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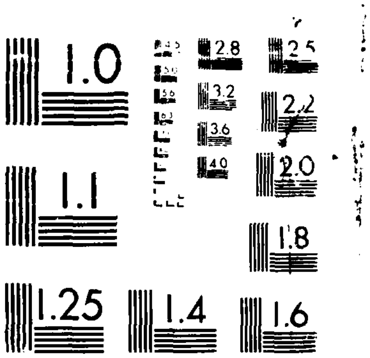

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SELECTED ISSUES
IN
DCS TECHNICAL INTEGRATION

Prepared Under
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Task 7-86

By

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This Defense Communications System Organization (DCSO) Technical Report presents and analyzes selected issues related to the technical integration of the evolving Defense Communications System (DCS). Areas considered are: the introduction of Digital Compression Rate Converters (DCRC), elastic buffer sizing in a plesiochronous DCS, the introduction of the Digital Patch and Access System (DPAS) and the newly developed Telecommunications Service Priority (TSP) system. The report also affirms the need for near-term planning: for control of the Secure Voice System (SVS), for the Integrated Services Digital Network (ISDN) as applied to the DCS, and for Integrated Data System (IDS) survivability and reconstitution. The central theme of the report is that the DCS Systems Integration Office (Code B200) is the focal point to ensure a formal integrated system design and documentation process for the DCS and for coordinating and controlling DCS subsystem design within the overall DCS architecture.

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IN

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Prepared for

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Washington, D.C. 20305

Under

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Task 7-86

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Computer Sciences Corporation
6565 Arlington Boulevard
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SECTION 1 - INTRODUCTION

This report was prepared under contract DCA100-84-C-0030, task 7-86, subtask 2 and addresses issues in Defense Communications System (DCS) technical integration. The task order called for separate analyses for the DCS areas of Germany, Philippines, United Kingdom, Italy and Turkey with the idea of supporting on-going preparation of Integrated Transition Implementation Plans (ITIP) for those areas. During the analysis, the major integration issues identified were of system-wide interest, rather than on a country or area basis. This report, therefore, focuses on system-wide issues.

Although the Defense Communications Agency (DCA) has been generally successful in the past in engineering DCS analog subsystems separately with only informal coordination, the technologies involved and systems wide control and synchronization required for digital systems dictate a formal system-level design process within DCA, and between DCA and the MILDEPS, to ensure that subsystem designs are compatible with overall DCS architecture and that design decisions are carefully documented. This conclusion is supported by many of the issues/problems raised in subsequent sections of the report which can be clearly traced to independent design of DCS subsystems.

The DCS is in transition with high emphasis on: all digital operations, survival of the majority of telecommunications services under all levels of stress, user-to-user communications, and an integrated system design. The total impact of this transition on the way DCA does business is potentially very large. If the DCS is to evolve to the desired goal system and provide many new services, such as ISDN, it is imperative that the DCA Code B200, "DCS Systems Integration" ensures a formal integrated system design and engineering process is maintained. The various DCA programs (DDN, DSN, etc.), and MILDEP initiatives in implementing programs and upgrades, must be coordinated and engineered on a system basis to include end user equipment, switching systems, transmission media and control.

There are many instances in which a subsystem designer may optimize his subsystem in a way that is cost effective from his (possibly restricted) viewpoint. However, from an overall system viewpoint the design may be far from optimum and may not provide the required level of performance on a user-to-user basis. This situation arises when features provided in several subsystems on the basis of local optimizations interact in an adverse way. This report contains several examples of such situations.

The following is a partial list of some of the dangers inherent in design on a subsystem or program (e.g. DSCS, JRSC, DSN, SVS, etc.) basis, and emphasizes the role B200 must maintain as the system integrator.

1. Subsystem designers may not always be aware of the other DCS subsystem design actions with an impact on their design. If for no other reason, this situation will arise because the individual designers do not have the time or the resources to keep track of all the actions which may have an impact.

2. The many changes and improvements that are being made in the DCS introduce new potentials for adverse interactions. Designers who are intent on their subsystem may not be aware of the interaction. It is frequently difficult to shift gears from the intensive and detailed activity involved in the design of a subsystem to the broader viewpoint required to identify system-wide interactions. This is true, if for no other reason than the fact that the subsystem designer is inherently focused on why their subsystem will work; the

system engineer must be focused on why the integrated system will work. It takes a specific viewpoint to identify system-wide difficulties.

3. The MILDEP initiatives may introduce technology or features that are not entirely compatible with the overall design. This situation can arise, even while MILDEPs follow design guidance which permits the particular technology, but provides a limit on the amount allowed in the system. Difficulties also arise when one faction changes the design approach and the change is not promulgated to all affected parties.

4. A "corporate memory" is required to provide a record of the decisions which have been made during the development of the DCS. Many of the DCS system difficulties which have been identified over the years were foreseen in the design and solved by restrictions, for example, on numbers of tandem equipments. Later, changes were made by other designers which reintroduced the problem that had been foreseen. Often the situation was not recognized in a timely fashion partly due to the fact that sufficient system resources had not been devoted to determining such cases. Another reason for slow recognition of such problems was that the early design decisions were not always effectively documented. Well documented and readily available historical records which show how the current state of the system was reached and the decisions and trade-offs made during the process would provide extremely helpful guidance to the evolution of the DCS.

The conclusion reached from consideration of the above is that continued emphasis is required on a formal system engineering process which provides an overall system viewpoint, a means for reaching optimum decisions from a system rather than a subsystem viewpoint, and a mechanism for documenting and promulgating summaries of the process.

Section 2 deals with integration issues raised by the introduction of Digital Compression Rate Converters (DCRCs) in the DCS. Section 3 analyzes issues related to the distribution of timing in the DCS and resulting potential synchronization problems. Section 4 analyzes issues related to the introduction of the Digital Patch and Access System (DPAS). Section 5 examines the Secure Voice System (SVS), identifies issues in the control of that system and recommends studies and actions leading to an SVS system control design.

Section 6 describes the Telecommunication Service Priority (TSP) system recently proposed by the Office of Manager, National Communications System (OMNCS) to replace the current Restoration Priority (RP) scheme. Some issues raised by this new scheme in the area of DCS technical control are presented and analyzed. Sections 7 and 8 argue the urgent need for an approved plan for ISDN as it will be in the DCS, and for a plan for Integrated Data System (IDS) survivability.

SECTION 2 - ISSUES RAISED BY THE INTRODUCTION OF DIGITAL COMPRESSION RATE CONVERTERS IN THE DCS

2.1 INTRODUCTION AND BACKGROUND

The Defense Communications Engineering Center has published a technical report (Reference 1) that describes the application of reduced rate and adaptive coding, time assignment speech interpolation (TASI), and digital speech interpolation (DSI) in primary or level-1 multiplex equipment of the DCS. DCA planning includes use of similar techniques in the transmission area of the DSN system. Some of the techniques are contained in CCITT recommendation G.821 (Reference 2) and thus have the potential for commercial application. In fact, similar techniques will be placed on the TAT-8 light-wave submarine cable system (Reference 3). These techniques offer significant improvement in the efficiency with which the transmission bandwidth is utilized. However, their introduction in the DCS poses significant integration considerations. Careful engineering planning must accompany their introduction if their potential savings are not to be greatly offset by adverse interactions with other portions of the DCS.

DCA has received a request to deploy Digital Compression Rate Converters (DCRCs) for many DCA sites in the United Kingdom (Reference 4). The reason given for this deployment is the need to provide an interface between the North American standard PCM-24 digital telephone switches and the European standard commercial PCM-30 transmission systems. As a minimum, this application involves the functions of frame structuring, traffic channel coding, line rate conversion, and line code conversion. Reference 2 also identifies the M/A-COM DCC Model 6019 Digital Channel Efficiency Model (DCEM) (Reference 5) as a commercially available DCRC. The Model 6019 is capable of performing the identified functions; however, it has additional capabilities that could cause integration problems unless careful attention is given to the way the Model 6019 is used in the network.

For the DSN, DCA is planning on the use of DCRCs with compression capability in addition to the rate and format change capability implied in the above. The specific use planned is an application on leased satellite facilities, but other high cost facilities are candidates.

