NUMBER = 1
      IAFTER = 0
      IPSP = 0
      ISPS = 0
C
C*****WRITE SOURCE AND DESTINATION NODE NUMBERS WHOSE PATH IS TO BE
C*****FOUND
C
      IF (IWR.NE.0.AND.IFIRST.EQ.0) WRITE(2,200) IS,ID
      L = 1
      M = 1
      ITS=IS
C
C*****DETERMINE NEXT NODE ON PATH
C
104   ITD = IRT(ITS,ID,L)
C
C*****CHECK TO SEE IF THIS NODE HAS BEEN PREVIOUSLY ENCOUNTERED
C*****THEREBY FORMING A LOOP
C
C
105   DO 106 I = 1,M
      IF (IABS(ITD) .EQ. IABS(IPATH(I))) GOTO 115
106   CONTINUE
C
C*****PUT NODE ON PATH
C
      M = M + 1
      IPATH(M)=ITD
      ITD = IABS(ITD)
C
C*****CHECK IF TEMPORARY SOURCE IS A SPILL NODE
C
```

```
      IDUM = M-1
      IF (ITS .EQ. IPATH(IDUM)) GOTO 109
C
C********** STORE THE SPILL NODE IN THE STACK
C
      ISPS=ITS
      IF (ISPS .EQ. IS) GOTO 107
C
C*****CHECK TO SEE IF THERE ARE TWO DISTINCT ROUTES TO SPILL NODES
C*****OR IF TWO SPILL NODES OCCUR ON THE SAME PATH
C
      IF (IAFTER.EQ.1) GO TO 116
      IF (IPSP.EQ.0) IPSP = ISPS
      IF (IPSP.EQ.ISPS) GO TO 107
C
C*****RETURN FOR TWO DISTINCT SPILL NODES
C
      ICON = 2
      RETURN
C
C*****FIND AND STORE THE NEXT ALTERNATE DESTINATION FROM THE SPILL NODE
C
107   L=L+1
      IAD = IRT(ITS,ID,L)
      IF (IAD.EQ.0) GO TO 108
      ISC = ISC + 1
      ITSS (ISC) = ITS
      ITDS (ISC) =IAD
      LS (ISC) = L
      MS (ISC) = M-1
      GO TO 109
C
C*****CHECK TO SEE IF THE NEXT PATH IS THE FIRST ONE AFTER THE LAST
C*****PATH OF A SPILL NODE
C
108   IF (IPSP.NE.0) IAFTER=1
C
C*****CHECK TO SEE IF THE DESTINATION NODE HAS BEEN REACHED
C
109   IF (ITD.EQ.ID) GO TO 112
C
C*****ADVANCE TO THE NEXT LINK OF PATH
C
      ITS = ITD
      L = 1
      GOTO 104
C
```

```
C******WITHDRAW THE LAST STORED ALTERNATE DESTINATION IN THE STACK
C
110     ITS = ITSS(ISC)
        ITD=ITDS(ISC)
        L = LS(ISC)
        M = MS(ISC)
        ISC = ISC - 1
        GO TO 105
C
C******INCREMENT THE SOURCE AND REINITIALIZE THE DESTINATION OR RETURN
C
111     IS = IS + 1
        IF (IS.GT.NS) RETURN
        IPATH(1) = - IS
        ID = 1
        GO TO 103
C
C******PUT THE COMPLETED PATH INTO SPARSE ARRAY AND NOTE ITS INITIAL AND
C******FINAL ADDRESSES
C
112     LOCATI (IS,ID,NUMBER) = KOUNT
        LOCATF (IS,ID,NUMBER) = KOUNT + M -1
        NUMBER = NUMBER + 1
C
C******WRITE THE SEQUENCE OF NODES ON THE PATH FROM SOURCE TO DESTINATION
C
        IF (IWR.NE.0.AND.IFIRST.EQ.0) WRITE(2,201)  (IPATH(I),I=1,M)
        DO 113 I = 1,M
        NPATH(KOUNT)=IPATH(I)
            KOUNT = KOUNT + 1
            IF (KOUNT.GT.3000) GO TO 114
113     CONTINUE
        IF (ISC.EQ.0) GO TO 102
        GO TO 110
C
C******MESSAGE FOR PATH ARRAY OVERFLOW
C
114     WRITE(2,202)
        STOP
C
C******RETURN FOR LOOP IN PATH
C
115     ICON = 1
        RETURN
C
C******RETURN FOR TWO PATHS TO SAME OR DISTINCT SPILL NODES
C
116     ICON = 3
        RETURN
  200  FORMAT(1H0,'FROM',I2,1X,'TO',1X,I2)
201     FORMAT (1H ,15('(',I3,')'))
202     FORMAT (1H0,20HPATH MEMORY OVERFLOW,/1H ,20HEXECUTION TERMINATED
        1)
        END
>
```

```
>TKB
TKB>START.TSK=MAIN,PATH
TKB>/
ENTER OPTIONS:
TKB>//
>RUN START.TSK
PDP 11 VERIFICATION CHECK--RUN THRU 10 TIMES--08/09/77
```

```
PDP 11 VERIFICATION CHECK--RUN THRU 10 TIMES--08/09/77

VERBATIM ACCOUNT OF INPUT DATA
1 1 2 0 0 ERG

1 1 2 0 0 ERG
 5  8 0.010 1.0    0.

 5  8 0.010 1.000 0.000
 1 2  1       14
 1 2  1       14
 1 3  2       12
 1 3  2       12
 2 4  3       10
 2 4  3       10
 4 5  4        7
 4 5  4        7
 3 5  5       10
 3 5  5       10
 2 3  6       12
 2 3  6       12
 2 5  7       13
 2 5  7       13
 3 4  8       15
 3 4  8       15
 1 2  2   0   0 1.5    1.0
 1 2  2   0   0  1.50   1.00
 1 3  3   0   0 2.0    1.0
 1 3  3   0   0  2.00   1.00
 1 4  2   3   0 2.0    1.0
 1 4  2   3   0  2.00   1.00
 1 5  3   2   0 4.0    1.0
 1 5  3   2   0  4.00   1.00
 2 1  1   0   0 1.5    1.0
 2 1  1   0   0  1.50   1.00
 2 3  3   4   0 2.8    1.0
 2 3  3   4   0  2.80   1.00
 2 4  4   3   0 3.0    1.0
 2 4  4   3   0  3.00   1.00
 2 5  5   3   0 1.2    1.0
 2 5  5   3   0  1.20   1.00
```

```
 3 1  1  0  0 2.0   1.0
 3 1  1  0  0  2.00  1.00
 3 2  2  0  0 2.5   1.0
 3 2  2  0  0  2.50  1.00
 3 4  4  0  0 5.0 1^U
3 4^U
 3 4  4  0  0 5.0   1.0
 3 4  4  0  0  5.00  1.00
 3 5  5  4  0 4.2   1.0
 3 5  5  4  0  4.20  1.00
 4 1  3  2  0 1.7   1.0
 4 1  3  2  0  1.70  1.00
 4 2  2  5  0 2.2   1.0
 4 2  2  5  0  2.20  1.00
 4 3  3  5  0 3.0   1.0
 4 3  3  5  0  3.00  1.00
 4 5  5  3  0 1.6   1.0
 4 5  5  3  0  1.60  1.00
 5 1  3  2  0 2.5   1.0
 5 1  3  2  0  2.50  1.00
 5 2  2  4  0 2.5   1.0
 5 2  2  4  0  2.50  1.00
 5 3  3  2  0 1.2   1.0
 5 3  3  2  0  1.20  1.00
 5 4  4  3  0 1.0   1.0
 5 4  4  3  0  1.00  1.00
```

USER SPECIFIED OPTIONS:

LIST OF PATHS REQUIRED: YES
DETAILS OF PATH RELIABILITY AND PATH CARRIED LOAD REQUIRED: YES

OPTION NUMBER FOR INITIALIZING ROUTING TABLE FORREVISION= 2
(NOTES ON THE OPTIONS USED
NO CHANGES TO THE ORIGINAL ROUTING TABLE MADEBEFORE REVISION)

MAXIMUM ALLOWABLE BLOCKING PROBABILITY (BPMAX) 0.010

STEP SIZE OF PBMAX REDUCTIONS=, 0.010

NETWORK DESCRIPTION

NUMBER OF SWITCHES INNETWORK 5
NUMBER OF TRUNK GROUPS IN NETWORK 8

LINK NUMBER	SWITCH PAIR		EXISTING NUMBER OF TRUNKS
1	1	2	14
2	1	3	12
3	2	4	10
4	4	5	7
5	3	5	10
6	2	3	12
7	2	5	13
8	3	4	15

SWITCH-TO-SWITCH TRAFFIC　　　　ORIGINAL ROUTINGTABLE

ROM	TO	TRAFFIC IN CCS	CHOICE 1	CHOICE 2	CHOICE 3	WEIGHT
		(PRIMARYROUTES 3)				
1	2	54.0	2	0	0	1.00
1	3	72.0	3	0	0	1.00
1	4	72.0	2	3	0	1.00
1	5	144.0	3	2	0	1.00
2	1	54.0	1	0	0	1.00
2	3	100.8	3	4	0	1.00
2	4	108.0	4	3	0	1.00
2	5	43.2	5	3	0	1.00
3	1	72.0	1	0	0	1.00
3	2	90.0	2	0	0	1.00
3	4	180.0	4	0	0	1.00
3	5	151.2	5	4	0	1.00
4	1	61.2	3	2	0	1.00
4	2	79.2	2	5	0	1.00
4	3	108.0	3	5	0	1.00
4	5	57.6	5	3	0	1.00
5	1	90.0	3	2	0	1.00
5	2	90.0	2	4	0	1.00
5	3	43.2	3	2	0	1.00
5	4	36.0	4	3	0	1.00

CHOICE LEVEL WITH MINUS SIGN DENOTES A SPILLSWITCH)

PATH DEFINED BY THE ORIGINAL ROUTING TABLE

ROM 1 TO 2
(-1) (2) (

ROM 1 TO 3
(-1) (3) (

ROM 1 TO 4
-1) (2) (4) (
(-1) (3) (4) (

```
FROM 1 TO  5
( -1) (  3) (  5) (
( -1) (  2) (  5) (

FROM 2 TO  1
( -2) (  1) (

FROM 2 TO  3
( -2) (  3) (
( -2) (  4) (  3) (

FROM 2 TO  4
( -2) (  4) (
( -2) (  3) (  4) (

FROM 2 TO  5
( -2) (  5) (
( -2) (  3) (  5) (

FROM 3 TO  1
( -3) (  1) (

FROM 3 TO  2
( -3) (  2) (

FROM 3 TO  4
( -3) (  4) (

FROM 3 TO  5
( -3) (  5) (
( -3) (  4) (  5) (

FROM 4 TO  1
( -4) (  3) (  1) (
( -4) (  2) (  1) (

FROM 4 TO  2
( -4) (  2) (
( -4) (  5) (  2) (

FROM 4 TO  3
( -4) (  3) (
( -4) (  5) (  3) (

FROM 4 TO  5
( -4) (  5) (
( -4) (  3) (  5) (
```

```
FROM 5 TO  1
( -5) (   3) (   1) (
( -5) (   2) (   1) (

FROM 5 TO  2
( -5) (   2) (
( -5) (   4) (   2) (

FROM 5 TO  3
( -5) (   3) (
( -5) (   2) (   3) (

FROM 5 TO  4
( -5) (   4) (
( -5) (   3) (   4) (

 0
TIME REQUIRED TO EXECUTE ENTIRE PROGRAM       1.441 SECONDS
STARTUP                         JULY 1976 VERSION
TT2  --   STOP
>
```

E.4 DEC LSI-11

The benchmark program for the LSI-11 microcomputer was run for 10 loops with a resulting time of 1.667 seconds. The resulting printout is given below. The result is accurate within ± 16 msec.

DEC PDP 11/3 LSI-11 10 LOOPS

