Packet switching services for the autodin community

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INTRODUCTION

The AUTODIN II Program brings the advantages of packet switching technology to the Defense community. The concepts and advantages demonstrated successfully in the AUTODIN I store and forward message switching technology are not being discarded, but rather supplemented by a parallel operating AUTODIN II in order that the best transmission techniques for the efficient transfer of bulk transaction and interactive type data can be made available to the community of data system users.

This paper reviews the management decision to add packet switching capabilities to the AUTODIN I store and forward message environment; examines the technology to

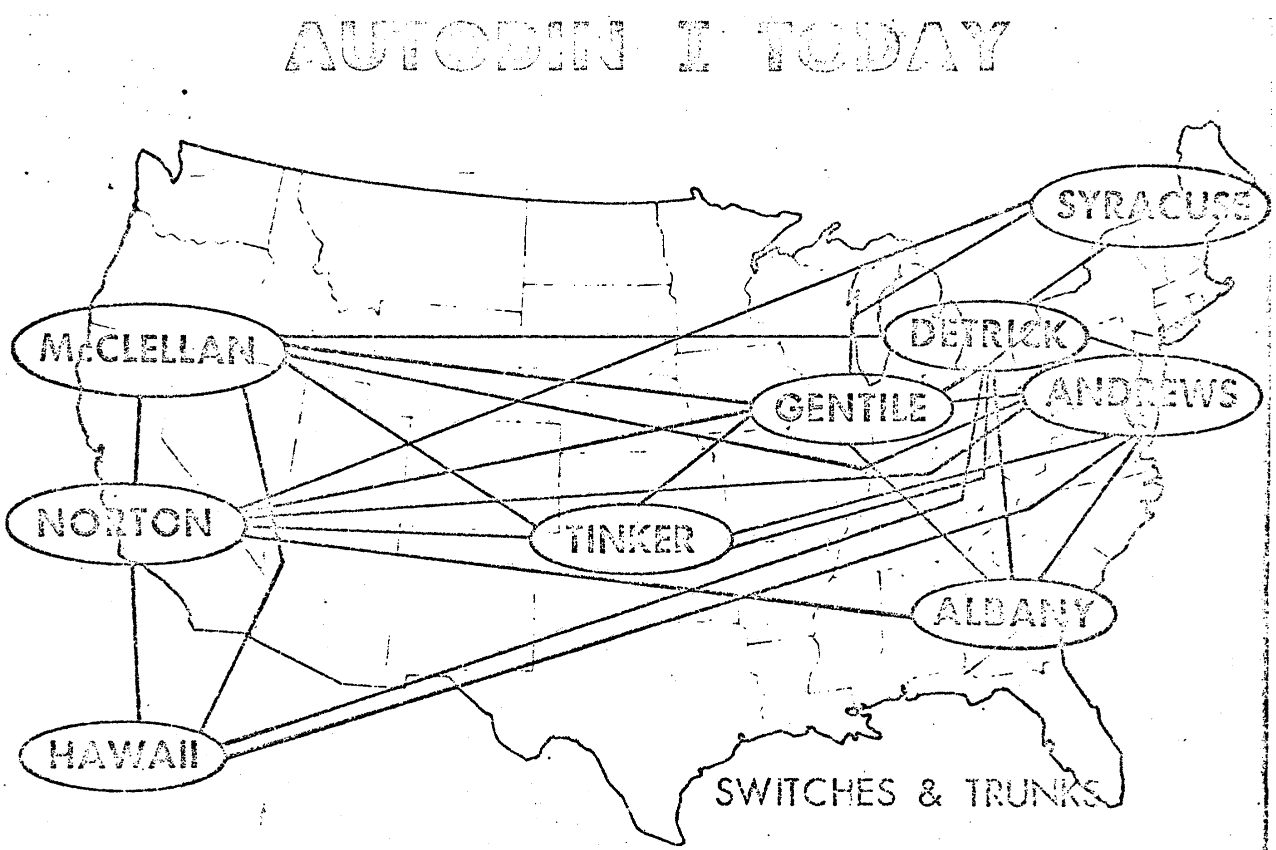

Chart I

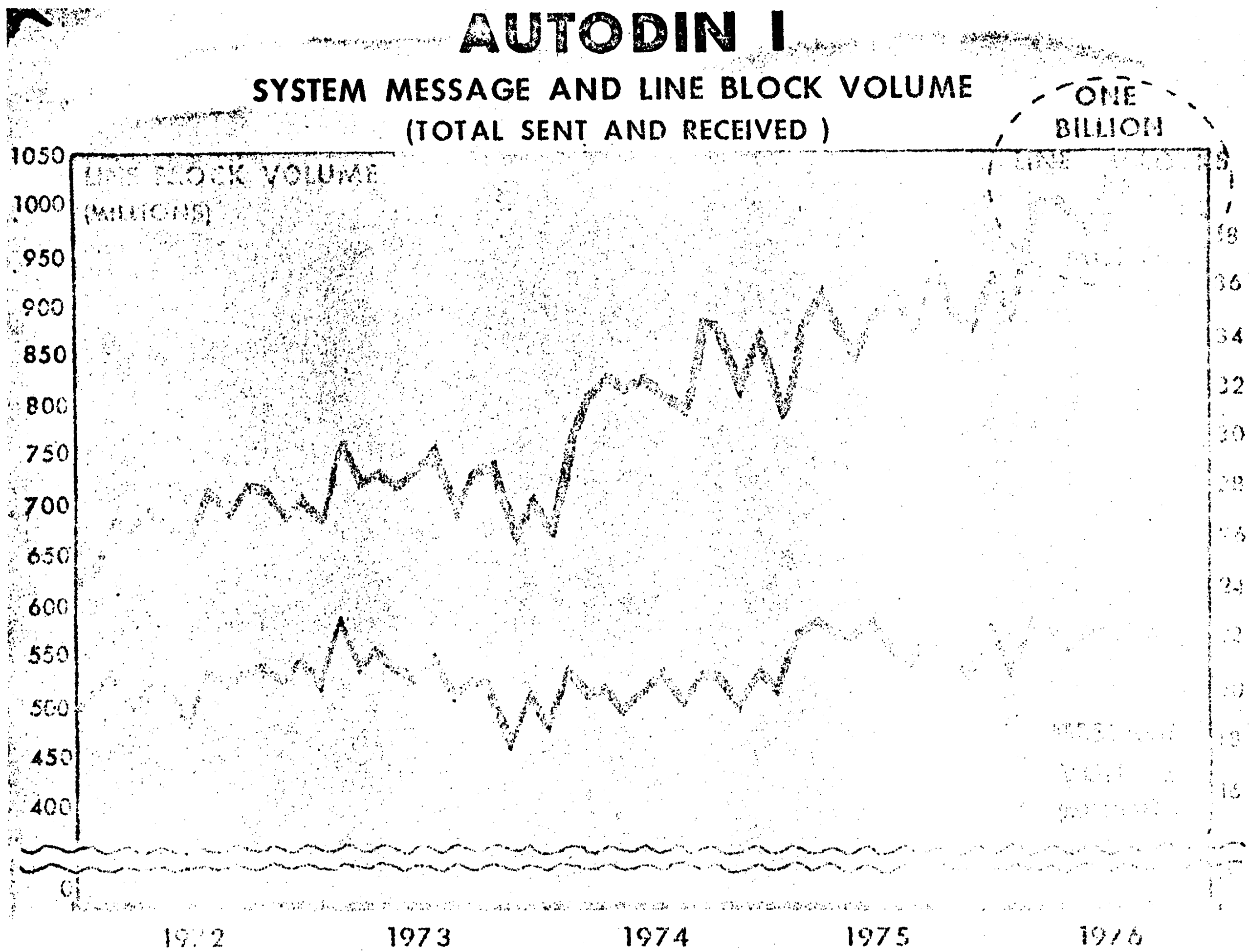

Chart II

be employed, discusses the implications for future growth and utility in this environment, and provides a report on the progress toward realizing that goal.

PLANNING FOR AUTODIN II

Since the advent of data processing, the Federal Government has experienced a steady growth in the numbers of computer based information systems employing remote terminals. The development and implementation of the AUTODIN I in the early 1960s was the first step in providing computer oriented communications network capabilities to this community of users. The AUTODIN I provides message switching store and forward communications on a worldwide basis.

Chart I shows the presently operating switches of the AUTODIN I System within the Continental limits. Eight additional switches located on foreign soil provide the overseas extensions of the AUTODIN I System.

The traffic on the AUTODIN I System has steadily grown through the years, requiring periodic increases in the system's capacity and the expansion in the type of services rendered. While the number of messages shown in Chart II has only grown at an average yearly rate of 5 percent, the type and length of messages have changed drastically over the past five years. The system traffic, measured in lineblocks (each lineblock equals 640 bits), has grown from 625 million lineblocks in 1972 to over one billion lineblocks per month in 1977 (640 billion bits per month). This increase in traffic, plus the characteristics of the traffic itself clearly indicated the increased use of AUTODIN I for computer oriented data transfer.