Reference 1 identifies more extensive applications of reduced rate coding, TASI, and DSI. The nature of the applications described in that reference could have major impact on the AO&M and switch designs in the DCS. The following paragraphs address some of these potential problems and make recommendations to provide guidance for the planning and use of the additional capabilities. Primary focus is on the DCEM, used as a representative of the broad class of DCRC's, but comments on the other applications and capabilities are made where appropriate.

The three functions that will be treated in this section are:

1. Reduced Rate Encoding. The standard voice message channel in the mid 1980s is the 64 kb/s PCM channel. The PCM code represents the absolute value of the signal. Newer speech digitizing techniques (ADPCM) code the difference between the absolute value of the signal and a predicted value based on the application of an algorithm to one or more previous samples of the speech signal. Subjective tests show that quality nearly equivalent to 64 kb/s PCM can be obtained with these techniques at channel rates of 32 kb/s. If tests show that satisfactory performance can be obtained with these techniques for all of the signals that a DCS "voice channel" can and does carry, a fixed system bandwidth can carry twice as many channels. If satisfactory

performance is not achieved with all signal types appearing in the voice channel, administrative action could segregate the signal types that are not satisfactorily processed by the newer algorithms for processing by the PCM technique. The actual increase in the number of channels would then depend on the ratios of the two types of signal.

2. Speech Compression. The fraction of time in which actual speech signals appear on a channel that is connected to a telephone averages in the range of 30 to 40 percent. Advantage can be taken of this fact to increase the number of active channels by assigning an input channel to a trunk channel only when active speech signals are present. A technique that accepts analog signals as input, called TASI, has had a long and relatively successful history on transatlantic submarine cables. Reference 6 gives an evaluation of the particular version of TASI applied to AUTOVON interswitch trunks. TASI equipments appear in both analog and digital processing versions. DSI equipment (such as the DCEM) operates on digital signals (such as the T-1 digroup) to do the speech interleaving. Some compression devices, including the DCEM, also employ adaptive rate encoding techniques rather than fixed reduced rate encoding to increase the compression ratio or to provide better channel performance at a lower compression ratio.

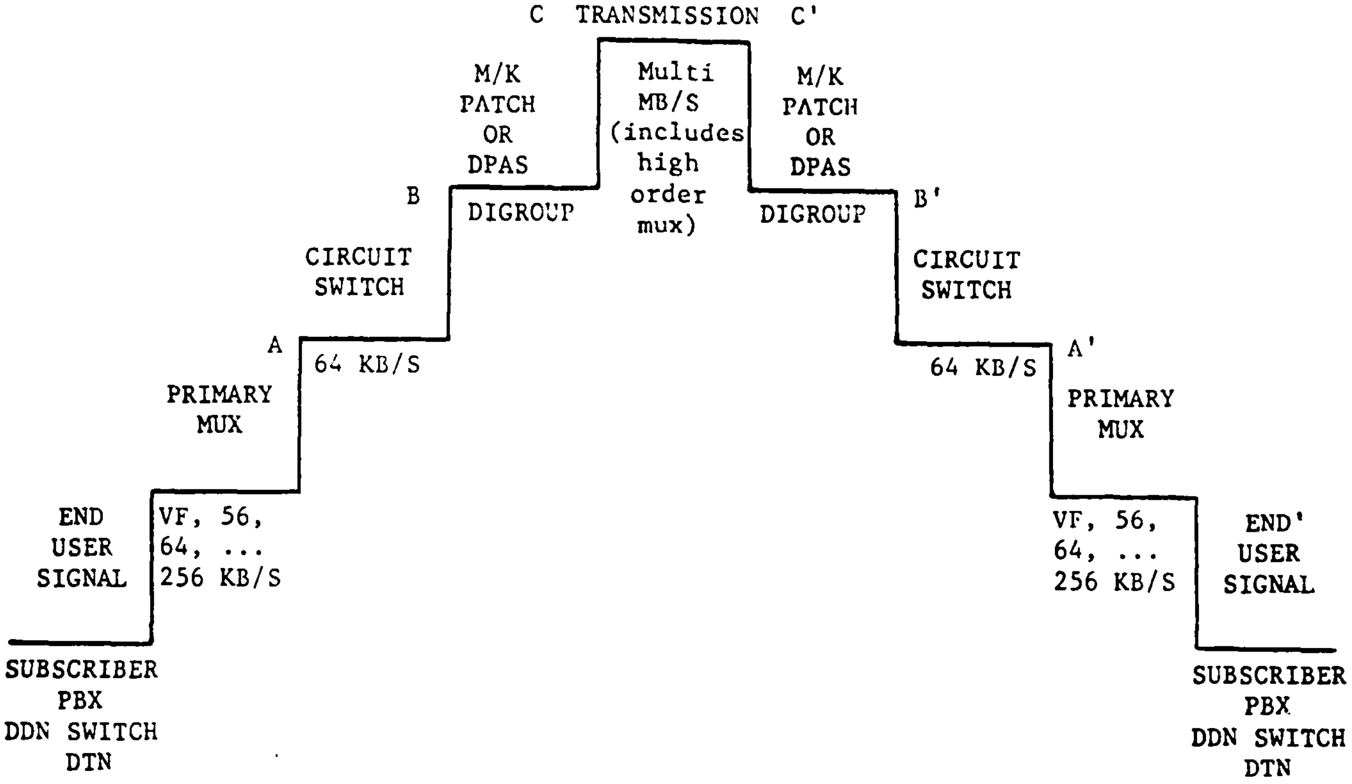
3. Code Conversion. There are two different PCM standards in use today. They employ different PCM coding rules, different companding rules, different number of channels in a frame, different treatment of the channel associated signaling codes, different frame codes, and different line codes. Probably the only commonality between these

standards is the sampling and framing rates, which are both 8000 per second. Interconnection between these two systems involves converting all of the above differences, where possible, between the two standards. In those cases where a channel is carrying direct digital data, the code and companding translations must be bypassed to achieve a transparent data channel. In those cases where speech compression is not used, the frame formats remain precisely standard for each area. Since the European standard provides more speech channels, the extra channels are not equipped in one direction and filled with dummy bits in the other direction. When compression is used, the frame format becomes drastically different. Inter-DCEM signaling is introduced to control the decompression process. The frame signal, however, is retained intact.

2.2 ALTERNATIVE DCEM LOCATIONS IN THE DCS

2.2.1 Introduction to the DCS Signal Processing Hierarchy

A signal may undergo several different types of signal processing between the end user locations. The processing generally will include A/D conversion, multiplexing, switching, patching, and transmission. In addition, the DCRC introduces compression and code changes. This situation is indicated in schematic form in Figure 2-1. Each level indicates a major type of signal processing. A major feature illustrated is the symmetry between the communication process on the left and right sides of the diagram. A necessary condition is that the process on the right side of each level must be capable of processing the result of the process on the left side so that the user's signal is not unduly distorted. While the processes do not need to be exact mirror images, proper protocol or format changes are required at appropriate points. For example, interoperability between first



Fiugre 2-1. Signal Processing Hierarchy in the DCS

level multiplexers operating in two different standards is possible if code and format conversions are provided at appropriate places in the connection. Finally, a user-to-user connection may involve either many more or fewer signal changes than is indicated in the diagram. Each level identifies a possible interface point where tandem links or trunks may be connected. As a minimum, the channel provided at each level of the DCS signal processing hierarchy should be transparent to the channels at the lower processing levels. An exception to this rule would be the processing of the code or protocol changes (mentioned in the previous paragraph) that are required to achieve interoperability. From a pure transmission orientation, it is sometimes necessary to achieve transparency from the lower to the high processing levels. The processing at a higher level does not need to be cognizant of the signaling, framing, or other structures in the signal. For example, digital radio depends only on the data signaling rate and the line code (AMI or NRZ, for example) of the mission bit stream and not on details of the signal frame structure. In other cases, transparency may not be desirable in this direction. For example, the DPAS operation depends intimately on the frame structure contained in the T-1 signal, while test and monitor functions depend on recognizing the signal type in the individual channels. The DPAS must recognize and align with the frame signal, and must determine time-slot boundaries with respect to the frame. Transparency considerations such as these will play a major role in determining the locations and mode of operation for which the DCRC is acceptable.