```
$dx0
RT-11SJ    V02C-02

.RUN MSCDM
************** EXAMPLE 5.1: 5-NODE, 8-LINK NETWORK*************
VERBATIM ACCOUNT OF INPUT DATA

1 1 2 0 0 ERG

 5  8 0.010 1.000 0.000
 1 2  1       14
 1 3  2       12
 2 4  3       10
 4 5  4        7
 3 5  5       10
 2 3  6       12
 2 5  7       13
 3 4  8       15
 1 2  2   0   0   1.50   1.00
 1 3  3   0   0   2.00   1.00
 1 4  2   3   0   2.00   1.00
 1 5  3   2   0   4.00   1.00
 2 1  1   0   0   1.50   1.00
 2 3  3   4   0   2.80   1.00
 2 4  4   3   0   3.00   1.00
 2 5  5   3   0   1.20   1.00
 3 1  1   0   0   2.00   1.00
 3 2  2   0   0   2.50   1.00
 3 4  4   0   0   5.00   1.00
 3 5  5   4   0   4.20   1.00
 4 1  3   2   0   1.70   1.00
 4 2  2   5   0   2.20   1.00
 4 3  3   5   0   3.00   1.00
 4 5  5   3   0   1.60   1.00
 5 1  3   2   0   2.50   1.00
 5 2  2   4   0   2.50   1.00
 5 3  3   2   0   1.20   1.00
USER SPECIFIED OPTIONS:

LIST OF PATHS REQUIRED:  YES
DETAILS OF PATH RELIABILITY AND PATH CARRIED LOAD REQUIRED:  YES

OPTION NUMBER FOR INITIALIZING ROUTING TABLE FORREVISION=   2
(NOTES ON THE OPTIONS USED
NO CHANGES TO THE ORIGINAL ROUTING TABLE MADEBEFORE REVISION)

MAXIMUM ALLOWABLE BLOCKING PROBABILITY (BPMAX)  0.010
```

STEP SIZE OF PBMAX REDUCTIONS=, 0.010

NETWORK DESCRIPTION

NUMBER OF SWITCHES INNETWORK 5
NUMBER OF TRUNK GROUPS IN NETWORK 8

LINK NUMBER	SWITCH PAIR		EXISTING NUMBER OF TRUNKS
1	1	2	14
2	1	3	12
3	2	4	10
4	4	5	7
5	3	5	10
6	2	3	12
7	2	5	13
8	3	4	15

SWITCH-TO-SWITCH TRAFFIC ORIGINAL ROUTINGTABLE

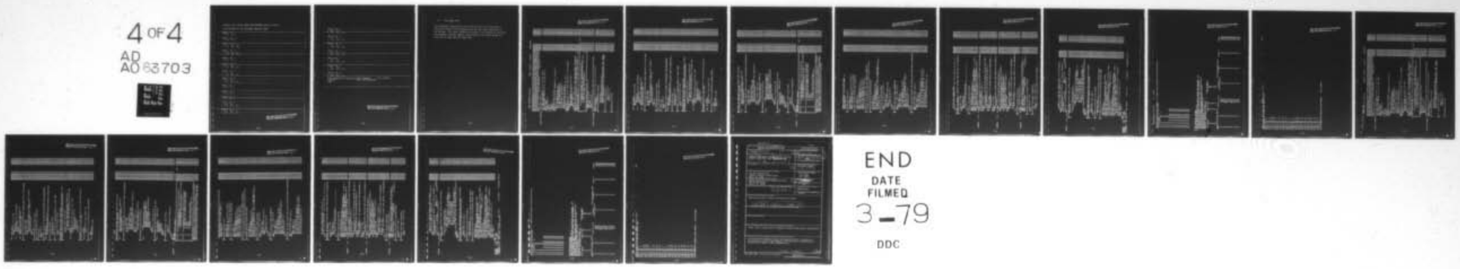
(PRIMARYROUTES 3)

FROM	TO	TRAFFIC IN CCS	CHOICE 1	CHOICE 2	CHOICE 3	WEIGH
1	2	54.0	2	0	0	1.0
1	3	72.0	3	0	0	1.0
1	4	72.0	2	3	0	1.0
1	5	144.0	3	2	0	1.0
2	1	54.0	1	0	0	1.0
2	3	100.8	3	4	0	1.0
2	4	108.0	4	3	0	1.0
2	5	43.2	5	3	0	1.0
3	1	72.0	1	0	0	1.0
3	2	90.0	2	0	0	1.0
3	4	180.0	4	0	0	1.0
3	5	151.2	5	4	0	1.0
4	1	61.2	3	2	0	1.0
4	2	79.2	2	5	0	1.0
4	3	108.0	3	5	0	1.0
4	5	57.6	5	3	0	1.0
5	1	90.0	3	2	0	1.0
5	2	90.0	2	4	0	1.0
5	3	43.2	3	2	0	1.0
5	4	36.0	4	3	0	1.0

AD-A063 703 BURROUGHS CORP PAOLI PA FEDERAL AND SPECIAL SYSTEMS GROUP F/G 17/2
MODULAR SYSTEM CONTROL DEVELOPMENT MODEL (MSCDM). APPENDICES A --ETC(U)
SEP 77 DCA100-76-C-0083

UNCLASSIFIED 64280-APP-A-E SBIE-AD-E100 146 NL

4 OF 4
AD
A063703



END
DATE
FILMED
3-79
DDC

```
(CHOICE LEVEL WITH MINUS SIGN DENOTES A SPILLSWITCH)

PATH DEFINED BY THE ORIGINAL ROUTING TABLE

FROM 1 TO  2
( -1)(  2)(

FROM 1 TO  3
( -1)(  3)(

FROM 1 TO  4
( -1)(  2)(  4)(
( -1)(  3)(  4)(

FROM 1 TO  5
( -1)(  3)(  5)(
( -1)(  2)(  5)(

FROM 2 TO  1
( -2)(  1)(

FROM 2 TO  3
( -2)(  3)(
( -2)(  4)(  3)(

FROM 2 TO  4
( -2)(  4)(
( -2)(  3)(  4)(

FROM 2 TO  5
( -2)(  5)(
( -2)(  3)(  5)(

FROM 3 TO  1
( -3)(  1)(

FROM 3 TO  2
( -3)(  2)(

FROM 3 TO  4
( -3)(  4)(

FROM 3 TO  5
( -3)(  5)(
( -3)(  4)(  5)(

FROM 4 TO  1
( -4)(  3)(  1)(
( -4)(  2)(  1)(
```

```
FROM 4 TO  2
( -4)(  2)(
( -4)(  5)(  2)(

FROM 4 TO  3
( -4)(  3)(
( -4)(  5)(  3)(

FROM 4 TO  5
( -4)(  5)(
( -4)(  3)(  5)(

FROM 5 TO  1
( -5)(  3)(  1)(
( -5)(  2)(  1)(

FROM 5 TO  2
( -5)(  2)(
( -5)(  4)(  2)(

FROM 5 TO  3
( -5)(  3)(
( -5)(  2)(  3)(

FROM 5 TO  4
( -5)(  4)(
( -5)(  3)(  4)(
TIME REQUIRED TO EXECUTE ENTIRE PROGRAM      1.667 SECONDS
STARTUP                      JULY 1976 VERSION
STOP --

.
```

E.5 Burroughs B776

The benchmark program was run on the B776 for 10 loops with a resulting time of 6.625 seconds and for 100 loops resulting in 66 seconds. The above values are within ± 1/8 second in accuracy. The program listings (ALGOL) and printouts are given below for both the 10 loop and 100 loop runs.

```
%**************************************************************************          0:0000:*
%****************** S T A R T U P ****************************************          0:0000:*
%******* STATISTICAL ANALYSIS AND ROUTING TABLE UPDATING PROGRAM *******          0:0000:*
%**************************************************************************          0:0000:*
%************************ JULY 1976 VERSION *****************************          0:0000:*
%**************************************************************************          0:0000:*
BEGIN                    % ALGOL TRANSLATION          MARCH 1977                      0:0000:*
 FILE INPUT (CARDS) ;                                                                 0:0000:*
START OF SEGMENT   1
 FILE CARD (DISK, POINTER ("T."), 20, 180, 100) ;                                     1:0004:1
 FILE OUTPUT (PRINTER) ;                                                              1:0011:2
 FILE LINE (DISK, POINTER ("T."), 33, 495, 200) ;                                     1:0016:0
 ARRAY A [33] ;                                                                       1:0023:1
 ARRAY T[33];                                                                         1:0023:3
 DEFINE TRACE(X) =                                                                    1:0024:1
    BEGIN                                                                             1:0024:2
$ OMIT                                                                                1:0024:2
$ POP OMIT                                                                            1:0024:2
    END#;                                                                             1:0024:2
 POINTER P ;                                                                          1:0024:1
 DEFINE Y = 6 #, Z = 16 #;                                                            1:0024:2
 PROCEDURE F (P, Q, N, W) ; POINTER P, Q ; NEW N, W ;                                 1:0024:2
 BEGIN                                                                                1:0027:1
    SCAN Q:P WHILE "- " ;                                                             1:0026:2
    SCAN Q:Q WHILE "0123456789" ;                                                     1:0028:3
    W := INT (P, DELTA (P, Q)) ;                                                      1:0031:0
    IF Q NEQ "." THEN RETURN (W/N) ;                                                  1:0032:3
    P := Q + 1 ;                                                                      1:0036:1
    SCAN Q:P WHILE "0123456789" ;                                                     1:0037:3
    N := 1 ;                                                                          1:0040:0
    THRU DELTA(P,Q) DO N:=10*N;                                                       1:0040:3
    RETURN (W + INT (P, DELTA (P, Q)) / N) ;                                          1:0045:2
 END ; % F                                                                            1:0048:1
 DEFINE F62 (P) = F (P, 0, 100)#, F63 (P) = F (P, 0, 1000)# ;                         1:0048:2
 DEFINE PRINT (S) =                                                                   1:0048:2
    BEGIN                                                                             1:0048:3
       REPLACE POINTER (A) BY 8" " FOR 132 ;                                          1:0048:3
       REPLACE POINTER (A) BY S ;                                                     1:0048:3
       WRITE (LINE, A) ;                                                              1:0048:3
    END# ;                                                                            1:0048:3
 NEW NS, NL, BPMAX, NPPO, NDPO, INLRT, NAUTVN, NCONRT, STEPX,FIRST;                   1:0048:2
 ARRAY LNUM [ Y,  Z, 5], WT [ Y,  Z], NTRK [105], TR [ Y,  Z],                        1:0051:0
  LOCATI [ Y,  Z, 5], LOCATF [ Y,  Z, 5], NPATH [ 200], ILLSDR [ Y,  Z];              1:0055:2
$ INCLUDE MSCDM/PATHX                                                                 1:0060:2
%************************************************************************** D  SEQ   1:0060:2
%                                                                           D        1:0060:2
%      THIS SUB-PROGRAM PERFORMS THE  FOLLOWING FUNCTION(S):                D        1:0060:2
%          1. ENUMERATE AND STORE ALL PATHS BETWEEN EVERY NODE PAIR         D        1:0060:2
%          2. WRITE ALL PATHS, IF REQUIRED                                 *D        1:0060:2
%    *     3. CHECK IF ILLEGAL PATHS ARE FORMED                            *D        1:0060:2
%    *                                                                     *D        1:0060:2
%************************************************************************** D        1:0060:2
   PROCEDURE PATH(IRT,IWR,IS,ID,ICON);                                      D        1:0060:2
      ARRAY IRT[ Y, Z,5];                                                   D        1:0063:2
      NEW IWR;                                                              D        1:0064:3
      NAME IS,ID,ICON;                                                      D        1:0064:3
      BEGIN                                                                 D        1:0064:3
 NEW I,J,K,KOUNT,ISC,NUMBER,IAFTER,IPSP,L,M,ITS,ITD,ISPS,IAD,IDUM;          D        1:0062:2
START OF SEGMENT   3
 ARRAY IPATH [16], ITSS [3], ITDS [3], LS [3], MS [3] ;                     D        3:0003:2
 DEFINE BUFFER=A# ;                                                         D        3:0006:0
            ICON:=0;                                                        D        3:0006:0
%*****INITIALIZE SPARSE MATRICES                                            D        3:0007:1
%                                                                           D        3:0007:1
             I:=NS***6-1;                                                   D        3:0007:1
             LOCATI[0,0,0]:=LOCATF[0,0,0]:=0;                               D        3:0009:2
             REPLACE POINTEP(LOCATI)+4 BY POINTER(LOCATI) FOR I WORDS;      D        3:0012:1
             REPLACE POINTER(LOCATF)+4 BY POINTER(LOCATF) FOR I WORDS;      D        3:0015:3
%                                                                           D        3:0019:1
%***** INITIALIZE PARAMETERTS                                               D        3:0019:1
%                                                                           D        3:0019:1
                KOUNT:=IS:=ID:=1;                                           D        3:0019:1
                ISC:=0;                                                     D        3:0022:0
                IPATH[1]:= -1;                                              D        3:0022:3
%                                                                           D        3:0024:1
%*****MAIN PART OF PATH                                                     D        3:0024:1
%                                                                           D        3:0024:1
```