Studies by the Department of Defense and others have

AUTODIN II

TRAFFIC ANALYSIS

	USAGE AT INSTALLATION		POSSIBLE PROJECTED USAGE IN THE '80 S
	% BUSY HOUR PACKETS	% BUSY HOUR BITS	
O INTERACTIVE	6	1.2	45.0 (INTERACTIVE and QUERY/RESPONSE combined)
O QUERY/RESPONSE	1	.5	
O BULK DATA	79	85.1	40.0
O NARRATIVE	5	4.5	10.0
O AUTODIN I TRUNKING	9	8.7	5.0
O OTHER NETWORKS	--	--	

Chart III

shown a continuing trend toward the growth of transaction oriented interactive systems, in addition to the established requirement for remote job entry and bulk data and narrative transmission. A study initiated in 1972 indicated that by 1976 there would be approximately 250 computers involved in on-line communications functions with approximately 8,000 terminals associated with these systems. Projections into the mid-1980s indicated that within the DOD, there will be approximately 2,500 computers with some 20,000 terminals involved. These studies led to an examination of the methodologies to be employed to meet these requirements. Among the earliest conclusions was the decision that to the fullest extent possible common-user rather than dedicated networks must be employed to ensure the most efficient and economical service possible.

- HIGH TRUNK UTILIZATION
- NO BUSY CONDITIONS (System accepts traffic-stores until transmitted.)
- MESSAGE RESPONSIBILITY
- SPEED, CODE AND FORMAT CONVERSION
- MESSAGE RETRIEVAL CAPABILITY
- MULTIPLE ADDRESSING
- INEFFICIENT FOR MIXTURE OF INTERACTIVE AND TRANSACTION ORIENTED OR PRECEDENCE GOVERNMENT TRAFFIC.

Chart IV—Characteristics of Message Switching vs. Circuit Switching

- EXCELLENT FOR INTERACTIVE AND TRANSACTION ORIENTED OR PRECEDENCE GOVERNMENT TRAFFIC
- TRANSPARENT TO ALL USERS DESPITE USER PROTOCOL
- HIGHER SPEED—LOWER ERROR RATE
- HIGH RELIABILITY—ADAPTIVE ROUTING
- RAPID TRANSIT THROUGH SYSTEM
- NO MESSAGE RESPONSIBILITY
- NO MESSAGE RETRIEVAL OR RECOVERY
- HIGHER OVERHEAD REQUIREMENTS
- TRAFFIC HELD AT SUBSCRIBER VIAL FLOW CONTROL
- SMALL INTRANSIT STORAGE