2.2.2 Possible DCEM Locations

The DCEM placements in the DCS must be chosen so that the advantages of its application are achieved without introducing an adverse impact on other network functions, such as switching or patching for alternate routing. The potential locations for the

DCEM are marked in Figure 2-1 as A, B, and C. The corresponding symmetric network locations are marked with corresponding primed letters (A', B', and C'). Level A is a single channel application. Level B is the digroup application. Level C is a higher rate application. Current DCS planning is for the digroup application (Level B in Figure 2-1). Two types of digroups may be involved. The first type is the North American Standard at 1.544 Mb/s (identified as T-1 herein) and the European CEPT standard at 2.048 Mb/s (referred to as E-1 herein). For interoperation between standards, only one DCEM is required. Its location depends on the transmission facility used. Those applications are shown as Modes 1-A, 1-B, and 1-C in Table 2-1. Other possible modes of operation are also shown in the table.

Figure 2-2 shows the communication network transmission hierarchy in the current DCS architecture. This illustration is a composite of requirements from MIL-STD-188-323 (Reference 7), DSN transmission planning, and the results of an integration support study reported in Reference 8.

The major elements, which form the bulk of the digital DCS transmission and switching equipment, are the switch (DSN), submultiplexers, level-1 and level-2 multiplexers, bulk encryption, automatic patch and test (DPAS or DACS), service channel multiplex, and the digital transmission media. The configuration of these equipment items, shown in Figure 2-2, is in accordance with the DCS Integrated Switching and Transmission concept.

When a CEPT standard (2.048 Mb/s) interconnection is leased to provide the transmission, a multiplex rate converter may be provided by the DCEM. Applications for this function could be as illustrated (DCEM 1 in Figure 2-2) in modes 1-B or 2-A. In mode 1-B, interoperation with CEPT standard equipment is desired and only one DCEM is required. In mode 2-A, the CEPT transmission is

Table 2-1. Correlation of DCEM Locations With Application Modes

Mode	Loc(s)	Comments
1-A	B'	Left side and Transmission T-1; Right side E-1
1-B	B	Left side T-1; Transmission and Right side E-1
1-C	B	Left side DCS 3.088 Mb/s; Right side E-1

(NOTE: Above modes involve intercommunication between equipment operating with different standard formats.)

Mode	Loc(s)	Comments
2-A	B,B'	Left and right sides T-1; Transmission 2.048 Mb/s E-1 (compression allows 2 T-1 into 1 E-1)
2-B	B,B'	Left and right sides E-1; Transmission DCS 3.088 Mb/s
2-C	B,B'	Left and right sides E-1; Transmission 1.544 Mb/s (compression transfers 30 channels across T-1)

(NOTE: Above modes involve operation between similar equipment employing transmission facilities at non-standard rates. When compression is involved, the non-standard rate is also non-standard frame format.)

Mode	Loc(s)	Comments
3-A	B,B'	Left and right sides two T-1; Transmission 1.544 Mb/s
3-B	B,B'	Left and right sides two E-1; Transmission 2.048 Mb/s

(NOTE: Compression prevents the use of current DPAS or DS-0 patching. The application of the DCEM is thus restricted to the DCEM-2 location shown in Figure 2-2. Level C processing can only be transparent multiplex.)

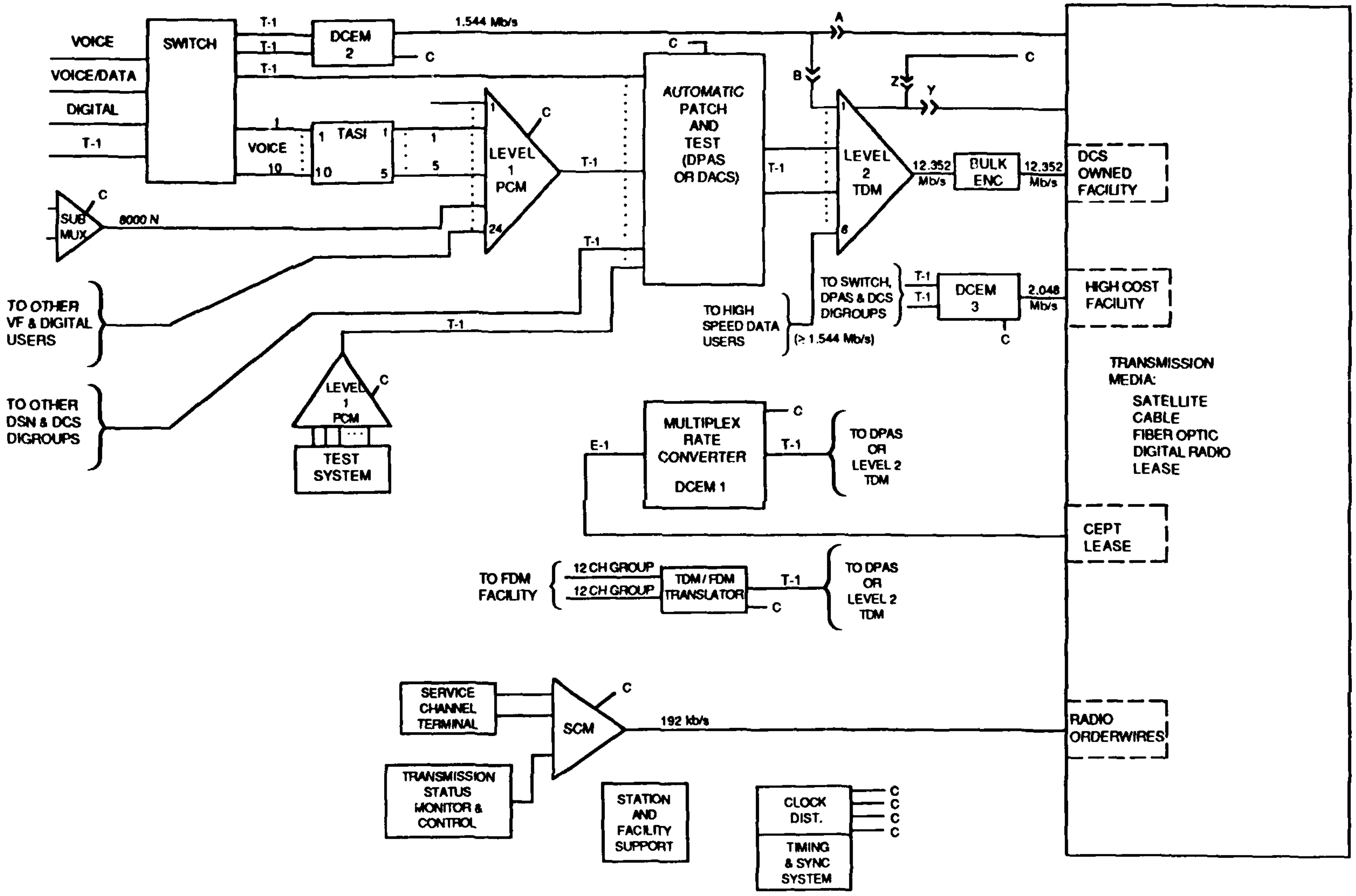


Figure 2-2. Transmission Hierarchy in the DCS

used to interconnect two DCS nodes. This configuration would involve converters at each end of the CEPT connection. Mode 2-A is the most likely mode in the DCS.

Two positions in the transmission hierarchy where DCEM could be implemented remain to be covered. In the first position, referred to as DCEM-2 in Figure 2-2, the DCEM is used in application mode 3-A (see Table 2-1). Since the frame format is non-standard due to signal compression, the 1.544 Mb/s output must bypass the automatic patch and test. Optional connections to the level-2 TDM (B) or directly to the transmission media (A) are shown.

Two DCEMs are involved in this application and no automatic patch and test facilities can appear between the two (DCRC) devices. Furthermore, the digital switch is not capable of terminating the 1.544 Mb/s signal.