```
102: TRACE(102);
     IF (ID:=ID+1) GTR NS THEN
     BEGIN
        TRACE(111);
111:    IF (IS:=IS+1) GTR NS THEN RETURN;
        IPATH[1]:=-IS;
        ID:=1;
     END ELSE IF ID=IS THEN GO TO 102;
103: NUMBER:=L:=M:=1; TRACE(103);
     IAFTER:=IPSP:=ISPS:=0;
%
%*****WRITE SOURCE AND DESTINATION NUMBERS WHOSE PATH IS TO BE FOUND
%
     IF NOT FIRST THEN
     IF IWR NEQ 0 THEN
     BEGIN
        REPLACE POINTER(BUFFER) BY "FROM", IS FOR 3 DIGITS,
        " TO", ID FOR 3 DIGITS, 6" " FOR 119;
        WRITE(LINE,BUFFER);
     END;
     ITS:=IS;
%
%*****DETERMINE NEXT NODE ON PATH
%
104: ITD:=IRT[ITS,ID,L]; TRACE(104);
%
%*****BIG LOOP
%
   WHILE TRUE DO
   BEGIN
%
%*****CHECK TO SEE IF THIS NODE HAS PREVIOUSLY BEEN ENCOUNTERED
%
105: TRACE(105);
     FOR I:=1 STEP 1 UNTIL M DO
     IF ABS(ITD)=ABS(IPATH[I]) THEN BEGIN ICON:=1; RETURN; END;
%
%*****PUT NODE ON PATH
%
     IPATH[(M:=M+1)]:=ITD;
     ITD:=ABS(ITD);
%
%*****CHECK TO SEE IF TEMPORARY SOURCE IS A SPILL NODE
%
     IF ITS NEQ IPATH[M-1] THEN
     BEGIN
%
%*****STORE THE SPILL NODE IN THE STACK
%*****ALSO CHECK TO SEE IF THERE ARE TWO DISTINCT ROUTES TO SPILL
%*****NODES OR IF TWO SPILL NODES OCCUR ON THE SAME PATH
%
        IF (ISPS:=ITS) NEQ IS THEN
        BEGIN
           IF IAFTER=1 THEN BEGIN ICON:=3; RETURN; END;
           IF IPSP EQL 0 THEN IPSP:=ISPS;
           IF IPSP NEQ ISPS THEN BEGIN ICON:=2; RETURN; END;
        END;
107: TRACE(107);
     IF(IAD:=IRT[ITS,ID,(L:=L+1)]) NEQ 0 THEN
        BEGIN
           ITSS[(ISC:=ISC+1)]:=ITS;
           ITDS[ISC]:=IAD;
          LS[ISC]:=L;
           MS[ISC]:=M-1;
        END ELSE
%
%*****CHECK TO SEE IF THE NEXT PATH IS THE FIRST ONE AFTER THE
%*****LAST PATH OF A SPILL NODE
%
        BEGIN
108: TRACE(108);
        IF IPSP NEQ 0 THEN IAFTER :=1;
        END;
%
%*****CHECK TO SEE IF DESTINATION HAS BEEN REACHED
%
     END;
109: TRACE(109);
     IF ITD EQL ID THEN
     BEGIN
```

```
%
%*****PUT THE COMPLETED PATH INTO SPARSE ARRAY AND NOTE
%*****INITIAL AND FINAL ADDRESSES
%
 112:      LOCATI[IS,ID,NUMBER]:=KOUNT;  TRACE(112);
           LOCATF[IS,ID,NUMBER]:=KOUNT+M-1;
           NUMBER:=NUMBER+1;
%
%*****WRITE THE SEQUENCE NODES ON THE PATH FROM SOURCE TO DESTINATION
%
           IF NOT FIRST THEN
           IF IWR NEQ 0 THEN
           BEGIN
              P:=POINTER(BUFFER);
              REPLACE P BY 6" " FOR 132;
              FOR I:=1 STEP 1 UNTIL M DO
              REPLACE P:P BY "(",IPATH[I] FOR 3 DIGITS,")";
              WRITE(LINE,BUFFER);
           END;
           FOR I:=1 STEP 1 UNTIL M DO
           BEGIN
              NPATH[(KOUNT:=KOUNT+1)]:=IPATH[I];
              IF KOUNT GEQ 3000 THEN
%
%*****MESSAGE FOR PATH ARRAY OVERFLOW
%
              BEGIN
 114:            P:=POINTER(BUFFER); TRACE(114);
                 REPLACE P BY 6" " FOR 132;
                 REPLACE P BY "MEMORY OVERFLOW";
                 WRITE(LINE,BUFFER);
                 REPLACE P BY "EXECUTION TERMINATED";
                 WRITE(LINE,BUFFER);
                 RETURN;
              END;
           END;
           IF ISC EQL 0 THEN GO TO 102;
%
%*****WITHDRAW THE LAST DESTINATION IN THE STACK
%
 110:      ITS:=ITSS[ISC];    TRACE(110);
           ITD:=ITDS[ISC];
           L:=LS[ISC];
           M:=MS[ISC];
           ISC:=ISC-1;
        END ELSE
        BEGIN
%
%*****ADVANCE TO NEXT LINK IN PATH
%
           ITS:=ITD;
           L:=1;
           ITD:=IRT[ITS,ID,L]; TRACE(104);
        END;
     END;
   END;
SEGMENT    3 IS    182 LONG.
   PROCEDURE DECOD1 FORWARD ;                                                        SEQ
%**************************************************************************
%       *                                                                 *
%*******  THIS SUB/PROGRAM PERFORMS THE FOLLOWING FUNCTION(S):            *
%       *        1. READ AND WRITE DATA                                   *
%       *        2. WRITE PERFORMANCE BASED UPON THE ORIGNAL AND REVISED  *
%       *           ROUTING TABLES(IF REVISION WAS DONE)                  *
%       *                                                                 *
%*******  THIS SUB-PROGRAM USES THE FOLLOWING SUBROUTINES(S):             *
%       *        1. DECOD1(ONLY FOR EUROPEAN AUTOVON NETWORK)             *
%       *        2. DECOD2(ONLY FOR EUROPEAN AUTOVON NETWORK)             *
%       *        3. PATH                                                  *
%       *        4. ACTGOS                                                *
%       *        5. SORT1                                                 *
%       *        6. REVRTO(IF REVISION IS NEEDED)                         *
%       *        7. SECOND(SYSTEM DEPENDENT SUBROUTINE)                   *
%       *                                                                 *
%**************************************************************************
   ARRAY IRT[16,16,5], FLTG[106], CLSD[16,16], IRRT[16,16,5], GOS[106],
   NODE[12], STR[16], CLS[16], PR[16,16,6], PL[16,16,6] ;
   NEW I,J,TO,LUNIT,OVLD,ITPG,ICON,ICONOLD,RP,CSSUM,CTSUM,WCSUM,SDBP,
    WSDBP, MARK, GOSNTK, WGOSNK, SBP, BIGBP, NEXD, T1, JCON, T2, TDIF,
    NRC,T3,TREV,TTOTAL,NPRINT,IS,ISOLD,ID,IDOLD,LN,W,DUM,IDUM;
```