Chart IV A—Characteristics of Packet Switching vs. Message Switching

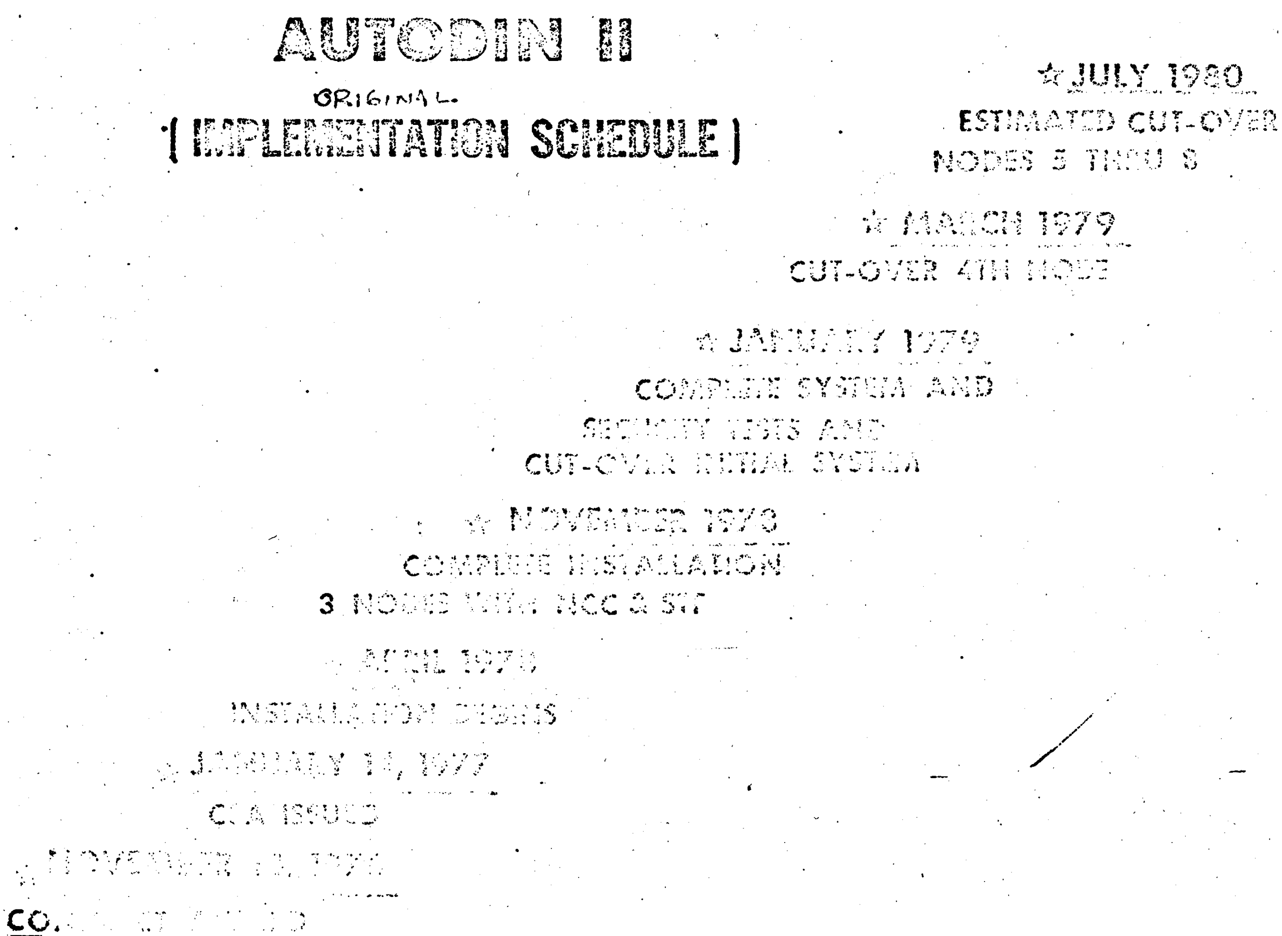

Chart V

The economies of AUTODIN I, as a common-user message system, have been well documented. With the possible demise of TELPAK rates and their replacement by higher cost facilities, the decision by the Defense Department to continue their dedication to the common-user network concept through the implementation of AUTODIN II, is even more commendable in today's world than it was even just five years ago when the basic design concepts of DIN II were originally conceived. A study of the various switching alternatives highlighted the characteristics of Circuit, Message and Pocket Switching.

An examination of these summaries suggests that there is an advantage to maintaining a store and forward capability in the Federal Communications environment for message type traffic while adding packet switching capabilities to satisfy the requirements of the interactive and transaction oriented user.

The trend toward interactive type traffic, as opposed to bulk transfer, has been clearly demonstrated (Chart III). While the initial traffic introduced into the AUTODIN II System shows that 85 percent of it is devoted to the transfer of bulk information, the amount of interactive and transaction oriented requirements will greatly expand so that by the early 1980s, a cross section of the AUTODIN II traffic will show that 45 percent will be in this category of service. Since packet switching, as indicated on Chart IVA, provides the most efficient transmission scheme for this mixture of traffic, the decision by the Department of Defense to implement a packet switching network, is commendable. Accordingly, a decision was reached to acquire packet switching network capabilities and to have that network (AUTODIN II) work in conjunction with AUTODIN I. High speed interconnect channels will connect the two systems together. The message type traffic handled by AUTODIN I will be transferred over these dedicated links to AUTODIN II and transmitted over a common high speed transmission net-