In the remaining position (DCEM-3) in Figure 2-2, the DCEM is used in application mode 2-A (see Table 2-1). In this case, the output is also non-standard and may impose restrictions on the AO&M actions within the CEPT standard area similar to the ones imposed on the DCS with DCEM-2. The lease of the facility should flag the fact that the signal is of a non-standard format, and test and re-routing actions may be limited. Otherwise, improper performance may be encountered if the 2.048 Mb/s channel supplier performs certain routine actions. As a minimum, the lease should specify bit-sequence independent operation.

2.2.3 Recommended System Integration Actions Concerning the Use of DCEMs in the DCS

The use of equipment, such as TASI, DSI, and DCEM, in the DCS is subject to particular constraints if interoperation and compatibility are to be maintained. The constraints depend on the specific mode of operation. Certain modes of operation introduce non-standard signal formats. The existence of such non-standard formats are of particular concern to the system integration process.

The first level of concern is with the interoperability considerations outlined in the preceding paragraphs. The application planning within DCA appears to be fully in accordance with the restrictions defined in the preceding paragraphs. However, this leaves open the concern that the restrictions may not be so fully understood within other design groups which may interface with the DCS in modes where specific restrictions apply. The system integration process must be sensitive to the ways such interfaces may arise and take particular pains to see that appropriate guidance is promulgated and that interoperability is achieved at the interface.

The second level of concern is that the existence of non-standard formats may have an impact on other subsystems of the DCS or on the suppliers of channel leases. The impact may take the form of incompatibility in signal processing as represented by the inability of the switch or DPAS equipment to process the non-standard DCEM formats. This can be taken care of by the first level process just described. Another form of impact would be on AO&M actions where test and monitoring equipment are incompatible with the non-standard format. The prime effect is to limit the points at which tests or monitoring can be applied to the system. This can be coordinated readily between DCS subsystems if the requisite degree of integration engineering is applied. A potentially more troublesome situation arises in the case of leases. When non-standard signal formats are a possibility, it is insufficient to specify the channel as "T-1" as is currently done. Not all T-1 channels will be equivalent when DCEM type equipment is installed. System integration engineering must assure that non-standard interfaces are identified and the requisite coordination guidance is promulgated.

The third level of concern is with survivability considerations. The existence of non-standard signal formats has been shown to require specific configurations of equipment at the ends of the transmission media. The restrictions imposed by these specific requirements will either limit reroute flexibility or lead to the requirement for standby equipment to meet the reconfiguration needs for reroute. In addition the existence of specific configuration requirements will impose the need for additional coordination actions which can serve to slow or reduce the effectiveness of the reroute process. System integration engineering should carefully consider these non-standard cases and ensure that the designs and procedures are adequate to meet survivability and availability requirements.

2.3 THE USE OF TASI/DSI IN THE DCS

In certain cases and certainly in the near term, a TASI device can provide economies in DCS transmission. The use of TASI is appropriate if the transmission facility is analog. A TASI function is shown in Figure 2-2 operating between the switch and a level-1 multiplexer. Although this mode of operation is possible, the use of DSI instead of TASI makes more sense in the all digital DCS cases. In an analog case, the level-1 PCM would be replaced with the corresponding FDM multiplex. Compression of 10:5 is indicated; a capability for 48:24 is commercially available. If a TASI device is used, the transmission design must be such that all of the channels in a trunk (on which TASI has been applied) follow essentially the same physical route and have nearly equal delays. Any allowed switching between channels with different delays would be noticeable and objectionable to the users.

The TASI/DSI technique relies on the silent periods in a speech signal and cannot be applied to data signals or to encrypted voice signals. The presence of data signals is detected by the TASI/DSI device and the TASI/DSI process is bypassed. The higher the percentage of data/encrypted voice therefore the less effective is TASI/DSI in reducing transmission costs.

The percentage of DCS traffic which is data and encrypted voice can be expected to increase markedly over the next few years. There is no doubt that TASI/DSI equipment can easily pay for itself in a short period in the near-term DCS. It is important, however, that DCA begins planning now for the increased transmission that will be required as the effectiveness of TASI/DSI is reduced particularly by the increased use of encrypted versus clear voice in the DCS.

2.4 CHANNEL QUALITY (QUANTIZING DISTORTION)

2.4.1 General

The standard of performance for digitizing analog signals for transmission over digital facilities is 64 kb/s PCM. The North American and CEPT standards differ slightly in performance but equivalent performance is achievable user-to-user in similar networks designed to either standard. There has been a great deal of activity directed toward the development of techniques for providing lower speed channels. Significant savings can result from reduced transmission cost if comparable quality is obtained from equipment that does not greatly exceed the PCM cost. Techniques providing VF channel rates ranging down to 2400 b/s have been developed. The trend is toward increasingly lower quality and higher terminal cost as the rate is reduced. Adaptive Differential PCM (ADPCM) has been effectively standardized and provides sightly reduced quality 32 kb/s channels at comparable cost. If the use of these lower rate channels is appropriately restricted, the advantage of effectively increased transmission capacity can be obtained while still providing acceptable channel quality to the users. Slightly different considerations apply to voice traffic and data traffic in the voice channel. These considerations are discussed in the following paragraphs.

2.4.2 Voice Traffic Considerations

The CCITT in its recommendations on telephone connections (Reference 9) defines the quantizing distortion (qd) unit to characterize the effects of digitizing analog signals. As defined, the qd unit is based on the effects of a single 8-bit PCM encoder and decoder. The 8-bit PCM encoder/decoder process is assigned one qd unit.

A summary of qd units per conversion process is compiled in Table 2-2 for functions operating with a mean input Gaussian Signal Level (GSL) of -20 dBm0 (Reference 10). These values of qd do not take into consideration any distortion caused by bit errors, which must be determined separately.

From a planning perspective, the qd units for each device or function in a segment can be summed to give the total qd units anticipated in the network path. In a network where the design is completely coordinated, the levels are suitably controlled and there are only minor deviations in the implementation from the design, the CCITT have allocated a total of 14 qd units to an international connection comprised of two national networks interconnected by an international transit segment. The CCITT have further allocated 5 qd units to each national network and four to the transit segment. This allocation is based on an integrated design and implementation. On an interim (temporary) basis during the transition to an integrated design the CCITT allocates 18 qd units to the international connection and 7 qd units to the national network.

2.4.3 Recommended System Integration Actions Concerning the Use of ADPCM in the DCS

An examination of the DCS hypothetical reference system shows that the limiting circuit is the overseas terrestrial reference circuit. It consists of six interswitch trunk circuits and two

Table 2-2. Summary of qd Units/Process
(References 9, 10 and 11)

Functions	Device	qd Unit Value
1. 8-bit PCM	Encoder/Decoder Pair (A-Law or U-Law)	1.0
2. 7-bit PCM (Reduction in SDR of $\geq$ 6 dB)	Encoder/Decoder Pair (A-Law or U-Law)	4.0
3. 7-bit PCM (Reduction in SDR of < 6 dB)	Encoder/Decoder Pair (A-Law or U-Law)	3.0
4. VF (Voice Frequency to U-Law)	Encoder/Decoder Pair	0.5
5. VF (Voice Frequency to A-Law)	Encoder/Decoder Pair	0.5
6. U-Law to A-Law	Format Converter	0.5
7. A-Law or U-Law Attenuator	Digital Loss Pad	0.7
8. 6 dB A-Law Attenuator	Digital Loss Pad	0.0
9. 8-7-8-bit Transcoding (A or U-Law)	Transcoder	3.0
10. Transmultiplexing Based on 8-bit PCM A- or U-Law	Transmultiplexer	1.0
11. A/U/A-Law Tandem Conversion; A/U-Law Tandem Conversion; U/A-Law Tandem Conversion	Tandem Converter	0.5
12. U/A/U-Law Tandem Conversion	Tandem Converter	0.25
13. 8-bit + A/U-Law Code	Encoder/Decoder + Tandem Converter	2.0
14. PCM to ADPCM to PCM Tandem Conversion	Tandem Converter	2.5
15. 32 Kbit/s ADPCM (Combination of an 8-bit PCM Encoder/Decoder Pair and a PCM-ADPCM-PCM Tandem Conversion)	Reduced Rate Coder	3.5

tail circuits. If it is assumed that this reference circuit corresponds to the CCITT national network segment and that the interim values of distortion allocation are permissible, seven qd units are allowed. This would allow up to seven links of PCM tandemed at the analog signal level. Current planning is to reduce the number of points at which the analog channel appears through an integrated system of digital switches, digital patch and test, and digital transmission. In an integrated, entirely digital circuit, there would be only one coder/decoder pair in the circuit. This configuration amounts to one qd unit. Table 2-2 shows that introduction of an ADPCM (reduced rate channel at 32 Kb/s) link in an otherwise PCM configuration increases the distortion by 2.5 units. Such a large amount serves to limit the number of links of this type to one (if the more stringent allocation of five units applies) or to two (if the less stringent seven unit allocation applies). It should be clear that very careful planning for the introduction of reduced rate coding channels is essential to meet established user channel quality goals.