```
REPLACE POINTER(I) BY 6" " FOR 132;
WHILE READ (INPUT, A) DO WRITE (CARD, A) ;
REWIND (CARD) ;
%
%*****READ AND WRITE TITLE
%
   READ (CARD, A) ;
   REPLACE POINTER (A) + 80 BY 8" " FOR 52 ;
   WRITE (LINE [0], A) ;
   PRINT ("VERBATIM ACCOUNT OF INPUT DATA") ;
%
%*****READ AND WRITE OPTION CARD INFORMATION
%
   READ (CARD, A) ;
   WRITE (LINE, A) ;
   NPPO := INT (POINTER (A), 1) ;
   NDPO := INT (POINTER (A) + 2, 1) ;
   INLRT := INT (POINTER (A) + 4, 1) ;
   NAUTVN := INT (POINTER (A) + 6, 1) ;
   NCONRT := INT (POINTER (A) + 8, 1) ;
   LUNIT := FETCH (POINTER (A) + 10, 3) ;
%
%*****CHECK IF THE TRAFFIC UNITS ARE CORRECTLY SPECIFIED
%
   IF LUNIT NEQ 8"CCS" AND LUNIT NEQ 8"ERG" THEN GO TO 152 ;
%
%*****READ AND WRITE PROGRAM PARAMETERS
%
   READ (CARD, A) ;
   NS := INT (A, 2) ;
   NL := INT (POINTER (A) + 2, 3) ;
   UPMAX := F63 (POINTER (A) + 5) ;
   IF (OVLD := F63 (POINTER (A) + 11)) = 0 THEN OVLD := 1 ;
   IF (STEPX := F63 (POINTER (A) + 17)) = 0 THEN STEPX := 0.01 ;
   WRITE (LINE, A) ;
%
%*****INITIALIZE SPARSE MATRICES
%
   FOR I := 1 STEP 1 UNTIL NS DO
   BEGIN
      % CLS [I] := 0 ;
      % STR [I] := 0 ;
      FOR J := 1 STEP 1 UNTIL NS DO
      BEGIN
         % LNUM [I, J] := 0 ;
         WT [I, J] := 1 ;
      END ;
   END ;
%
%*****READ AND WRITE TRUNK INFORMATION
%
   FOR I := 1 STEP 1 UNTIL NL DO
   BEGIN
      READ (CARD, A) ;
      WRITE (LINE, A) ;
      IS := INT (A, 2) ;
      ID := INT (POINTER (A) + 2, 2) ;
      LN := INT (POINTER (A) + 4, 3) ;
      LNUM [IS, ID] := LNUM [ID, IS] := LN ;
      NTRK [LN] := INT (POINTER (A) + 13, 2) ;
      NPATH [LN] := IS ;
      NPATH [105 + LN] := ID ;
      GOS [I] := 0.9 ;
   END ;
%
%*****READ AND WRITE ROUTING TABLE,TRAFFIC,AND NNGOS WEIGHT INFORMATION
%
   IDUM := NS * (NS - 1) ;
   FOR I := 1 STEP 1 UNTIL IDUM DO
   BEGIN
      READ (CARD, A) ;
      WRITE (LINE, A) ;
      IS := INT (A, 2) ;
      ID := INT (POINTER (A) + 2, 2) ;
      IRT [IS, ID, 1] := INT (POINTER (A) + 4, 3) ;
      IRT [IS, ID, 2] := INT (POINTER (A) + 7, 3) ;
      IRT [IS, ID, 3] := INT (POINTER (A) + 10, 3) ;
      % IRT [IS, ID, 4] := 0 ;
      DUM := F62 (POINTER (A) + 13) ;
      IF LUNIT = 8"ERG" THEN DUM := DUM * 36 ;
```

```
        IB [IS, ID] := DUM * OVLD ;                                                      1:0247:3
        IF (W := F62 (POINTER (A) + 19)) NEQ 0 THEN WT [IS, ID] := W ;                   1:0251:3
    END ;                                                                                1:0260:0
%                                                                                        1:0261:0
%*****IF THE NETWORK IS EUROPEAN AUTOVON, READ AND WRITE THE ACRONYMS                    1:0261:0
%*****FOR ITS OFFICES                                                                    1:0261:0
%                                                                                        1:0261:0
    IF NAUTVN = 1 THEN                                                                   1:0261:0
    BEGIN                                                                                1:0261:3
        READ (CARD, A) ;                                                                 1:0262:3
        WRITE (LINE, A) ;                                                                1:0265:2
        FOR I := 1 STEP 1 UNTIL 11 DO                                                    1:0268:1
            NODE [I] := FETCH (POINTER (A) + 4 * (I - 1), 3) ;                           1:0273:0
    END ;                                                                                1:0277:3
%                                                                                        1:0277:3
%*****WRITE USER SPECIFIED OPTIONS                                                       1:0277:3
%                                                                                        1:0277:3
    THRU 5 DO PRINT (" ") ;                                                              1:0277:3
    PRINT ("USER SPECIFIED OPTIONS:") ;                                                  1:0287:2
    NPRINT := (IF NPPO = 0 THEN 8"NO " ELSE 8"YES") ;                                    1:0295:1
    PRINT ("LIST OF PATHS REQUIRED:  ", POINTER (NPRINT) + 1 FOR 3) ;                    1:0300:0
    NPRINT := (IF NDPO = 0 THEN 8"NO " ELSE 8"YES") ;                                    1:0309:2
    PRINT ("DETAILS OF PATH RELIABILITY AND PATH CARRIED LOAD ",                         1:0314:1
        "REQUIRED:  ", POINTER (NPRINT) + 1 FOR 3) ;                                     1:0314:1
SEGMENT    2 IS    74 LONG.
    PRINT ("OPTION NUMBER FOR INITIALIZING ROUTING TABLE FOR REVISION=",                 1:0325:2
        INLRT FOR 4 DIGITS) ;                                                            1:0325:2
    PRINT ("(NOTES ON OPTION USED:") ;                                                   1:0334:0
    IF INLRT = 1 THEN                                                                    1:0341:3
    BEGIN                                                                                1:0342:2
        PRINT ("ALL SPILL SWITCHES OF THE ORIGNAL ROUTING TABLE ARE ",                   1:0343:2
            "CONVERTED") ;                                                               1:0343:2
        PRINT ("INTO NON-SPILL SWITCHES BEFORE REVISION)") ;                             1:0353:0
    END ELSE                                                                             1:0360:3
    IF INLRT = 2 THEN                                                                    1:0361:3
        PRINT ("NO CHANGES TO THE ORIGNAL ROUTING TABLE MADE BEFORE ",                   1:0362:2
            "REVISION)")                                                                 1:0362:2
    ELSE                                                                                 1:0373:0
    IF INLRT = 3 THEN                                                                    1:0374:0
    BEGIN                                                                                1:0374:3
        PRINT ("ALL NON-SPILL SECOND AND THIRD CHOICES IN THE ORIGNAL ",                 1:0375:3
            "ROUTING") ;                                                                 1:0375:3
SEGMENT    4 IS    66 LONG.
        PRINT ("TABLE ARE DELETED BEFORE REVISION)") ;                                   1:0385:1
    END ;                                                                                1:0393:0
    PRINT ("MAXIMUM ALLOWABLE BLOCKING PROBABILITY(BPMAX)",                              1:0393:0
        ENTIER (BPMAX) FOR 3 DIGITS, ".",                                                1:0393:0
        ROUND (BPMAX MOD 1 * 1000) FOR -3 DIGITS) ;                                      1:0393:0
    PRINT ("STEP SIZE OF PDPMAX REDUCTIONS=",                                            1:0405:1
        ENTIER (STEPX) FOR 2 DIGITS, ".",                                                1:0405:1
        ROUND (STEPX MOD 1 * 1000) FOR -3 DIGITS) ;                                      1:0405:1
    IF NAUTVN = 1 THEN                                                                   1:0418:0
    BEGIN                                                                                1:0418:3
        PRINT ("GIVEN NETWORK IS AUTOVON") ;                                             1:0419:3
        IF NCONRT = 1 THEN                                                               1:0427:2
            PRINT ("AN ATTEMPT TO IMPROVE CONUS TRAFFIC IS REQUIRED")                    1:0428:1
        ELSE                                                                             1:0437:0
        IF NCONRT = 0 THEN                                                               1:0438:0
            PRINT ("AN ATTEMPT TO IMPROVE CONUS TRAFFIC IS NOT REQUIRED") ;              1:0438:2
    END ;                                                                                1:0447:1
%                                                                                        1:0447:1
%*****WRITE NETWORK DESCRIPTION                                                          1:0447:1
%                                                                                        1:0447:1
    PRINT ("NETWOPK DESCRIPTION") ;                                                      1:0447:1
SEGMENT    5 IS    76 LONG.
    PRINT ("NUMBER OF SWITCHES IN NETWORK ", NS FOR 2 DIGITS) ;                          1:0455:0
    PRINT ("NUMBER OF TRUNK GROUPS IN NETWORK ", NL FOR 3 DIGITS) ;                      1:0463:2
    PRINT (8" " FOP 42, "EXISTING NUMBER") ;                                             1:0472:0
    PRINT ("LINK NUMBER            SWITCH PAIR               OF TRUNKS") ;               1:0480:2
%                                                                                        1:0488:1
%*****CHECK IF NETWORK IS EUROPEAN AUTOVON                                               1:0488:1
%                                                                                        1:0488:1
    IF NAUTVN NEQ 1 THEN                                                                 1:0488:1
    BEGIN                                                                                1:0489:0
%                                                                                        1:0490:0
%*****WRITE TRUNK GROUP INFORMATION                                                      1:0490:0
%                                                                                        1:0490:0
        FOR I := 1 STEP 1 UNTIL NL DO                                                    1:0490:0
        BEGIN                                                                            1:0494:3
            PRINT (I FOR 7 DIGITS, NPATH [I] FOR 17 DIGITS,                              1:0494:3
```

```
            NPATH [I + 105] FOR 7 DIGITS, NTRK [I] FOR 20 DIGITS) ;          1:0494:3
         NPATH [I] := NPATH [I + 105] := 0 ;                                  1:0507:1
      END ;                                                                   1:0511:2
      PRINT ("SWITCH-TO-SWITCH TRAFFIC", 8" " FOR 37, "ORIGINAL ",            1:0512:2
         "ROUTING TABLE") ;                                                   1:0512:2
      PRINT ("FROM            TO            TRAFFIC IN CCS          CHOICE"   1:0524:2
         " 1          CHOICE 2            CHOICE 3         WEIGHT") ;         1:0524:2
      PRINT (8" " FOR 46, "(PRIMARY ROUTES)") ;                               1:0532:3
SEGMENT    6 IS   81 LONG.
   %                                                                          1:0541:1
   %*****WRITE ORIGNAL ROUTING TABLE, TRAFFIC MATRIX AND WEIGHT               1:0541:1
   %     INFORMATION                                                          1:0541:1
   %                                                                          1:0541:1
         FOR I := 1 STEP 1 UNTIL NS DO                                        1:0541:1
            FOR J := 1 STEP 1 UNTIL NS DO                                     1:0546:0
               IF I NEQ J THEN                                                1:0550:3
                  PRINT (I FOR 3 DIGITS, J FOR 13 DIGITS,                     1:0552:0
                     ENTIER ((W := TR [I, J])) FOR 18 DIGITS, ".",            1:0552:0
                        ENTIER (W MOD 1 * 10) FOR 1 DIGITS,                   1:0552:0
                     IRT [I, J, 1] FOR 19 DIGITS,                             1:0552:0
                     IRT [I, J, 2] FOR 18 DIGITS,                             1:0552:0
                     IRT [I, J, 3] FOR 18 DIGITS,                             1:0552:0
                     ENTIER ((W := WT [I, J])) FOR 16 DIGITS, ".",            1:0552:0
                        ENTIER (W MOD 1 * 100) FOR -2 DIGITS) ;               1:0552:0
         PRINT ("(CHOICE LEVEL WITH MINUS SIGN DENOTES A SPILL SWITCH)") ;    1:0588:1
      END ELSE                                                                1:0596:0
      BEGIN                                                                   1:0597:0
   %                                                                          1:0597:0
   %*****WRITE TRUNK GROUP,ORIGNAL ROUTING TABLE;TRAFFIC AND WEIGHT           1:0597:0
   %*****INFORMATION FOR THE EUROPEAN AUTOVON NETWORK                         1:0597:0
   %                                                                          1:0597:0
         ITRG := 0 ;                                                          1:0597:0
         DECOD1 (IRT, ITRG, NODE) ;                                           1:0598:0
      END ;                                                                   1:0601:0
   %                                                                          1:0601:0
   %*****CHECK IF PATHS ARE TO BE PRINTED                                     1:0601:0
   %                                                                          1:0601:0
      IF NPPO NEQ 0 THEN                                                      1:0601:0
         PRINT ("PATHS DEFINED BY THE ORIGINAL ROUTING TABLE") ;              1:0601:3
   %                                                                          1:0610:2
   %*****CHECK FOR ILLEGAL PATHS IN THE ORIGINAL ROUTING TABLE                1:0610:2
   %                                                                          1:0610:2
      T0:=TIME(4);                                                            1:0610:2
      THRU 10 DO BEGIN                                                        1:0612:2
      ISOLD:=IS; IDOLD:=ID; ICONOLD:=ICON; FIRST:=TRUE;                       1:0614:3
     % THE ABOVE TWO STATEMENTS ARE FOR TIMING.                               1:0619:2
     % FIRST RUN FOR TIMING ONLY.                                             1:0619:2
      PATH (IRT, NPPO, POINTER (IS), POINTER (ID), POINTER (ICON)) ;          1:0619:2
      IS:=ISOLD;ID:=IDOLD; ICON:=ICONOLD;END;                                 1:0623:0
      T3 := TIME (4) ;                       % CALL SECOND (T3)               1:0627:2
      TTOTAL := T3 - T0 ;                                                     1:0629:2
     % NOW PERFORM PRINT RUN.                                                 1:0631:2
      IS:=ISOLD; ID:=IDOLD; ICON:=ICONOLD; FIRST:=FALSE;                      1:0631:2
      PATH (IRT, NPPO, POINTER (IS), POINTER (ID), POINTER (ICON)) ;          1:0636:1
      PRINT ("TIME REQUIRED TO EXECUTE ENTIRE PROGRAM",                       1:0639:3
         ENTIER (TTOTAL) FOR 6 DIGITS, ".",                                   1:0639:3
         ENTIER (TTOTAL MOD 1 * 1000) FOR -3 DIGITS, " SECONDS") ;            1:0639:3
      REWIND (LINE) ;                                                         1:0654:1
      WHILE READ (LINE, A) DO WRITE (OUTPUT, A) ;                             1:0656:2
      CLOSE (CARD) ;                                                          1:0663:1
      CLOSE (LINE) ;                                                          1:0665:2
   END?                                                                       1:0667:3
SEGMENT    1 IS  669 LONG.
SEGMENT    7 IS   41 LONG.
SEGMENT    0 IS    1 LONG.
  0 ERRORS   452 CARDS.   3306 TOKENS.     5712 RULES.       90 SECONDS.    2 SEQUENCE ERRORS.
```

BURROUGHS B776 10 LOOPS