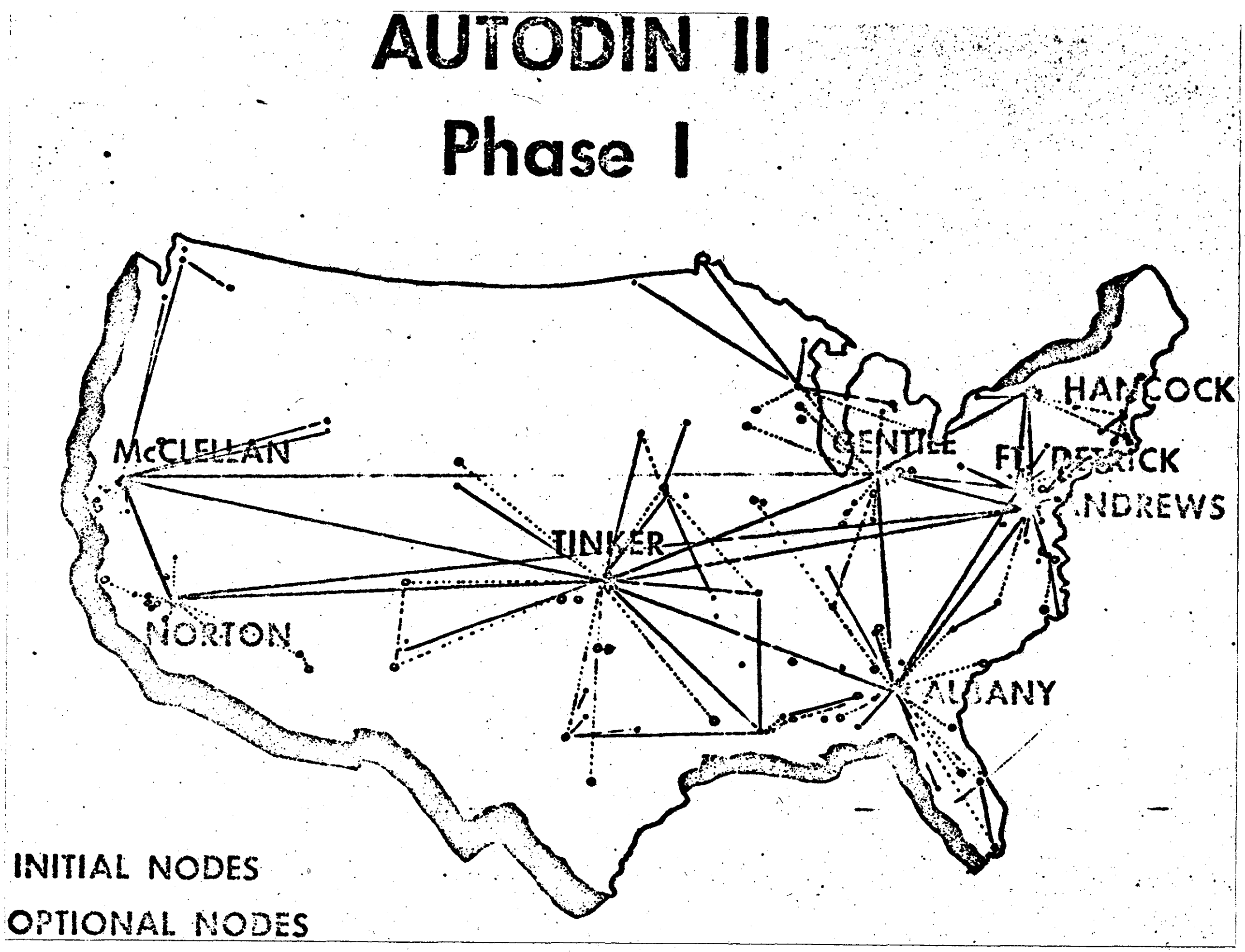

Chart VI

work, thereby providing to the users the choice of two types of data switching facilities through a common transmission network.

The request for proposal for this service was released to industry on November 26, 1975. An award of a contract for development and implementation of the system was made to The Western Union Telegraph Company on November 10, 1976 with the Commercial Service Order issued January 1977. Computer Sciences Corporation and Ford Aerospace and Communications Corporation are the primary sub-contractors to Western Union. (Chart V)

The contract awarded for AUTODIN II, Phase I, covers the CONUS operation only. Phase II will expand AUTODIN II into overseas locations. Until Phase II is implemented, the overseas AUTODIN I System will handle data traffic and will be interconnected into the AUTODIN II System overseas at suitable gateway locations. (Chart VI)

TECHNOLOGY EMPLOYED

At this point it is advisable to ask "What is Packet Switching?" The answer could fill volumes but, here we will restrict ourselves to the CCITT definition (Chart VII).

"A group of binary digits, including data and call control signals (address) which is switched as a composite whole. The data, call control signals and possibly error control information, are arranged in a specified format." Essentially, each addressed packet occupies a transmission channel for the duration of the transmission of the packet only. The channel is then available for use by packets being transferred between other users. Thus, channels between packet switches are shared between many users on a demand basis, and it becomes possible for a user having a single link to engage in the exchange of data packets with a number of other users at the same time. This technique results in the

WHAT IS PACKET SWITCHING ?

- PACKET SWITCHING IS A TRANSMISSION TECHNIQUE FOR SENDING DATA
  - DATA IS SEGMENTED INTO SMALL PACKETS (UP TO 5300 BITS EACH)
  - SMALL PACKETS FIND THEIR WAY THRU SYSTEM INDIVIDUALLY AND OVER THE BEST OF MULTIPLE TRANSMISSION PATHS AVAILABLE BETWEEN NODES AT THE MOMENT OF TRANSMISSION (ADAPTIVE ROUTING OVER DISTRIBUTED NETWORK)
  - ALL PACKETS ENTERING AND MOVING THRU SYSTEM ARE UNDER CONSTANT FLOW CONTROL -- ELIMINATING THE NEED FOR HIGH INTRANSIT STORAGE

Chart VII

achievement of adaptive routing over a distributed network. With all packets entering the system and moving under constant flow control, therefore, the need for intransit storage is eliminated.

To the maximum extent possible (Chart XIII), the AUTODIN II specification and performance recognizes the technological advancements which evolved over many years from the development and operation of the Defense Department's ARPA network. While the AUTODIN II System is based on this technology, the operational characteristics and the operating performance varies greatly as shown on the following chart. Unavailable within the ARPA technology were the requirements for multilevel classified and precedence type traffic, high throughput with tremendous surge requirements in case of national emergencies and an unprecedented 12 percent growth factor each year through the life of the system.

REQUIREMENTS SPECIFICATION

Based upon a series of studies, the DOD developed the following list of primary requirements:

1. Phase I network configuration of four nodes, network control center and test facility, with capacity for 200 subscribers with 13 subsystems.
2. Modular growth capability to eight or more nodes with some 1500 subscribers operating in 47 subsystems.
3. Node capacities:
   - 150-200 full duplex line terminations.
   - Each line can be 110 bits per second to 56 kilobits per second (KBPS) for subscribers and 9.6 KBPS to 230 KBPS for trunks.
   - Throughput form 300 KBPS to 2.5 MBPS.

NEEDED: A NEW APPROACH TO PACKET SWITCHING

ARPANET CHARACTERISTICS	AUTODIN II CHARACTERISTICS
○ NORMAL DEGREE OF RELIABILITY	○ HIGHER RELIABILITY AND AVAILABILITY REQUIRED
○ 55 NODES	○ 8 NODES
○ AVERAGE NODES TRANSVERSED : 6	○ AVERAGE NODES TRANSVERSED : 1.2
○ TRUNK UTILIZATION : 7%	○ TRUNK UTILIZATION : 80%
○ AVERAGE PACKET SIZE: 200 CHARACTERS	○ AVERAGE PACKET SIZE : 2000 CHARACTERS

Chart VIII

4. Maximum packet size—5300 bits.
5. 16-level precedence system.
6. Non-blocking for high precedence interactive traffic.
7. Availability of 99 percent for single-homed and 99.5 percent for dual-homed subscribers.
8. Minimum impact on existing subscriber equipment software system.
9. End-to-end undetected error rate of less than 1×10^{-12}
10. Segment misdelivery rate of less than 1×10^{-11}
11. 300 ms. max backbone delay for interactive and query response, based on 600 bit packets.
12. Transparent to text.
13. Capable of being certified to handle all levels of classified traffic.