With regard to data applications of the voice channel, the situation is somewhat different. Tests have indicated that modems operating at data signaling rates higher than 4800 b/s are adversely affected by just one link of reduced rate coding. Therefore, the introduction of such links into the DCS will limit the speed of operation of digital service in the form of modem signals in the VF channel to 4800 b/s or less. This is less than some users currently operate at. However, at the lower rates, satisfactory operation is achieved over as many as four tandemed reduced rate links. Therefore, design to voice requirements will satisfy the data requirements provided they do not exceed 4800 b/s.

It is essential that planning and implementation for ADPCM equipment be coordinated so that there will be minimum impact on the overall system performance. A major difficulty with this coordination is that it will have impact on transmission, switching, MILDEP initiatives, and the user terminal equipment areas. The DCA Systems Integration Division (B200) is the focal point for such coordination and must ensure formal procedures are adhered to in order to ensure overall system optimization.

SECTION 3 - ISSUES RELATED TO TIMING AND SYNCHRONIZATION OF THE DIGITAL DCS

3.1 INTRODUCTION TO DCS TIMING AND SYNCHRONIZATION

The DCS is evolving to a fully synchronous system deriving its timing from the U.S. Naval observatory. There is a program to provide or upgrade timing and synchronization references in DCS TCFs. However, there are clocks currently in use in the DCS which will not be affected by this program. It can therefore be expected that there will be multiple sources of timing in the DCS. On top of this there will always be the issue of interconnection to foreign networks which derive their timing from different standards. There can, therefore, be no guarantee that the reference rates will be the same at all of the nodes. For this reason, proper accommodation must be made for the inherent clock errors which may arise. Plesiochronous operation will also be an important fall-back mode in case of damage to the timing and synchronization subsystem of the DCS.

The DCS transmission subsystem is best described as a synchronous network embedded in a pulse-stuffing network. At a given node the primary multiplex and DPAS equipment are operating synchronously, referred to station clock. The station clocks are referenced to the U.S. Naval Observatory time standard. However, failure of the reference link may cause the affected station clock to drift with respect to the other node clocks. The need for buffers to compensate for transmission path length changes, such as implemented at the satellite terminals introduces an additional complexity in assuring slip-free operation is achieved in both transmission and switching elements of the DCS.

It is essential that the timing and synchronization of the DCS be approached from a system integration viewpoint. A plan for the distribution of the required synchronization references is essential. The impact of the plan on the interface with foreign networks when restoral under stress is necessary must be included in the planning. The maintenance of an integrated timing and synchronization subsystem will require close coordination among the transmission, switching and control subsystems during both stressed and unstressed operations.

3.2 THE ISSUE OF ELASTIC BUFFER SIZING

The above introduction identified several factors which could have an impact on the rate error of the clocks in the DCS nodes. Buffers are provided in the transmission and switching equipment to accommodate the clock error that could develop. DCA planning must ensure that sufficient buffering capacity is provided between the transmission and switching to be certain that synchronous operation is maintained for the specified operational interval.

The introduction of the DPAS and of digital switches demands a synchronous interface at the digroup level. This mode of operation imposes the requirement for synchronizing buffers at this level. The most appropriate location for such buffers would be at the second level multiplex receive side where the digroup first appears at the node. An alternative location would be in the DPAS (or switch if there is no DPAS). Both the DPAS and the digital switch provide frame alignment buffers. The purpose of this buffer is to provide the ability to align in time the receive and transmit frames to facilitate the patch or switch function. It is possible that there is sufficient capacity provided in the buffering to also accommodate the clock error. The system engineering must ensure that sufficient buffering has been provided.

SECTION 4 - ISSUES RELATED TO THE INTRODUCTION OF THE DIGITAL PATCH AND ACCESS SYSTEM

The Digital Patch and Access System (DPAS) will provide automated patching (cross-connect) and test access capability for digital communications channels within the DCS. DPAS will provide a major improvement in flexibility of management and reconfiguration of DCS transmission facilities and will support virtually all DCS users (DSN, DDN, dedicated circuits).

DPAS is capable of cross-connecting under keyboard control amongst up to 160 digital groups (digroups) conforming to the North American Standard (24 channels/1.544 Mb/s) and/or the European standard (30 channels/2.048 Mb/s). DPAS is capable of cross-connecting down to the 64 kb/s channel level in either standard but not below. DPAS has a 64 kb/s clear channel capability in which the full 64 kb/s channel is passed through without alteration.

A number of issues associated with the introduction of DPAS have been identified in Reference 12.

1. The DPAS must be able to detect and track the framing signal in all connected digroups. It cannot therefore handle a bulk encrypted digroup.
2. DPAS is a synchronous device and digroups connected to it must be nearly synchronous with the DPAS reference clock if frame slips are not to occur at an unacceptable rate. This may place limitations on interconnection with leased transmission facilities deriving clock from a different source and upon the transition to the all-digital DCS when multiple clock sources may be used.

3. DPAS provides complete flexibility to route the circuits of a DSN interswitch trunk group and the associated Common Channel Signaling (CCS) circuit over multiple different routes. The present plan is to use associated CCS in the DSN and this has been interpreted to mean that the CCS channel must traverse the same transmission path as the interswitch trunks it supports. With this interpretation, either some flexibility to react to transmission plant outages must be lost, or the DPAS must be provided a capability to split the CCS channel.

The first and second issues are fully and adequately treated in Reference 12. No modifications to DPAS are proposed and the following practical conclusions are drawn:

1. A crypto device should be developed for bulk encryption at the digroup level which encrypts only the information signal and passes the framing information through unmodified. This device would be used where end-to-end encryption is required and its use would not preclude link encryption if this were desired to prevent denial of service attacks against the framing signal. In the interim period until such a bulk encryption device can be produced, encrypted digroups will have to bypass the DPAS and be manually patched.

2. In many cases, infrequent framing slips due to timing differences on a differently timed digroup may be tolerable. Where the slip rate is not tolerable and the timing mismatch cannot be solved, the digroup must be manually patched around all DPAS's or converted to analog and redigitized.

The third issue is not neatly solved in Reference 12, or in Reference 13 where a CCS applique processor for DPAS and a new TDM format for the DSN CCS are proposed. The following paragraphs present the "problem" in some depth and provide the background to the "solutions" proposed at the end of the section.

The DSN will be a richly connected network with relatively small numbers of interswitch trunks per connection. An individual DSN multifunction switch will be directly connected to at least 3 and in one case as many as 18 other switches but these trunk groups will average only 35 channels each. With associated CCS each trunk group would have its own CCS channel. Considering that a single 64 kb/s CCS channel can serve 1000 channels this represents an inefficient use of the transmission facilities. The inefficiency of associated CCS is even worse following damage to the DCS when the number of channels to support DSN interswitch trunk groups becomes less, and diverse routing of the individual trunks becomes very desirable.