```
********************************* EXAMPLE 5.1: 5-NODE,8-LINK NETWORK ******************************
VERBATIM ACCOUNT OF INPUT DATA
1 1 2 0 0 ERG
 5  8 0.010 1.0   0.
 1 2 1          14
 1 3 2          12
 2 4 3          10
 4 5 4           7
 3 5 5          10
 2 3 6          12
 2 5 7          13
 3 4 8          15
 1 2 2  0  0 1.5     1.0
 1 3 3  0  0 2.0     1.0
 1 4 2  3  0 2.0     1.0
 1 5 3  2  0 4.0     1.0
 2 1 1  0  0 1.5     1.0
 2 3 3  4  0 2.8     1.0
 2 4 4  3  0 3.0     1.0
 2 5 5  3  0 1.2     1.0
 3 1 1  0  0 2.0     1.0
 3 2 2  0  0 2.5     1.0
 3 4 4  0  0 5.0     1.0
 3 5 5  4  0 4.2     1.0
 4 1 3  2  0 1.7     1.0
 4 2 2  5  0 2.2     1.0
 4 3 3  5  0 3.0     1.0
 4 5 5  3  0 1.6     1.0
 5 1 3  2  0 2.5     1.0
 5 2 2  4  0 2.5     1.0
 5 3 3  2  0 1.2     1.0
 5 4 4  3  0 1.0     1.0
```

USER SPECIFIED OPTIONS:
LIST OF PATHS REQUIRED: YES
DETAILS OF PATH RELIABILITY AND PATH CARRIED LOAD REQUIRED: YES
OPTION NUMBER FOR INITIALIZING ROUTING TABLE FOR REVISION= 2
(NOTES ON OPTION USED:
NO CHANGES TO THE ORIGNAL ROUTING TABLE MADE BEFORE REVISION)
MAXIMUM ALLOWABLE BLOCKING PROBABILITY(BPMAX) 0.010
STEP SIZE OF POPMAX REDUCTIONS= 0.010
NETWORK DESCRIPTION
NUMBER OF SWITCHES IN NETWORK 5
NUMBER OF TRUNK GROUPS IN NETWORK 8

LINK NUMBER	SWITCH PAIR		EXISTING NUMBER OF TRUNKS
1	1	2	14
2	1	3	12
3	2	4	10
4	4	5	7
5	3	5	10
6	2	3	12
7	2	5	13
8	3	4	15

SWITCH-TO-SWITCH TRAFFIC / ORIGINAL ROUTING TABLE

FROM	TO	TRAFFIC IN CCS	CHOICE 1 (PRIMARY ROUTES)	CHOICE 2	CHOICE 3	WEIGHT
1	2	54.0	2	0	0	1.00
1	3	72.0	3	0	0	1.00
1	4	72.0	2	3	0	1.00
1	5	144.0	3	2	0	1.00
2	1	54.0	1	0	0	1.00
2	3	100.7	3	4	0	1.00
2	4	108.0	4	3	0	1.00
2	5	43.2	5	3	0	1.00
3	1	72.0	1	0	0	1.00
3	2	90.0	2	0	0	1.00
3	4	180.0	4	0	0	1.00
3	5	151.2	5	4	0	1.00
4	1	61.2	3	2	0	1.00
4	2	79.2	2	5	0	1.00
4	3	108.0	3	5	0	1.00
4	5	57.6	5	3	0	1.00
5	1	90.0	3	2	0	1.00
5	2	90.0	2	4	0	1.00
5	3	43.2	3	2	0	1.00

```
    5          4               36.0                4                     3                     0                    1.00
(CHOICE LEVEL WITH MINUS SIGN DENOTES A SPILL SWITCH)
PATHS DEFINED BY THE ORIGINAL ROUTING TABLE
FROM  1 TO  2
( -1)(   2)
FROM  1 TO  3
( -1)(   3)
FROM  1 TO  4
( -1)(   2)(   4)
( -1)(   3)(   4)
FROM  1 TO  5
( -1)(   3)(   5)
( -1)(   2)(   5)
FROM  2 TO  1
( -2)(   1)
FROM  2 TO  3
( -2)(   3)
( -2)(   4)(   3)
FROM  2 TO  4
( -2)(   4)
( -2)(   3)(   4)
FROM  2 TO  5
( -2)(   5)
( -2)(   3)(   5)
FROM  3 TO  1
( -3)(   1)
FROM  3 TO  2
( -3)(   2)
FROM  3 TO  4
( -3)(   4)
FROM  3 TO  5
( -3)(   5)
( -3)(   4)(   5)
FROM  4 TO  1
( -4)(   3)(   1)
( -4)(   2)(   1)
FROM  4 TO  2
( -4)(   2)
( -4)(   5)(   2)
FROM  4 TO  3
( -4)(   3)
( -4)(   5)(   3)
FROM  4 TO  5
( -4)(   5)
( -4)(   3)(   5)
FROM  5 TO  1
( -5)(   3)(   1)
( -5)(   2)(   1)
FROM  5 TO  2
( -5)(   2)
( -5)(   4)(   2)
FROM  5 TO  3
( -5)(   3)
( -5)(   2)(   3)
FROM  5 TO  4
( -5)(   4)
( -5)(   3)(   4)
TIME REQUIRED TO EXECUTE ENTIRE PROGRAM      6.625 SECONDS
```

```
                  %**************************************************************         0:0000:*
                  %************************ S T A R T U P ******************************  0:0000:*
                  %******* STATISTICAL ANALYSIS AND ROUTING TABLE UPDATING PROGRAM *****    0:0000:*
                  %**************************************************************         0:0000:*
                  %*************************** JULY 1976 VERSION **********************     0:0000:*
                  %**************************************************************         0:0000:*
                  BEGIN                  % ALGOL TRANSLATION          MARCH 1977          0:0000:*
                   FILE INPUT (CARDS) ;                                                   0:0000:*
START OF SEGMENT     1
                   FILE CARD (DISK, POINTER ("T."), 20, 180, 100) ;                       1:0004:1
                   FILE OUTPUT (PRINTER) ;                                                1:0011:2
                   FILE LINE (DISK, POINTER ("T."), 33, 495, 200) ;                       1:0016:0
                   ARRAY A [33] ;                                                         1:0023:1
                   ARRAY T[33];                                                           1:0023:3
                   DEFINE TRACE(X) =                                                      1:0024:1
                      BEGIN                                                               1:0024:2
                  $ OMIT                                                                  1:0024:2
                  $ POP OMIT                                                              1:0024:2
                      END#;                                                               1:0024:2
                   POINTER P ;                                                            1:0024:1
                   DEFINE Y = 6 #, Z = 16 #;                                              1:0024:2
                   PROCEDURE F (P, Q, N, W) ; POINTER P, Q ; NEW N, W ;                   1:0024:2
                   BEGIN                                                                  1:0027:1
                      SCAN Q:P WHILE "- " ;                                               1:0026:2
                      SCAN Q:Q WHILE "0123456789" ;                                       1:0028:3
                      W := INT (P, DELTA (P, Q)) ;                                        1:0031:0
                      IF Q NEQ "." THEN RETURN (W/N) ;                                    1:0032:3
                      P := Q + 1 ;                                                        1:0036:1
                      SCAN Q:P WHILE "0123456789" ;                                       1:0037:3
                      N := 1 ;                                                            1:0040:0
                      THRU DELTA(P,Q) DO N:=10*N;                                         1:0040:3
                      RETURN (W + INT (P, DELTA (P, Q)) / N) ;                            1:0045:2
                   END ; % F                                                              1:0048:1
                   DEFINE F62 (P) = F (P, 0, 100)#, F63 (P) = F (P, 0, 1000)# ;           1:0048:2
                   DEFINE PRINT (S) =                                                     1:0048:2
                      BEGIN                                                               1:0048:3
                         REPLACE POINTER (A) BY 8" " FOR 132 ;                            1:0048:3
                         REPLACE POINTER (A) BY S ;                                       1:0048:3
                         WRITE (LINE, A) ;                                                1:0048:3
                      END# ;                                                              1:0048:3
                   NEW NS, NL, BPMAX, NPPO, NDPO, INLRT, NAUTVN, NCONRT, STEPX,FIRST;     1:0048:2
                   ARRAY LNUM [ Y,  Z, 5], WT [ Y,  Z], NTRK [105], TR [ Y,  Z],          1:0051:0
                    LOCATI [ Y,  Z, 5], LOCATF [ Y,  Z, 5], NPATH [ 200], ILLSDR [ Y,  Z]; 1:0055:2
                  $ INCLUDE MSCDM/PATHX                                                   1:0060:2
                  %*************************************************************** D  SEQ  1:0060:2
                  %                                                                 D      1:0060:2
                  %      THIS SUB-PROGRAM PERFORMS THE  FOLLOWING FUNCTION(S):     D      1:0060:2
                  %         1. ENUMERATE AND STORE ALL PATHS BETWEEN EVERY NODE PAIR D    1:0060:2
                  %         2. WRITE ALL PATHS, IF REQUIRED                       * D      1:0060:2
                  %    *    3. CHECK IF ILLEGAL PATHS ARE FORMED                  * D      1:0060:2
                  %    *                                                          * D      1:0060:2
                  %*************************************************************** D      1:0060:2
                     PROCEDURE PATH(IRT,IWR,IS,ID,ICON);                            D      1:0060:2
                        ARRAY IRT[ Y, Z,5];                                         D      1:0063:2
                        NEW IWR;                                                    D      1:0064:3
                        NAME IS,ID,ICON;                                            D      1:0064:3
                        BEGIN                                                       D      1:0064:3
                   NEW I,J,K,KOUNT,ISC,NUMBER,IAFTER,IPSP,L,M,ITS,ITD,ISPS,IAD,IDUM; D    1:0062:2
START OF SEGMENT     3
                   ARRAY IPATH [16], ITSS [3], ITDS [3], LS [3], MS [3] ;          D      3:0003:2
                   DEFINE BUFFER=A# ;                                               D      3:0006:0
                           ICON:=0;                                                 D      3:0006:0
                  %*****INITIALIZE SPARSE MATRICES                                 D      3:0007:1
                  %                                                                 D      3:0007:1
                           I:=NS**6-1;                                              D      3:0007:1
                           LOCATI[0,0,0]:=LOCATF[0,0,0]:=0;                         D      3:0009:2
                           REPLACE POINTER(LOCATI)+4 BY POINTER(LOCATI) FOR I WORDS; D     3:0012:1
                           REPLACE POINTER(LOCATF)+4 BY POINTER(LOCATF) FOR I WORDS; D     3:0015:3
                  %                                                                 D      3:0019:1
                  %***** INITIALIZE PARAMETERTS                                     D      3:0019:1
                  %                                                                 D      3:0019:1
                              KOUNT:=IS:=ID:=1;                                     D      3:0019:1
                              ISC:=0;                                               D      3:0022:0
                              IPATH[1]:= -1;                                        D      3:0022:3
                  %                                                                 D      3:0024:1
                  %*****MAIN PART OF PATH                                           D      3:0024:1
```