NETWORK DESIGN

The Network Design was predicated on the following Government provided projected subscriber data on the present AUTODIN I System and the future system:

TRAFFIC STATISTICS (BUSY HOUR)

Average Traffic Volume, including AUTODIN I	7.2×10**9 Bits
AUTODIN I Traffic Volume Trunk	4.9×10**8 Bits
Peak Traffic Volume Originated in any one second	8.1×10**6 Bits
Computer Traffic Volume	5.9×10**9 Bits
Terminal Traffic Volume	8.5×10**8 Bits

Based upon these and other data, a network design of eight packet switching nodes (PSNs) located at the eight AUTODIN I sites in the Continental U.S. was developed. Backbone trunks between these nodes will operate at 56 KBPS with sufficient connectivity to provide at least three routes out of each node.

Chart IX shows the trunk speeds between DIN II sites and between AUTODIN II and AUTODIN I sites.

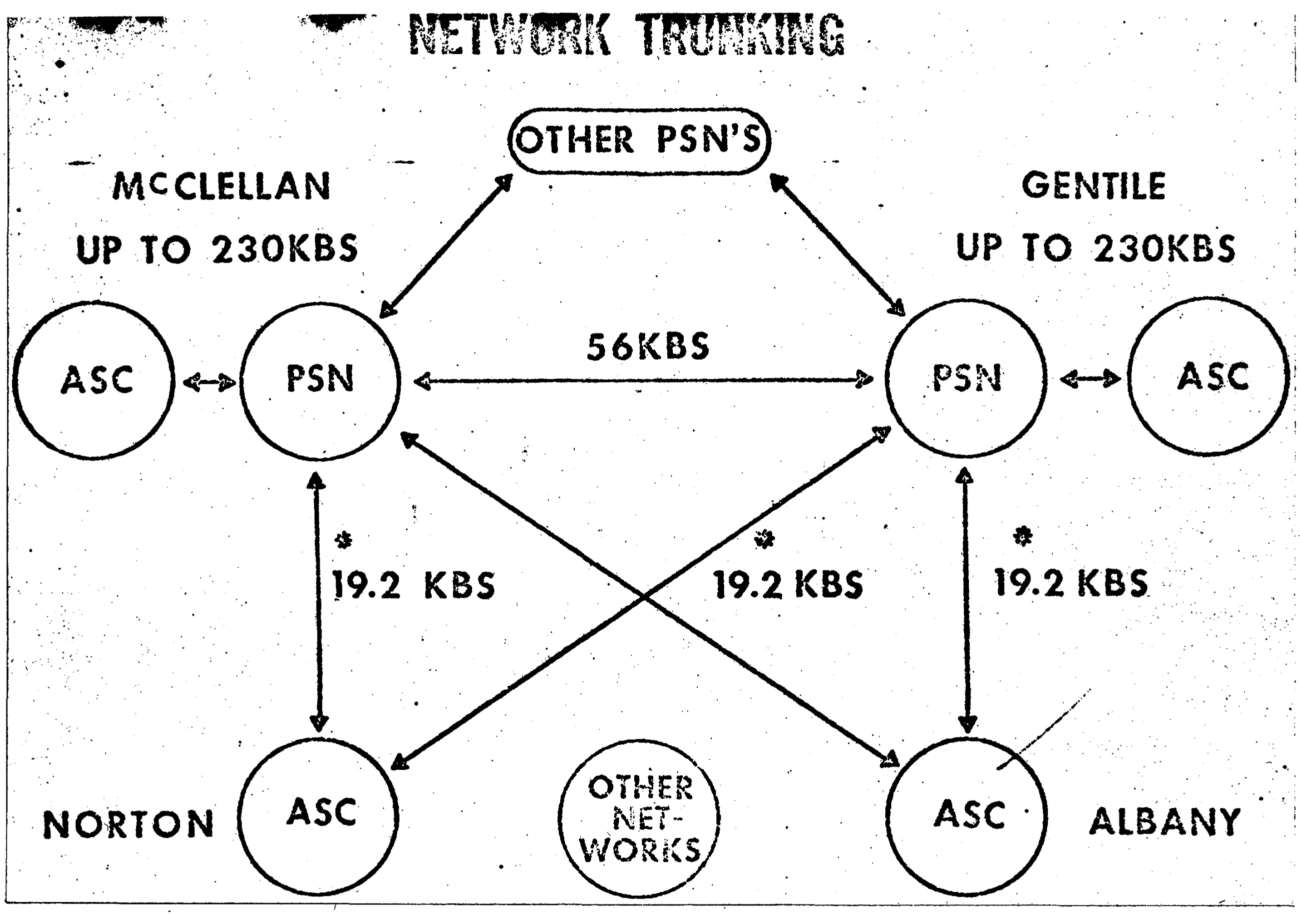

Chart IX

The initial network is scheduled for cutover in January 1979 with three nodes at Fort Detrick, Frederick, Maryland; Tinker Air Force Base, Oklahoma City, Oklahoma; and McClellan Air Force Base, Sacramento, California. After system testing, a fourth node will be added at Gentle Air Force Base, Dayton, Ohio in April 1979. The system capacity can be increased by modularly expanding the four initial nodes and by adding additional nodes.

It is anticipated that by 1981 traffic will have increased to require four additional nodes to be located at the Hancock Air Force Base, Syracuse, New York; Marine Corp Base, Albany, Georgia; Andrews Air Force Base, Maryland; Norton Air Force Base, California. At this point in the implementation plan, all CONUS AUTODIN I sites, except Hawaii, will have a colocated DIN II switching center.

SECURITY REQUIREMENTS

The overall AUTODIN II security requirement is to provide a system which does not allow unauthorized acquisition or alteration of classified information.

This is accomplished by a combination of techniques and procedures which include personnel security, physical security, administrative security, communications security, emanations security and software security.