Consider an interswitch trunk group which in undamaged conditions consists of 23 communications channels and a CCS channel. When this trunk is severed by wartime damage it will be the task of the Defense Communications Operations Support System (DCOSS) to reroute as many of the channels as possible consistent with their restoration priority. It is worth noting here that it is important to reroute this trunk group if at all possible, and not to rely wholly on the DSN's other connectivity and very capable routing algorithm. If interswitch trunks are not restored the grade-of-service will certainly degrade even for high precedence users. In attempting to reroute our severed interswitch trunk, then, it is very important to reroute at least one of the channels of the trunk to support the high precedence traffic. In some cases it might be possible to reroute all 24 channels (including the CCS channel) along a common route. However, based upon present plans for numbers of spare channels, the expected wartime damage, and studies reported in Reference 14, it is clear that in most cases the controller will have to accept a reroute of considerably less than the full number of channels. The controller would certainly be able to get more channels rerouted if the common route requirements were relaxed. The major survivability point here is:

- As damage increases in a system using associated common channel signaling, the percentage of the transmission plant used for signaling can become substantial.

One of the main reasons given for using associated CCS in the DSN is that with this scheme, the CCS channel is just as survivable as the communications channels it supports. Certainly, when the signaling channel follows the same transmission path as the interswitch trunk it supports, when one is disrupted so is the other. However from the above arguments, it is clear that when the need to reroute is considered, a forced common routing of the CCS and the communications channels can reduce survivability in terms of the all important number of transmission channels available to support DSN interswitch trunks.

At this point in the discussion some tight definitions of the various modes of common channel signaling are required. In each of the following cases the CCITT definition is given followed by a transmission oriented restatement in a DSN context.

Associated Common Channel Signaling

- The mode where messages for a signaling relation involving two adjacent signaling points are conveyed over a directly interconnecting signaling link.
- The CCS channels parallel the interswitch trunks and go directly between the switches served by the trunk without encountering a third switch or Signaling Transfer Point (STP).

Quasi-Associated Common Channel Signaling

- A non-associated mode (of signaling) in which the (signaling) message route is predetermined and, at a given point in time, is fixed.

- The CCS channels parallel the interswitch trunks and interconnect the switches served by the trunk but pass through a third switch which performs a relaying function for signaling messages.

Non-Associated Common Channel Signaling

- The mode where messages for a signaling relation involving two (nonadjacent) signaling points are conveyed, between these signaling points, over two or more signaling links in tandem passing through one or more signaling transfer points.
- The CCS channels are not constrained at all to the topology of the communications network. They may parallel one of the trunks they serve but in general the CCS channels serve multiple trunks.

It is to be noted from the definition of associated common channel signaling that there is no requirement, from a switching viewpoint, for the CCS channel to be routed through the transmission plant in the same manner as the trunk it serves so long as it is not relayed by a switch along the route. A DPAS equipment is not a switch in this sense; the DPAS simply patches the CCS channel through without modifying or even interpreting the signaling messages.

If then there truly is a requirement in the DSN for the CCS channels to be associated in the transmission sense, it does not stem from a switch requirement, it must be based upon a survivability argument and that argument has been largely refuted above. The remaining issue concerns a trunk which is routed differently (by DPAS) from its CCS channel and what occurs if the CCS channel is then disrupted. Of course, as stated above, the DCOSS will in time restore the CCS channel but is there a problem in the intervening time? DSN has been designed to use quasi-associated signaling in case of malfunction of an associated

CCS channel. The switch itself will detect the CCS problem and use an alternate route until such time as the associated CCS channel is restored. There would appear to be no survivability problem whatever with DSN CCS and certainly none that is associated with DPAS. In fact DPAS considerably improves survivability as shown above.

There is no question that non-associated CCS is more efficient in transmission resources than associated signaling and therefore it is interesting to explore if it can be otherwise as survivable as associated/quasi-associated signaling. In a non-associated system each switch is connected via a CCS channel to one or more STPs. Each STP examines the signaling messages and forwards them to the addressed switch. There are two vulnerabilities here, the STPs themselves are vulnerable; the CCS links are separately vulnerable from the many trunks they support.

If the DSN Europe were to be designed as commercial non-associated networks are, there would be, say, five STPs at distributed non-target locations. Each European switch would be connected to at least two of these STPs. Each STP would act as a backup to one or more of the others in case of STP failures or damage. Failures of CCS channels or STPs would be detected by the individual switches through the standard timeout mechanism and the switches would react to the failure by routing signaling to an alternate STP. Transmission plant failures affecting individual switch-STP signaling circuits would also be detected through DPAS, TRAMCOM and/or DCOSS and these circuits would be rerouted around the failure. To ensure that CCS circuits receive rapid reroute attention they should be assigned the highest priority as should one or more circuits on each interswitch trunk. (In the AUTOVON system interswitch trunks have been assigned the 00, "don't care," priority.) The concept is self-healing in that the switches use alternate STPs in response to damage. As a second line of adaptation the DCOSS will attempt to restore CCS Links as rapidly as possible.

Unlike the commercial world in the United States, DSN switches are presently specified to have an integral STP. If this capability were retained and non-associated signaling were adopted, the whole network could become extremely survivable through heavy redundancy of the STP function. The consequences of non-associated signaling in such a system appear to be only a new routing data base for CCS messages and an activation of certain features of CCS No. 7 that are presently unused in the DSN design. This issue is being studied by DCEC R600.

If the above scheme for non-associated common channel signaling were coupled with a concept such as distributed circuit control (see Reference 15 and 16) for rapid, distributed and automated, reroute of circuits (including interswitch trunks) within DCOSS, there is no reason why non-associated signaling could not be <u>much</u> <u>more</u> survivable than the presently planned associated scheme.

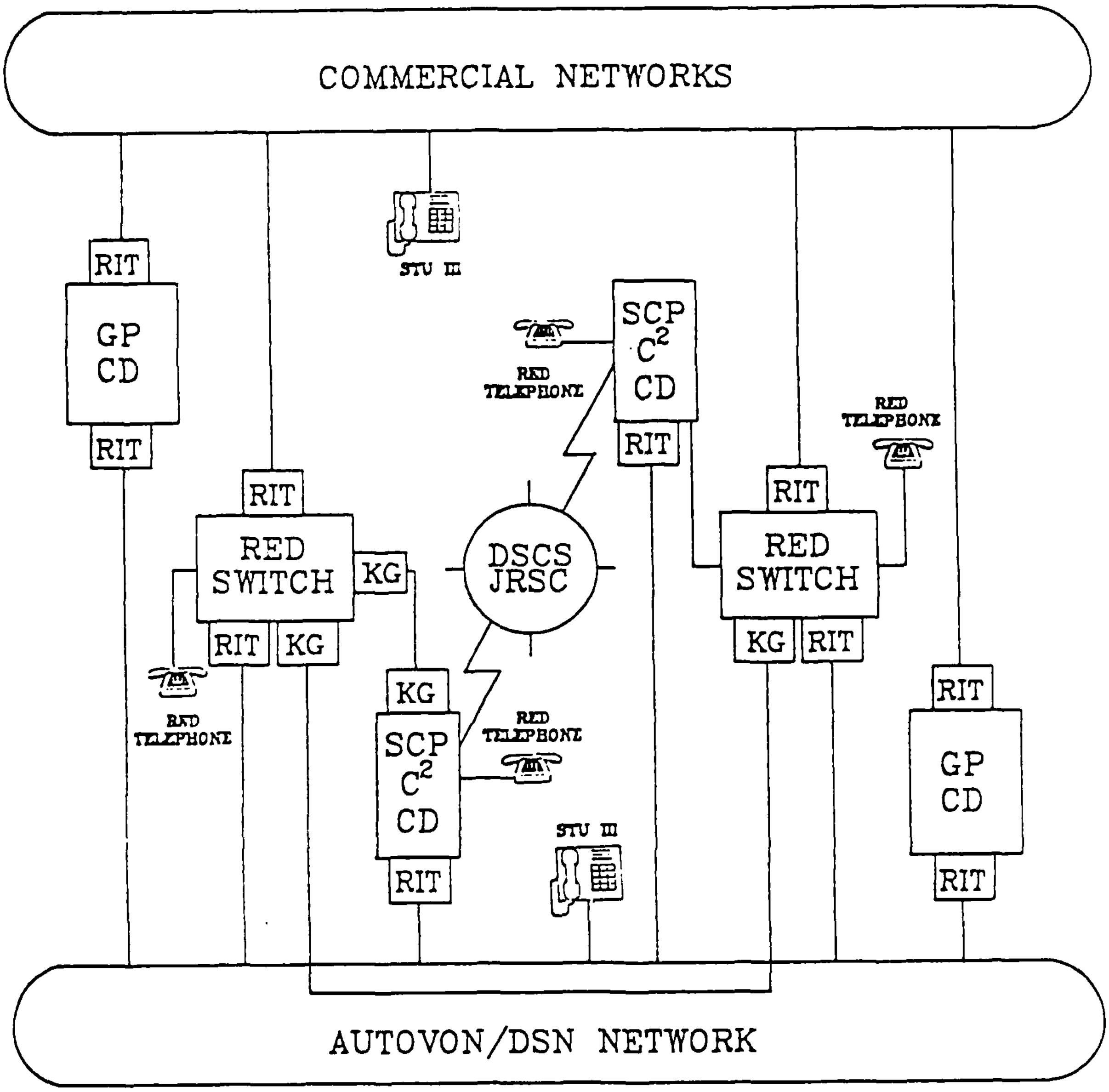
The conclusion from the above arguments is that there is no problem with DPAS and the present DSN associated/quasi-associated signaling scheme. DPAS and DCOSS enhance the survivability of DSN both with inband signaling and CCS. However, since associated common channel signaling is inefficient in the use of transmission resources, particularly when the transmission plant suffers wartime damage, it is recommended that non-associated signaling be seriously considered to enhance the effectiveness of the DSN.