```
%                                                                        D   3:0024:1
102: TRACE(102);                                                         D   3:0024:1
     IF (ID:=ID+1) GTR NS THEN                                           D   3:0024:1
     BEGIN                                                               D   3:0027:0
        TRACE(111);                                                      D   3:0028:0
111:    IF (IS:=IS+1) GTR NS THEN RETURN;                                D   3:0028:0
        IPATH[1]:=-IS;                                                   D   3:0032:1
        ID:=1;                                                           D   3:0034:1
     END ELSE IF ID=IS THEN GO TO 102;                                   D   3:0035:2
103: NUMBER:=L:=M:=1; TRACE(103);                                        D   3:0039:3
     IAFTER:=IPSP:=ISPS:=0;                                              D   3:0041:2
%                                                                        D   3:0043:1
%*****WRITE SOURCE AND DESTINATION NUMBERS WHOSE PATH IS TO BE FOUND     D   3:0043:1
%                                                                        D   3:0043:1
     IF NOT FIRST THEN                                                   D   3:0043:1
     IF IWR NEQ 0 THEN                                                   D   3:0044:0
     BEGIN                                                               D   3:0046:0
        REPLACE POINTER(BUFFER) BY "FROM", IS FOR 3 DIGITS,              D   3:0047:0
        " TO", ID FOR 3 DIGITS, 6" " FOR 119;                            D   3:0051:0
        WRITE(LINE,BUFFER);                                              D   3:0055:2
     END;                                                                D   3:0058:3
     ITS:=IS;                                                            D   3:0058:3
%                                                                        D   3:0060:0
%*****DETERMINE NEXT NODE ON PATH                                        D   3:0060:0
%                                                                        D   3:0060:0
104: ITD:=IRT[ITS,ID,L]; TRACE(104);                                     D   3:0060:0
%                                                                        D   3:0063:3
%*****BIG LOOP                                                           D   3:0063:3
%                                                                        D   3:0063:3
  WHILE TRUE DO                                                          D   3:0063:3
  BEGIN                                                                  D   3:0064:0
%                                                                        D   3:0065:0
%*****CHECK TO SEE IF THIS NODE HAS PREVIOUSLY BEEN ENCOUNTERED          D   3:0065:0
%                                                                        D   3:0065:0
105: TRACE(105);                                                         D   3:0065:0
     FOR I:=1 STEP 1 UNTIL M DO                                          D   3:0065:0
     IF ABS(ITD)=ABS(IPATH[I]) THEN BEGIN ICON:=1; RETURN; END;          D   3:0069:0
%                                                                        D   3:0073:3
%*****PUT NODE ON PATH                                                   D   3:0073:3
%                                                                        D   3:0073:3
     IPATH[(M:=M+1)]:=ITD;                                               D   3:0073:3
     ITD:=ABS(ITD);                                                      D   3:0075:3
%                                                                        D   3:0076:3
%*****CHECK TO SEE IF TEMPORARY SOURCE IS A SPILL NODE                   D   3:0076:3
%                                                                        D   3:0076:3
     IF ITS NEQ IPATH[M-1] THEN                                          D   3:0076:3
     BEGIN                                                               D   3:0078:0
%                                                                        D   3:0079:0
%*****STORE THE SPILL NODE IN THE STACK                                  D   3:0079:0
%*****ALSO CHECK TO SEE IF THERE ARE TWO DISTINCT ROUTES TO SPILL        D   3:0079:0
%*****NODES OR IF TWO SPILL NODES OCCUR ON THE SAME PATH                 D   3:0079:0
%                                                                        D   3:0079:0
        IF (ISPS:=ITS) NEQ IS THEN                                       D   3:0079:0
        BEGIN                                                            D   3:0080:3
           IF IAFTER=1 THEN BEGIN ICON:=3; RETURN; END;                  D   3:0081:3
           IF IPSP EQL 0 THEN IPSP:=ISPS;                                D   3:0085:1
           IF IPSP NEQ ISPS THEN BEGIN ICON:=2; RETURN; END;             D   3:0087:2
        END;                                                             D   3:0091:0
107: TRACE(107);                                                         D   3:0091:0
     IF(IAD:=IRT[ITS,ID,(L:=L+1)]) NEQ 0 THEN                            D   3:0091:0
        BEGIN                                                            D   3:0096:0
           ITSS[(ISC:=ISC+1)]:=ITS;                                      D   3:0097:0
           ITDS[ISC]:=IAD;                                               D   3:0099:1
           LS[ISC]:=L;                                                   D   3:0100:3
           MS[ISC]:=M-1;                                                 D   3:0102:1
        END ELSE                                                         D   3:0104:0
%                                                                        D   3:0105:0
%*****CHECK TO SEE IF THE NEXT PATH IS THE FIRST ONE AFTER THE           D   3:0105:0
%*****LAST PATH OF A SPILL NODE                                          D   3:0105:0
%                                                                        D   3:0105:0
        BEGIN                                                            D   3:0105:0
108: TRACE(108);                                                         D   3:0105:0
        IF IPSP NEQ 0 THEN IAFTER :=1;                                   D   3:0105:0
        END;                                                             D   3:0107:2
%                                                                        D   3:0107:2
%*****CHECK TO SEE IF DESTINATION HAS BEEN REACHED                       D   3:0107:2
%                                                                        D   3:0107:2
     END;                                                                D   3:0107:2
109: TRACE(109);                                                         D   3:0107:2
     IF ITD EQL ID THEN                                                  D   3:0107:2
```

```
      BEGIN
%
%*****PUT THE COMPLETED PATH INTO SPARSE ARRAY AND NOTE
%*****INITIAL AND FINAL ADDRESSES
%
 112:      LOCATI[IS,ID,NUMBER]:=KOUNT;   TRACE(112);
           LOCATF[IS,ID,NUMBER]:=KOUNT+M-1;
           NUMBER:=NUMBER+1;
%
%*****WRITE THE SEQUENCE NODES ON THE PATH FROM SOURCE TO DESTINATION
%
           IF NOT FIRST THEN
           IF IWR NEQ 0 THEN
           BEGIN
              P:=POINTER(BUFFER);
              REPLACE P BY 6" " FOR 132;
              FOR I:=1 STEP 1 UNTIL M DO
              REPLACE P:P BY "(",IPATH[I] FOR 3 DIGITS,")";
              WRITE(LINE,BUFFER);
           END;
           FOR I:=1 STEP 1 UNTIL M DO
           BEGIN
              NPATH[(KOUNT:=KOUNT+1)]:=IPATH[I];
              IF KOUNT GEQ 3000 THEN
%
%*****MESSAGE FOR PATH ARRAY OVERFLOW
%
              BEGIN
 114:            P:=POINTER(BUFFER);  TRACE(114);
                 REPLACE P BY 6" " FOR 132;
                 REPLACE P BY "MEMORY OVERFLOW";
                 WRITE(LINE,BUFFER);
                 REPLACE P BY "EXECUTION TERMINATED";
                 WRITE(LINE,BUFFER);
                 RETURN;
              END;
           END;
           IF ISC EQL 0 THEN GO TO 102;
%
%*****WITHDRAW THE LAST DESTINATION IN THE STACK
%
 110:      ITS:=ITSS[ISC];    TRACE(110);
           ITD:=ITDS[ISC];
           L:=LS[ISC];
           M:=MS[ISC];
           ISC:=ISC-1;
        END ELSE
        BEGIN
%
%*****ADVANCE TO NEXT LINK IN PATH
%
           ITS:=ITD;
           L:=1;
           ITD:=IRT[ITS,ID,L];  TRACE(104);
        END;
     END;
   END;
SEGMENT     3 IS   182 LONG.
   PROCEDURE DECOD1 FORWARD ;
%*************************************************************************
%       *                                                              *
%*******   THIS SUB/PROGRAM PERFORMS THE FOLLOWING FUNCTION(S):        *
%       *         1. READ AND WRITE DATA                               *
%       *         2. WRITE PERFORMANCE BASED UPON THE ORIGNAL AND REVISED *
%       *            ROUTING TABLES(IF REVISION WAS DONE)              *
%       *                                                              *
%*******   THIS SUB-PROGRAM USES THE FOLLOWING SUBROUTINES(S):         *
%       *         1. DECOD1(ONLY FOR FUROPEAN AUTOVON NETWORK)         *
%       *         2. DECOD2(ONLY FOR FUROPEAN AUTOVON NETWORK)         *
%       *         3. PATH                                              *
%       *         4. ACTGOS                                            *
%       *         5. SORT1                                             *
%       *         6. REVRTO(IF REVISION IS NEEDED)                     *
%       *         7. SECOND(SYSTEM DEPENDENT SUBROUTINE)               *
%       *                                                              *
%*************************************************************************
   ARRAY IRT[16,16,5], FLTG[106], CLSD[16,16], IRRT[16,16,5], GOS[106],
    NODE[12], STR[16], CLS[16], PR[16,16,6], PL[16,16,6] ;
   NEW I,J,TO,LUNIT,OVLD,ITRG,ICON,ICONOLD,BP,CSSUM,CTSUM,WCSUM,SDBP,
    WSDBP, MARK, GOSNTK, WGOSNK, SBP, BIGBP, NEXO, T1, JCON, T2, TDIF,
```