The first five of these are well developed and well-known to military communicators. Software Security, however, is not so well developed and considerable research is still going on in this area. In AUTODIN II, software security will be achieved by use of security kernel technology derived from the MITRE model of DOD security regulations. This approach integrates all of the security controls for the system into a small portion of the operating system code which can be verified to operate correctly and to be unalterable by any other part of the system.

The basic elements are summarized as follows:

1. *PACKET SWITCHING NODE (PSN)*

   (a) Switch Control Module (SCM)
   (b) Line Control Module (LCM)

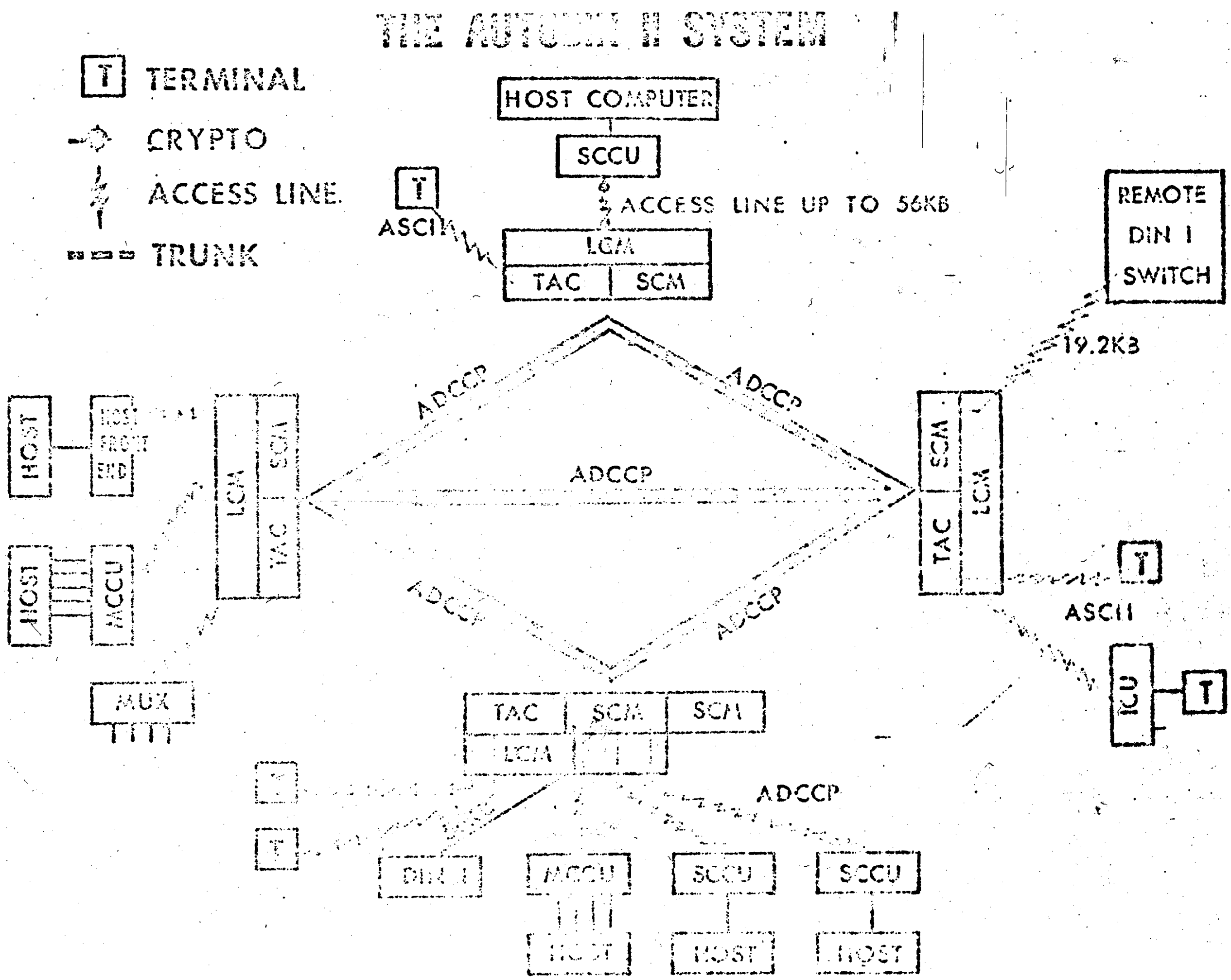

Chart X

2. *TRANSPARENT TERMINAL INTERFACE*
   (a) Terminal Access Controller (TAC)
   (b) Interface Control Unit (ICU)
3. *TRANSPARENT HOST INTERFACE*
   (a) Single Channel Control Unit (SCCU)
   (b) Multiple Channel Control Unit (MCCU)
4. *TRANSMISSION NETWORK*
5. *NETWORK ENCRYPTION EQUIPMENT*
   (a) Crypto Auxiliary Unit (CAU)
   (b) KG-13
6. *TEST FACILITIES AT EACH CENTER*
7. *CENTRAL NETWORK CONTROL CENTER AT DCA HEADQUARTERS*

Chart X highlights, in an overall system configuration, most of the above-mentioned network elements. The distributed network, using 56 KBS trunks initially interconnects all four of the initial system nodes directly providing the adapted routing principle to this packet switching network. A colocated DIN I facility illustrated in the southern switching node is directly interconnected by a high speed local trunk, while a remote AUTODIN I switch is terminated into the eastern node by a 19.2 KBS interstate transmission circuit. The chart also illustrates the use of the various host interface devices that may eliminate the need for reprogramming directly in the various host computers interconnect into the AUTODIN II System. Single-channel (1) and Multi-channel (32) Control Units are illustrated at each of the four packet switching nodes. The SCCU and MCCUs are located on customer premises directly associated with the host computers.