SECTION 5 - PLANNING FOR THE CONTROL OF THE SECURE VOICE SYSTEM

5.1 THE SECURE VOICE SYSTEM

Several initiatives, which will comprise the Secure Voice System (SVS), will satisfy DoD secure voice and conferencing requirements. The SVS architecture consolidates the capabilities of the NSA Future Secure Voice System (FSVS) program, the Secure Conferencing Project (SCP), General Purpose (GP) STU-III Conferencing, and the RED Switch Project. The STU-III family of equipment being developed as part of the FSVS program will be the primary secure voice terminal used within the SVS. STU-IIIs will be replacing the STU-IIs developed under the Secure Voice Improvement Program (SVIP), except in NATO. GP STU-III Conferencing will provide worldwide secure conferencing for general purpose STU-III users. The SCP will provide conferencing for Command and Control (C^2) users worldwide. Each RED Switch in the RED Switch Network will function for unencrypted secure voice traffic as a private branch exchange (PBX) within a secure red enclave and will contain the features necessary to satisfy C^2 requirements. Encrypted interfaces will connect RED Switches to external components of the SVS. A generic line diagram of the SVS is contained in Figure 5-1.

The SVS aims to provide user-friendly, automatic, and interoperable secure voice service to support the C^2 missions of the National Command Authorities (NCA) and selected supporting elements. The SVS will also provide high quality, user-friendly secure voice service to satisfy general purpose missions of the DoD as resources permit. Non-DoD entities may obtain SVS service in order to satisfy special defense-related requirements when approved by the Assistant Secretary of Defense (C^3I) in coordination with the JCS.



CD - CONFERENCE DIRECTOR
DSCS - DEFENSE SATELLITE COMMUNICATIONS SYSTEM
GP - GENERAL PURPOSE
JRSC - JAM RESISTANT SECURE COMMUNICATIONS
KG - KEY GENERATOR
RIT - RED INTERFACE TERMINAL
SCP - SECURE CONFERENCING PROJECT

Figure 5-1. Generic Line Diagram of SVS

5.2 CONTROL REQUIREMENTS OF STU-III GP CONFERENCING

The GP secure conferencing subsystem will provide the GP community of users with a secure voice capability composed of secure Conference Directors (CDs), STU-III telephone terminals, RED Interface Terminals (RITs), a public key system, and the transmission resources of AUTOVON/DSN.

In the past, GP conferencing has been part of the Secure Conferencing Project (SCP), but it is anticipated that in the near future GP will be separated from SCP and become a capability provided by DSN. The STU-III family of equipment being developed as part of the Future Secure Voice System (FSVS) program will be the primary secure voice terminal used for GP conferencing. The chief connectivity between voice terminals and conferencing bridges will be provided by AUTOVON/DSN.

GP STU-III conferencing requirements can be meet by the standard DSN control hierarchy. However, some authority (probably NSA) must be responsible for the administration of the Key Management Center (KMC) and for issuing Crypto Ignition Keys (CIKs).

5.3 CONTROL REQUIREMENTS OF THE RED SWITCH

The RED Switch Network supports command and control secure voice users located within a physically secured enclave (RED enclave). Each RED Switch forms a switching hub for its own RED enclave, users within which will have telephone sets connected to the RED Switch by physically secured unencrypted lines. Some RED Switches will also have Digital Subscriber Voice Terminal links to the TRI-TAC subsystem and trunks to collocated SCP Digital Conference Directors (DCDs). RED Switches will also interoperate with low cost terminals and KY-77s via RED Interface Terminal interfaces to AUTOVON/DSN and commercial telephone networks.

Since RED Switches are connected to each other through crypto units and dedicated circuits through DSN, RED Switch control requirements can be met by the standard DSN control hierarchy.

5.4 CONTROL REQUIREMENTS OF SCP

5.4.1 A Description of the SCP

The SCP C^2 will provide a survivable, flexible, responsive, secure voice and graphics communications capability to the National Command Authority (NCA) and the Unified/Specified CINCs in support of strategic decision making, and command and control during global or regional crisis situations. The SCP C^2 conferencing will be provided to major command centers through DCDs utilizing the Jam Resistant Secure Communications (JRSC) portion of the Defense Satellite Communications System (DSCS) Electronic Counter Countermeasures (ECCM) transponder. Fully distributed, user-controlled voice conferencing; two-party secure voice calls; and secure graphics (facsimile and teletype) conferencing will be provided to the designated C^2 users. Conferencing (secure voice and graphics) will be provided intra- and inter-node, and intra- and inter-satellite area between two or more parties.

Not only will SCP C^2 conference nodes be allowed to establish conferences over independent DSCS satellite channels, but the SCP DCDs will provide access to the planned and existing terrestrial communications assets of AUTOVON/DSN. It will allow the SCP C^2 system to have enhanced redundancy through the use of alternate paths through the terrestrial network. This will also allow GP STU-III and RED Switch users to participate in a C^2 conference, if required. Additionally, certain designated remote C^2 STU-III users will be allowed to establish intra-node conferences through the SCP DCD.

The SCP C^2 conferencing system is scheduled to evolve from the Early Operational Capability (EOC) to the Final Operational Capability (FOC) between 1991 and 1995. EOC is separated into two phases. Phase I (which began in 1985) uses Navy-developed

Advanced Development Model Digital Conference Directors (ADM-DCDs), Multiple Rate Voice Terminals (MRVTs), graphics terminals, and JRSC spread spectrum modulation equipment to introduce secure voice and graphics conferencing to eight command centers in the PACOM area through the WESTPAC DSCS II satellite. Phase II will extend this capability to a total of three satellite areas serving eight CONUS command centers and four European command centers. FOC will only consist of enhancements to the EOC.

The number of active nodes for the SCP C^2 system will be limited to a maximum of 20 for each of the five DSCS satellite coverage areas. Some of these nodes will serve as relays between satellite areas.

5.4.2 Issues in SCP Control

Difficulties have arisen in network management and system control for fault isolation and restoral of the SCP network, seemingly from the inability to recognize and isolate the faults occurring in the network due to insufficient alarm mechanisms and the lack of a means for providing the coordination required for rapid fault isolation and restoral. Part of the problem is the lack of desired orderwires between the command center locations and the earth terminals. It is strongly recommended that either TTY or voice orderwires be provided in the SCP EOC as soon as possible.

As the SCP moves toward its final operational configuration, an improved network maintenance and system control is being explored by NOSC. One alternative is to develop a centralized maintenance concept to provide a more responsive system. A centralized network controller in each satellite area would include a network maintenance console connected via remote monitor and control circuits to command center equipment, earth terminal equipment, and network orderwires. The goals of this concept are the efficient gathering, processing, display, and analysis of data (e.g., system status, system configurations, traffic data, equipment performance) from critical network elements in a timely manner, allowing for the tech controller to take corrective action via the orderwire circuits.