```
NRC,I3,IREV,ITOTAL,NPRINT,IS,ISOLD,ID,IDOLD,LN,W,DUM,IDUM;                    1:0080:2
   REPLACE POINTER(T) BY 6" " FOR 132;                                        1:0083:3
   WHILE READ (INPUT, A) DO WRITE (CARD, A) ;                                 1:0086:0
   REWIND (CARD) ;                                                            1:0092:3
%                                                                             1:0095:0
%*****READ AND WRITE TITLE                                                    1:0095:0
%                                                                             1:0095:0
   READ (CARD, A) ;                                                           1:0095:0
   REPLACE POINTER (A) + 80 BY 8" " FOR 52 ;                                  1:0097:3
   WRITE (LINE [0], A) ;                                                      1:0100:2
   PRINT ("VERBATIM ACCOUNT OF INPUT DATA") ;                                 1:0103:0
%                                                                             1:0110:3
%*****READ AND WRITE OPTION CARD INFORMATION                                  1:0110:3
%                                                                             1:0110:3
   READ (CARD, A) ;                                                           1:0110:3
   WRITE (LINE, A) ;                                                          1:0113:2
   NPPO := INT (POINTER (A), 1) ;                                             1:0116:1
   NDPO := INT (POINTER (A) + 2, 1) ;                                         1:0118:0
   INLRT := INT (POINTER (A) + 4, 1) ;                                        1:0120:1
   NAUTVN := INT (POINTER (A) + 6, 1) ;                                       1:0122:2
   NCONRT := INT (POINTER (A) + 8, 1) ;                                       1:0124:3
   LUNIT := FETCH (POINTER (A) + 10, 3) ;                                     1:0127:0
%                                                                             1:0129:2
%*****CHECK IF THE TRAFFIC UNITS ARE CORRECTLY SPECIFIED                      1:0129:2
%                                                                             1:0129:2
   IF LUNIT NEQ 8"CCS" AND LUNIT NEQ 8"ERG" THEN GO TO 152 ;                  1:0129:2
%                                                                             1:0134:3
%*****READ AND WRITE PROGRAM PARAMETERS                                       1:0134:3
%                                                                             1:0134:3
   READ (CARD, A) ;                                                           1:0134:3
   NS := INT (A, 2) ;                                                         1:0137:2
   NL := INT (POINTER (A) + 2, 3) ;                                           1:0139:0
   BPMAX := F63 (POINTER (A) + 5) ;                                           1:0141:1
   IF (OVLD := F63 (POINTER (A) + 11)) = 0 THEN OVLD := 1 ;                   1:0144:2
   IF (STEPX := F63 (POINTER (A) + 17)) = 0 THEN STEPX := 0.01 ;              1:0150:1
   WRITE (LINE, A) ;                                                          1:0156:2
%                                                                             1:0159:1
%*****INITIALIZE SPARSE MATRICES                                              1:0159:1
%                                                                             1:0159:1
   FOR I := 1 STEP 1 UNTIL NS DO                                              1:0159:1
   BEGIN                                                                      1:0164:0
      % CLS [I] := 0 ;                                                        1:0164:0
      % STR [I] := 0 ;                                                        1:0164:0
      FOR J := 1 STEP 1 UNTIL NS DO                                           1:0164:0
      BEGIN                                                                   1:0168:3
         % LNUM [I, J] := 0 ;                                                 1:0168:3
         WT [I, J] := 1 ;                                                     1:0168:3
      END ;                                                                   1:0171:3
   END ;                                                                      1:0172:1
%                                                                             1:0172:3
%*****READ AND WRITE TRUNK INFORMATION                                        1:0172:3
%                                                                             1:0172:3
   FOR I := 1 STEP 1 UNTIL NL DO                                              1:0172:3
   BEGIN                                                                      1:0177:2
      READ (CARD, A) ;                                                        1:0177:2
      WRITE (LINE, A) ;                                                       1:0180:1
      IS := INT (A, 2) ;                                                      1:0183:0
      ID := INT (POINTER (A) + 2, 2) ;                                        1:0184:3
      LN := INT (POINTER (A) + 4, 3) ;                                        1:0187:1
      LNUM [IS, ID] := LNUM [ID, IS] := LN ;                                  1:0189:3
      NTRK [LN] := INT (POINTER (A) + 13, 2) ;                                1:0195:3
      NPATH [LN] := IS ;                                                      1:0199:0
      NPATH [105 + LN] := ID ;                                                1:0201:0
      GOS [I] := 0.9 ;                                                        1:0204:0
   END ;                                                                      1:0206:1
%                                                                             1:0207:1
%*****READ AND WRITE ROUTING TABLE,TRAFFIC,AND NNGOS WEIGHT INFORMATION        1:0207:1
%                                                                             1:0207:1
   IDUM := NS * (NS - 1) ;                                                    1:0207:1
   FOR I := 1 STEP 1 UNTIL IDUM DO                                            1:0209:0
   BEGIN                                                                      1:0214:0
      READ (CARD, A) ;                                                        1:0214:0
      WRITE (LINE, A) ;                                                       1:0216:3
      IS := INT (A, 2) ;                                                      1:0219:2
      ID := INT (POINTER (A) + 2, 2) ;                                        1:0221:1
      IRT [IS, ID, 1] := INT (POINTER (A) + 4, 3) ;                           1:0223:3
      IRT [IS, ID, 2] := INT (POINTER (A) + 7, 3) ;                           1:0229:0
      IRT [IS, ID, 3] := INT (POINTER (A) + 10, 3) ;                          1:0234:2
      % IRT [IS, ID, 4] := 0 ;                                                1:0240:0
      DUM := F62 (POINTER (A) + 13) ;                                         1:0240:0
```

```
      IF LUNIT = 8"ERG" THEN DUM := DUM * 36 ;                               1:0243:2
      TR [IS, ID] := DUM * OVLD ;                                            1:0247:3
      IF (W := F62 (POINTER (A) + 19)) NEQ 0 THEN WT [IS, ID] := W ;         1:0251:3
   END ;                                                                     1:0260:0
%                                                                            1:0261:0
%*****IF THE NETWORK IS EUROPEAN AUTOVON, READ AND WRITE THE ACRONYMS        1:0261:0
%*****FOR ITS OFFICES                                                        1:0261:0
%                                                                            1:0261:0
   IF NAUTVN = 1 THEN                                                        1:0261:0
   BEGIN                                                                     1:0261:3
      READ (CARD, A) ;                                                       1:0262:3
      WRITE (LINE, A) ;                                                      1:0265:2
      FOR I := 1 STEP 1 UNTIL 11 DO                                          1:0268:1
         NODE [I] := FETCH (POINTER (A) + 4 * (I - 1), 3) ;                  1:0273:0
   END ;                                                                     1:0277:3
%                                                                            1:0277:3
%*****WRITE USER SPECIFIED OPTIONS                                           1:0277:3
%                                                                            1:0277:3
   THRU 5 DO PRINT (" ") ;                                                   1:0277:3
   PRINT ("USER SPECIFIED OPTIONS:") ;                                       1:0287:2
   NPRINT := (IF NPPO = 0 THEN 8"NO " ELSE 8"YES") ;                         1:0295:1
   PRINT ("LIST OF PATHS REQUIRED:  ", POINTER (NPRINT) + 1 FOR 3) ;         1:0300:0
   NPRINT := (IF NDPO = 0 THEN 8"NO " ELSE 8"YES") ;                         1:0309:2
   PRINT ("DETAILS OF PATH RELIABILITY AND PATH CARRIED LOAD ",              1:0314:1
      "REQUIRED:  ", POINTER (NPRINT) + 1 FOR 3) ;                           1:0314:1
SEGMENT    2 IS   74 LONG.
   PRINT ("OPTION NUMBER FOR INITIALIZING ROUTING TABLE FOR REVISION=",      1:0325:2
      INLRT FOR 4 DIGITS) ;                                                  1:0325:2
   PRINT ("(NOTES ON OPTION USED:") ;                                        1:0334:0
   IF INLRT = 1 THEN                                                         1:0341:3
   BEGIN                                                                     1:0342:2
      PRINT ("ALL SPILL SWITCHES OF THE ORIGNAL ROUTING TABLE ARE ",         1:0343:2
         "CONVERTED") ;                                                      1:0343:2
      PRINT ("INTO NON-SPILL SWITCHES BEFORE REVISION)") ;                   1:0353:0
   END ELSE                                                                  1:0360:3
   IF INLRT = 2 THEN                                                         1:0361:3
      PRINT ("NO CHANGES TO THE ORIGNAL ROUTING TABLE MADE BEFORE ",         1:0362:2
         "REVISION)")                                                        1:0362:2
   ELSE                                                                      1:0373:0
   IF INLRT = 3 THEN                                                         1:0374:0
   BEGIN                                                                     1:0374:3
      PRINT ("ALL NON-SPILL SECOND AND THIRD CHOICES IN THE ORIGNAL ",       1:0375:3
         "ROUTING") ;                                                        1:0375:3
SEGMENT    4 IS   66 LONG.
      PRINT ("TABLE ARE DELETED BEFORE REVISION)") ;                         1:0385:1
   END ;                                                                     1:0393:0
   PRINT ("MAXIMUM ALLOWABLE BLOCKING PROBABILITY(BPMAX)",                   1:0393:0
      ENTIER (BPMAX) FOR 3 DIGITS, ".",                                      1:0393:0
      ROUND (BPMAX MOD 1 * 1000) FOR -3 DIGITS) ;                            1:0393:0
   PRINT ("STEP SIZE OF PDPMAX REDUCTIONS=",                                 1:0405:1
      ENTIER (STEPX) FOR 2 DIGITS, ".",                                      1:0405:1
      ROUND (STEPX MOD 1 * 1000) FOR -3 DIGITS) ;                            1:0405:1
   IF NAUTVN = 1 THEN                                                        1:0418:0
   BEGIN                                                                     1:0418:3
      PRINT ("GIVEN NETWORK IS AUTOVON") ;                                   1:0419:3
      IF NCONRT = 1 THEN                                                     1:0427:2
         PRINT ("AN ATTEMPT TO IMPROVE CONUS TRAFFIC IS REQUIRED")           1:0428:1
      ELSE                                                                   1:0437:0
      IF NCONRT = 0 THEN                                                     1:0438:0
         PRINT ("AN ATTEMPT TO IMPROVE CONUS TRAFFIC IS NOT REQUIRED") ;     1:0438:2
   END ;                                                                     1:0447:1
%                                                                            1:0447:1
%*****WRITE NETWORK DESCRIPTION                                              1:0447:1
%                                                                            1:0447:1
   PRINT ("NETWORK DESCRIPTION") ;                                           1:0447:1
SEGMENT    5 IS   76 LONG.
   PRINT ("NUMBER OF SWITCHES IN NETWORK ", NS FOR 2 DIGITS) ;               1:0455:0
   PRINT ("NUMBER OF TRUNK GROUPS IN NETWORK ", NL FOR 3 DIGITS) ;           1:0463:2
   PRINT (8" " FOR 42, "EXISTING NUMBER") ;                                  1:0472:0
   PRINT ("LINK NUMBER          SWITCH PAIR          OF TRUNKS") ;           1:0480:2
%                                                                            1:0488:1
%*****CHECK IF NETWORK IS EUROPEAN AUTOVON                                   1:0488:1
%                                                                            1:0488:1
   IF NAUTVN NEQ 1 THEN                                                      1:0488:1
   BEGIN                                                                     1:0489:0
%                                                                            1:0490:0
%*****WRITE TRUNK GROUP INFORMATION                                          1:0490:0
%                                                                            1:0490:0
      FOR I := 1 STEP 1 UNTIL NL DO                                          1:0490:0
      BEGIN                                                                  1:0494:3
```