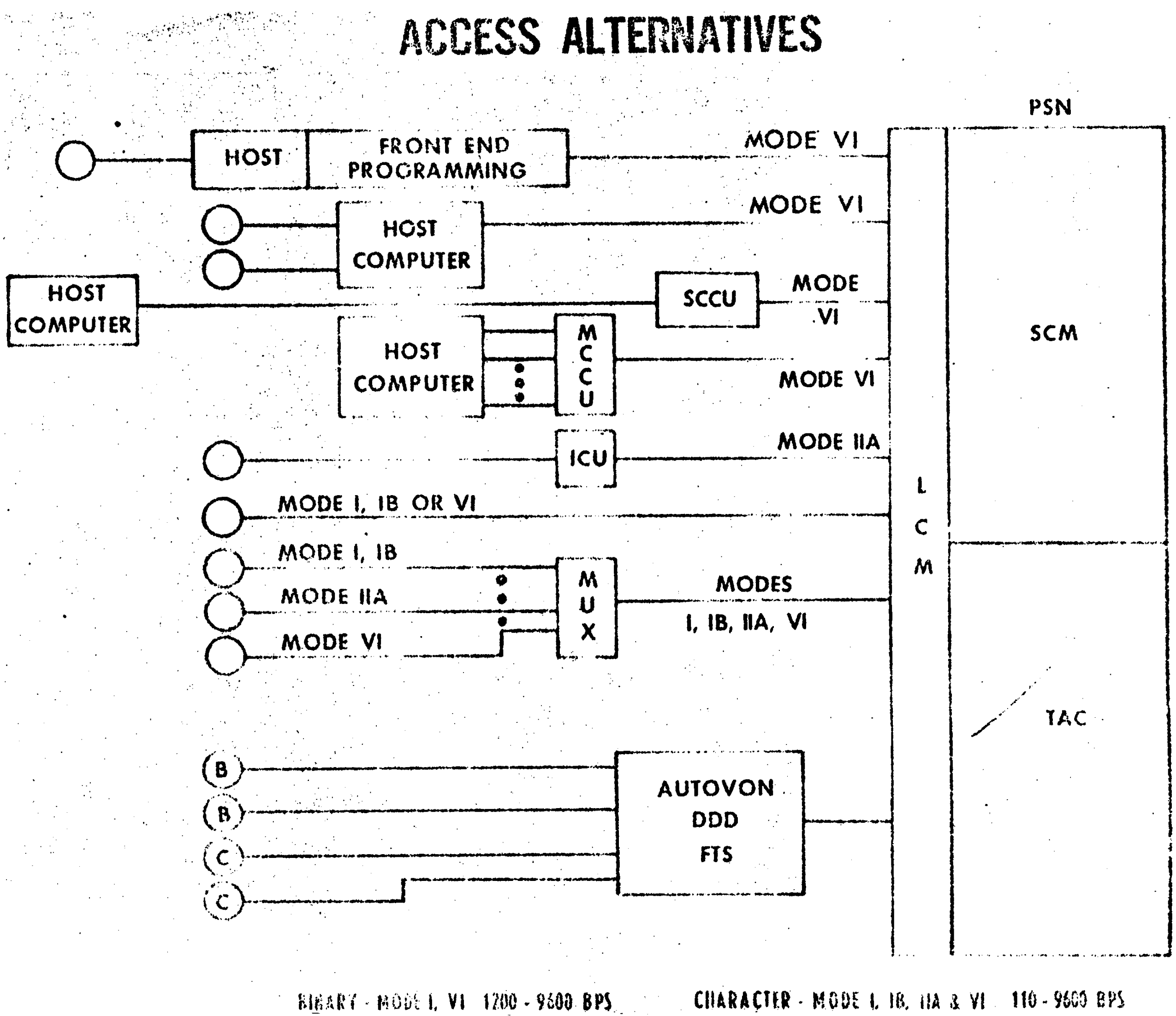

Chart XI

The system also indicates that terminal devices connected to the system go directly to the Terminal Access Controller (TAC). The TAC, however, is located within each node for one TAC unit can, in fact, handle 250 individual remote terminal devices. An Interconnect Control Unit (ICU) can be provided, if necessary, when terminals do not themselves have direct interconnectability.

Chart XI highlights in more detail the various means to access the system. Host computers can provide the interconnect protocol himself by reprogramming the host computer or adding a front-end device, or more simply they can employ either of the Western Union furnished Channel Control Units (single or multichannel) and avoid any local software modification. Shown also are the various terminal modes terminating directly into the TAC, either directly or through the ICU device. Also illustrated is the ability of the system to terminate circuits utilizing the DDDs, the Government AUTOVON, or the Federal Telephone System.

Chart XII illustrates the makeup of the packet, which is distributed throughout the network. The packet is 5300 bits in length with approximately 600 bits devoted to overhead and 4700 bits reserved for the transmission of data. The host information coming through the Channel Control Units and terminal information coming through the Terminal Access