```
          PRINT (I FOR 7 DIGITS, NPATH [I] FOR 17 DIGITS,                 1:0494:3
             NPATH [I + 105] FOR 7 DIGITS, NTRK [I] FOR 20 DIGITS) ;      1:0494:3
          NPATH [I] := NPATH [I + 105] := 0 ;                             1:0507:1
       END ;                                                              1:0511:2
       PRINT ("SWITCH-TO-SWITCH TRAFFIC", 8" " FOR 37, "ORIGINAL ",       1:0512:2
          "ROUTING TABLE") ;                                              1:0512:2
       PRINT ("FROM          TO            TRAFFIC IN CCS         CHOICE" 1:0524:2
          " 1         CHOICE 2          CHOICE 3          WEIGHT") ;      1:0524:2
       PRINT (8" " FOR 46, "(PRIMARY ROUTES)") ;                          1:0532:3
SEGMENT    6 IS   81 LONG.
    %                                                                     1:0541:1
    %*****WRITE ORIGNAL ROUTING TABLE, TRAFFIC MATRIX AND WEIGHT          1:0541:1
    %     INFORMATION                                                     1:0541:1
    %                                                                     1:0541:1
       FOR I := 1 STEP 1 UNTIL NS DO                                      1:0541:1
          FOR J := 1 STEP 1 UNTIL NS DO                                   1:0546:0
             IF I NEQ J THEN                                              1:0550:3
                PRINT (I FOR 3 DIGITS, J FOR 13 DIGITS,                   1:0552:0
                   ENTIER ((W := TR [I, J])) FOR 18 DIGITS, ".",          1:0552:0
                      ENTIER (W MOD 1 * 10) FOR 1 DIGITS,                 1:0552:0
                   IRT [I, J, 1] FOR 19 DIGITS,                           1:0552:0
                   IRT [I, J, 2] FOR 18 DIGITS,                           1:0552:0
                   IRT [I, J, 3] FOR 18 DIGITS,                           1:0552:0
                   ENTIER ((W := WT [I, J])) FOR 16 DIGITS, ".",          1:0552:0
                      ENTIER (W MOD 1 * 100) FOR -2 DIGITS) ;             1:0552:0
       PRINT ("(CHOICE LEVEL WITH MINUS SIGN DENOTES A SPILL SWITCH)") ;  1:0588:1
     END ELSE                                                             1:0596:0
     BEGIN                                                                1:0597:0
    %                                                                     1:0597:0
    %*****WRITE TRUNK GROUP,ORIGNAL ROUTING TABLE,TRAFFIC AND WEIGHT      1:0597:0
    %*****INFORMATION FOR THE EUROPEAN AUTOVON NETWORK                    1:0597:0
    %                                                                     1:0597:0
       ITRG := 0 ;                                                        1:0597:0
       DECOD1 (IRT, ITRG, NODE) ;                                         1:0598:0
     END ;                                                                1:0601:0
    %                                                                     1:0601:0
    %*****CHECK IF PATHS ARE TO BE PRINTED                                1:0601:0
    %                                                                     1:0601:0
     IF NPPO NEQ 0 THEN                                                   1:0601:0
       PRINT ("PATHS DEFINED BY THE ORIGINAL ROUTING TABLE") ;            1:0601:3
    %                                                                     1:0610:2
    %*****CHECK FOR ILLEGAL PATHS IN THE ORIGINAL ROUTING TABLE           1:0610:2
    %                                                                     1:0610:2
     T0:=TIME(4);                                                         1:0610:2
     THRU 100 DO BEGIN                                                    1:0612:2
     ISOLD:=IS; IDOLD:=ID; ICONOLD:=ICON; FIRST:=TRUE;                    1:0615:1
    % THE ABOVE TWO STATEMENTS ARE FOR TIMING.                            1:0620:0
    % FIRST RUN FOR TIMING ONLY.                                          1:0620:0
     PATH (IRT, NPPO, POINTER (IS), POINTER (ID), POINTER (ICON)) ;       1:0620:0
     IS:=ISOLD;ID:=IDOLD; ICON:=ICONOLD;END;                              1:0623:2
     T3 := TIME (4) ;                        % CALL SECOND (T3)           1:0628:0
     TTOTAL := T3 - T0 ;                                                  1:0630:0
    % NOW PERFORM PRINT RUN.                                              1:0632:0
     IS:=ISOLD; ID:=IDOLD; ICON:=ICONOLD; FIRST:=FALSE;                   1:0632:0
     PATH (IRT, NPPO, POINTER (IS), POINTER (ID), POINTER (ICON)) ;       1:0636:3
     PRINT ("TIME REQUIRED TO EXECUTE ENTIRE PROGRAM",                    1:0640:1
       ENTIER (TTOTAL) FOR 6 DIGITS, ".",                                 1:0640:1
       ENTIER (TTOTAL MOD 1 * 1000) FOR -3 DIGITS, " SECONDS") ;          1:0640:1
     REWIND (LINE) ;                                                      1:0654:3
     WHILE READ (LINE, A) DO WRITE (OUTPUT, A) ;                          1:0657:0
     CLOSE (CARD) ;                                                       1:0663:3
     CLOSE (LINE) ;                                                       1:0666:0
    END?                                                                  1:0668:1
SEGMENT    1 IS  669 LONG.
SEGMENT    7 IS   41 LONG.
SEGMENT    0 IS    1 LONG.
 0 ERRORS    452 CARDS.   3306 TOKENS.      5712 RULES.        90 SECONDS.    2 SEQUENCE ERRORS.
 PROGRAM SIZE =  1190 WORDS   38 DISK SECTORS.
```

[redacted] [redacted] [redacted] [redacted]

```
************************ EXAMPLE 5.1: 5-NODE,8-LINK NETWORK ********************
VERBATIM ACCOUNT OF INPUT DATA
1 1 2 0 0 ERG
 5  8 0.010 1.0   0.
 1  2  1        14
 1  3  2        12
 2  4  3        10
 4  5  4         7
 3  5  5        10
 2  3  6        12
 2  5  7        13
 3  4  8        15
 1  2  2  0  0 1.5   1.0
 1  3  3  0  0 2.0   1.0
 1  4  2  3  0 2.0   1.0
 1  5  3  2  0 4.0   1.0
 2  1  1  0  0 1.5   1.0
 2  3  3  4  0 2.8   1.0
 2  4  4  3  0 3.0   1.0
 2  5  5  3  0 1.2   1.0
 3  1  1  0  0 2.0   1.0
 3  2  2  0  0 2.5   1.0
 3  4  4  0  0 5.0   1.0
 3  5  5  4  0 4.2   1.0
 4  1  3  2  0 1.7   1.0
 4  2  2  5  0 2.2   1.0
 4  3  3  5  0 3.0   1.0
 4  5  5  3  0 1.6   1.0
 5  1  3  2  0 2.5   1.0
 5  2  2  4  0 2.5   1.0
 5  3  3  2  0 1.2   1.0
 5  4  4  3  0 1.0   1.0
```

USER SPECIFIED OPTIONS:
LIST OF PATHS REQUIRED: YES
DETAILS OF PATH RELIABILITY AND PATH CARRIED LOAD REQUIRED: YES
OPTION NUMBER FOR INITIALIZING ROUTING TABLE FOR REVISION= 2
(NOTES ON OPTION USED:
NO CHANGES TO THE ORIGNAL ROUTING TABLE MADE BEFORE REVISION)
MAXIMUM ALLOWABLE BLOCKING PROBABILITY(BPMAX) 0.010
STEP SIZE OF PDPMAX REDUCTIONS= 0.010
NETWORK DESCRIPTION
NUMBER OF SWITCHES IN NETWORK 5
NUMBER OF TRUNK GROUPS IN NETWORK 8

LINK NUMBER	SWITCH PAIR		EXISTING NUMBER OF TRUNKS
1	1	2	14
2	1	3	12
3	2	4	10
4	4	5	7
5	3	5	10
6	2	3	12
7	2	5	13
8	3	4	15

SWITCH-TO-SWITCH TRAFFIC FROM	TO	TRAFFIC IN CCS	ORIGINAL ROUTING TABLE CHOICE 1 (PRIMARY ROUTES)	CHOICE 2	CHOICE 3	WEIGHT
1	2	54.0	2	0	0	1.00
1	3	72.0	3	0	0	1.00
1	4	72.0	2	3	0	1.00
1	5	144.0	3	2	0	1.00
2	1	54.0	1	0	0	1.00
2	3	100.7	3	4	0	1.00
2	4	108.0	4	3	0	1.00
2	5	43.2	5	3	0	1.00
3	1	72.0	1	0	0	1.00
3	2	90.0	2	0	0	1.00
3	4	180.0	4	0	0	1.00
3	5	151.2	5	4	0	1.00
4	1	61.2	3	2	0	1.00
4	2	79.2	2	5	0	1.00
4	3	108.0	3	5	0	1.00
4	5	57.6	5	3	0	1.00
5	1	90.0	3	2	0	1.00
5	2	90.0	2	4	0	1.00
5	3	43.2	3	2	0	1.00

```
5           4           36.0        4                    3                    0                    1.00
(CHOICE LEVEL WITH MINUS SIGN DENOTES A SPILL SWITCH)
PATHS DEFINED BY THE ORIGINAL ROUTING TABLE
FROM  1 TO  2
( -1)(  2)
FROM  1 TO  3
( -1)(  3)
FROM  1 TO  4
( -1)(  2)(  4)
( -1)(  3)(  4)
FROM  1 TO  5
( -1)(  3)(  5)
( -1)(  2)(  5)
FROM  2 TO  1
( -2)(  1)
FROM  2 TO  3
( -2)(  3)
( -2)(  4)(  3)
FROM  2 TO  4
( -2)(  4)
( -2)(  3)(  4)
FROM  2 TO  5
( -2)(  5)
( -2)(  3)(  5)
FROM  3 TO  1
( -3)(  1)
FROM  3 TO  2
( -3)(  2)
FROM  3 TO  4
( -3)(  4)
FROM  3 TO  5
( -3)(  5)
( -3)(  4)(  5)
FROM  4 TO  1
( -4)(  3)(  1)
( -4)(  2)(  1)
FROM  4 TO  2
( -4)(  2)
( -4)(  5)(  2)
FROM  4 TO  3
( -4)(  3)
( -4)(  5)(  3)
FROM  4 TO  5
( -4)(  5)
( -4)(  3)(  5)
FROM  5 TO  1
( -5)(  3)(  1)
( -5)(  2)(  1)
FROM  5 TO  2
( -5)(  2)
( -5)(  4)(  2)
FROM  5 TO  3
( -5)(  3)
( -5)(  2)(  3)
FROM  5 TO  4
( -5)(  4)
( -5)(  3)(  4)
TIME REQUIRED TO EXECUTE ENTIRE PROGRAM     66.000 SECONDS
```

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