DATA PRODUCT OF SCM

A PACKET

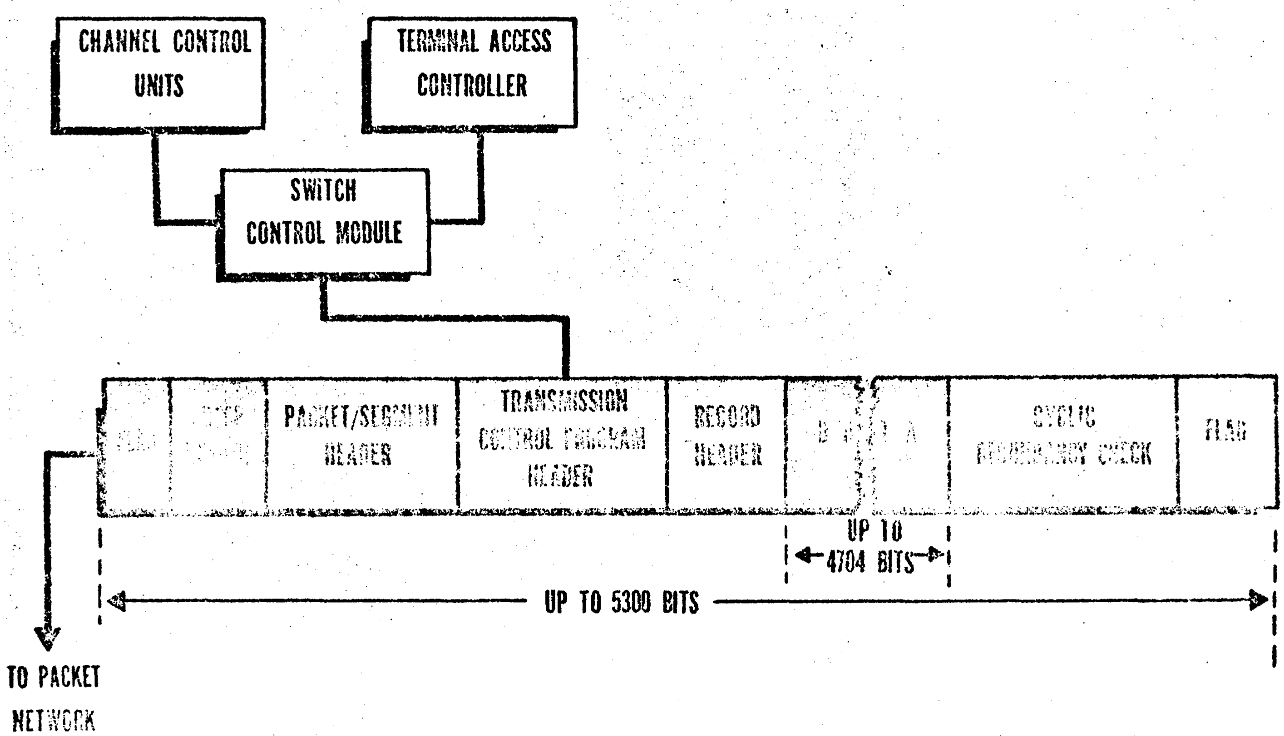

Chart XII

Controllers are first converted to segments in these two units and then converted to packets in the Switch Control Module just before entering the transmission system.

NETWORK CONTROL CENTER (NCC)

A Network Control Center monitors the operational status of the circuits, switching computers and user computer. It will assist in the diagnosing and correction of malfunctions. The NCC will achieve this by using the same DEC PPD 11/70 Processor as is used in the PSN. This PDP 11/70 will be complemented with magnetic tape and disc storage, high speed printers and four CRT positions for operator interface. It will be connected to at least one PSN and possibly two for redundancy connection will take place via communication links.

PATCH AND TEST FACILITY SUBSYSTEM

The second segment of the PSN is the Patch and Test Facility. At the AUTODIN I colocated sites, the AUTODIN II PTF will be integrated with the existing AUTODIN I PTF. In these combined facilities monitoring function will be performed by the SCM. All monitor points that have a direct bearing on circuit reliability and quality will be automatically scanned, and the scan results sent to the SCM. All control commands required to restore or maintain opera-

AUTODIN I AND AUTODIN II
PATCH & TEST FACILITY FUNCTIONAL CONTROL

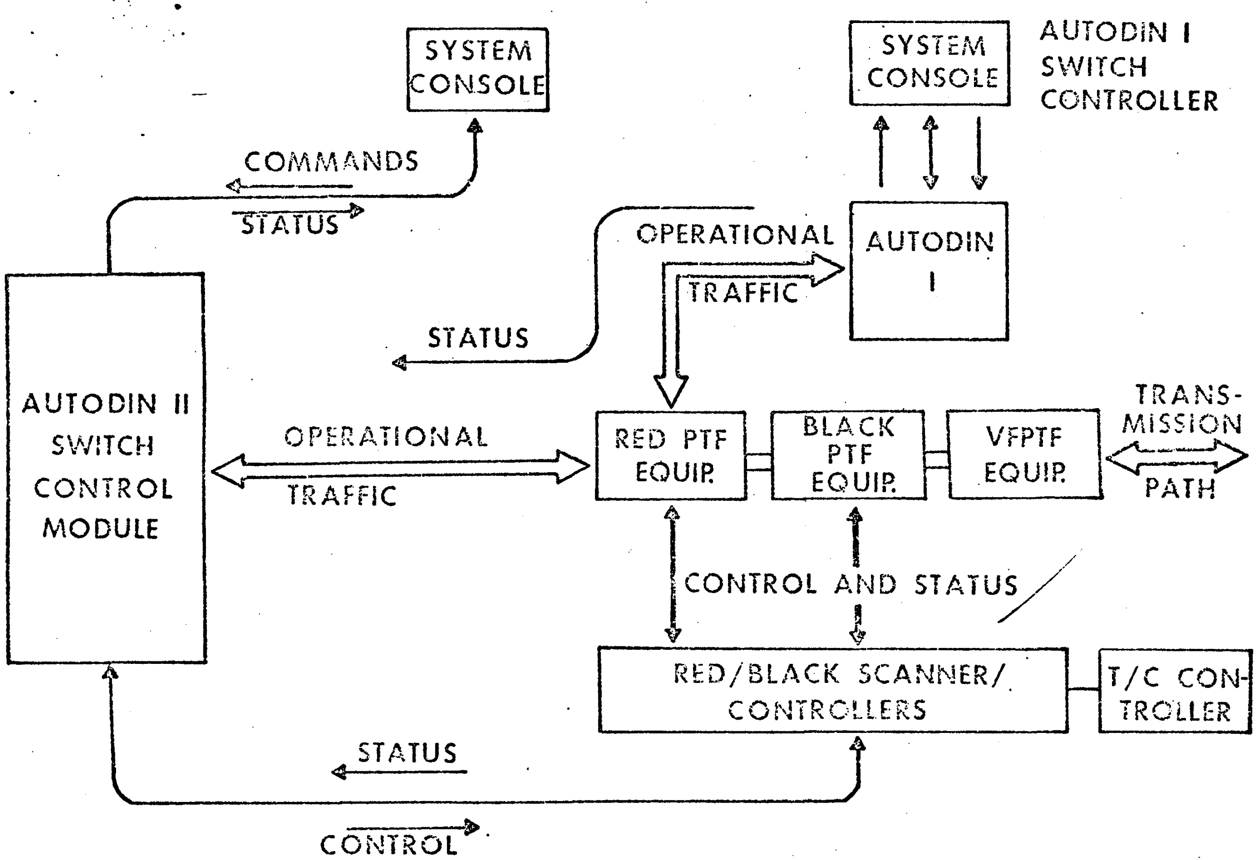

Chart XIII

tional circuit integrity will be formatted and transmitted by the SCM (either automatically or upon request from the tech controller) and will be executed by the PTF equipment. (Chart XIII)

CONCLUSIONS

Packet switching technology as added to the AUTODIN provides an example of the adaptation of new technology to an established environment. The user of this and the earlier implemented message switch technologies now has an opportunity to employ that unique capability that best satisfied his data communications need.

With the interconnect capability to be established between the AUTODIN I and AUTODIN II, the user can select that optimal network which meets his immediate need.

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