Before beginning on the design of any new network maintenance and system control concept, it is recommended that several steps be taken. The first step would be to make an exhaustive search and collection effort identifying all types of outages and failures and the frequency with which these occur in the SCP EOC network. Then for each type of failure or outage noted, determine from critical network elements whether a circuit was disrupted, and if so, whether it could be restored with existing control systems and procedures. If restoration is possible, what would it take in terms of time, equipment, and manpower? (Therefore, was it a practical and efficient solution?) Could these problems be solved by using orderwires between subsystem elements and better training procedures?

These types of questions need to be answered to provide input for an analysis identifying weaknesses and gaps in the control system - including possible interoperability problems among different control elements and identifying any areas that can be improved.

Testing to identify some of the weak points in areas such as equipment performance, reliability, subsystem performance, overall network maintenance, and system control should commence as soon as possible.

Once the nature of these problems has been identified, an examination of proper alternative approaches and recommendations for improving on the current weaknesses of the control system can begin. However, it must be pointed out that if the testing is not given a high priority, thus requiring a commitment from network operation and testing personnel in relation to other tasks, the test results will most likely prove inconclusive.

As mentioned above, one alternative for improved control is a centralized concept for a remote monitoring and fault isolation. Other attractive alternatives include control systems that involve elements of centralization coupled with distribution. The SCP has been designed as a distributed system in order to provide enhanced survivability. Thus, the loss of any node should not bring down operation of the network. The centralized system described in the SCP EOC draft network maintenance concept would seem to have limited survivability since only one control center in each theater has a span of knowledge and control over SCP within the theater. A more distributed operational control concept for the SCP would be advantageous for ensuring survivability of the SCP; thus, it would be more in keeping with the overall SCP design, which utilizes distributed control as depicted by the nature of the Network Control Channel (NCC).

One alternative for distributed control would be to interface the SCP system with the Defense Communications Operations Support System (DCOSS). Although this alternative is more complex, it would benefit from the work already being done under the DCOSS effort and thus would mitigate the need to design an expensive control system solely for SCP. The SCP could fit into the AO&M structure and interface with the DCOSS at the Sub-Regional Control Facility (SRCF) level. The SCP DCD would be connected to the SRCF by appropriate means (either dedicated or through DDN) to allow the DCOSS to serve the SCP network for such things as surveillance of the status of critical SCP equipment, coordination among network elements, initiation of required support, and implementation of required maintenance actions. The DCOSS is also scheduled to interface with the DSCS ECCM Control System (DECS) thus receiving information on all segments utilized by the SCP. Due to both the abundance of DCOSS-SRCFs scheduled to be installed (beginning in FY88) in each satellite area and the overall survivability objectives of the DCS AO&M structure, SCP would most likely benefit from such an alternative, which would obviate the requirement to design a control system solely for SCP.

5.4.3 Recommendations for SCP Control System Design

A methodical, step-by-step detailed analysis of the current SCP EOC control system should be made before work begins on any one alternative for providing network maintenance and system control in the current network. It is recommended that a study should be initiated to determine the weaknesses in the current SCP EOC network maintenance and control structure, characterize these flaws, and then analyze different alternatives for providing effective network maintenance and system control against a set of criteria. It is also recommended that a study be initiated on the Local Area Orderwire and Satellite Area Orderwire to meet the immediate urgent need to improve coordination between the command center and earth terminals as well as between earth terminals.

SECTION 6 - ISSUES RELATED TO TELECOMMUNICATION SERVICE PRIORITY SYSTEM FOR NATIONAL SECURITY EMERGENCY PREPAREDNESS (NSEP) TELECOMMUNICATIONS

6.1 BACKGROUND

On 1 April 1987, the Secretary of Defense, acting as executive agent on behalf of the National Communications System (NCS), requested that the Federal Communications Commission (FCC) issue a Notice of Proposed Rulemaking proposing to promulgate a set of NSEP Telecommunication Service Priority system (TSP) rules. The TSP system provides the legal framework for NSEP telecommunication service providers to initiate, restore, or otherwise act on a priority basis to ensure effective NSEP telecommunication services. This regulatory, administrative, and operational system will authorize and provide for priority treatment of NSEP telecommunication services, both private line and public switched services, and will replace the existing United States Restoration Priority (RP) System.

The new service priority system arose out of problems with and the obsolescence of the current RP system, and the changing U.S. industry environment. Environmental changes include emerging technological innovations, the AT&T divestiture which fractured the once closely-knit AT&T capability for restoring commercial telecommunication services, and increasing presidential emphasis on national security emergency preparedness.

The NSEP TSP System will consist of three components:

1. A legal and administrative component comprising the laws and regulations authorizing the system, and the procedures for documenting and disseminating information about the system

2. A categories and criteria component which addresses the NSEP telecommunication categories for service initiation and restoration, and the criteria for determining which services qualify for what priority level
3. an operational component to manage the assignment, implementation, and monitoring processes.

The new system has two categories, "Emergency NSEP" and "Essential NSEP", each consisting of four subcategories. The subcategories cover everything from telecommunications needed during national, state, or local disasters, national command authority communications for military command and control (much of it provided by the DCS), communications essential to conducting warfare and diplomatic communications for arresting or limiting hostilities, and telecommunications supporting attack warning for the U.S. population, continuity of federal, state, and local governments, public health and safety, maintenance of law and order, and maintenance of the public welfare and the national economic posture. Five priority levels are available for assignment to these essential services, plus one "E" priority for those new emergency telecommunication services so critical as to require provisioning of the service at the earliest possible time without regard to cost. Different priorities may be assigned for the three time periods: peacetime/crisis/mobilization, attack/war, and post-attack/recovery. Limitations may be placed on the number of services that can be assigned priorities. These and many other details about the NSEP TSP System are available in the FCC's Public Notice Number 2626 dated April 3, 1987.

From the perspective of DCA, the new system brings both complications and simplifications when compared to the existing restoration priority (RP) system. In the RP system, there are more than four times as many priority levels than the five contained in the TSP, so the TSP represents a simplification. But the RP system does not address multiple time periods so the three

TSP time periods and the procedures to be followed in designating the current time period as one of the three represents a complication. There was no limitation on the number of circuits at each priority level under the RP system, while the new TSP system permits limitations to be placed on the number of services that can be assigned priorities.

6.2 ISSUES

As delegated by Executive Order 12472, and under the regulatory oversight of the FCC, the Manager NCS will be responsible for implementing and managing the TSP system, and for assigning priorities to all telecommunication users authorized to apply for priority service provisioning and/or restoration under the proposed rules. This includes federal, state, and local governments, private industry users sponsored by a federal organization, and foreign governments requesting TSP priorities through the Departments of State and Defense.

The Manager NCS will have to establish a new set of procedures to implement and manage the TSP system. Major modifications to the NCS data base will also be required. He will assuredly require technical assistance from the Director DCSO whose personnel are experts in the design, installation/procurement, operation, and maintenance of telecommunication systems.

Major technical issues will arise in implementing the TSP system because of the shift from the old RP system where priorities were assigned to identifiable circuit appearances to a system where priorities are assigned to users of telecommunication services. Profound technological changes have occurred in recent years, particularly in the conversion from analog systems to digital transmission, signaling and switching. In this environment, many telecommunication services are virtual, and have no separate, identifiable physical appearance in switching and transmission facilities and equipment. These include data terminals connected to local or distant host computers. Consequently it is no longer always feasible to identify specific physical circuits and associate them with specific restoration priorities. This situation will be aggravated by realization of the telecommunication industry's goal of an integrated-services digital network (ISDN) which would combine in a single architecture such existing forms of communication as telephone, telex, facsimile and data retrieval that are now the province of independent, specialized networks, along with new forms of communication such as video-conferencing.

Long-term solutions are more apparent than near-term solutions. In an ISDN environment, the older concept of point-to-point physical circuits will be replaced by the allocation of available bandwidth between transmission nodes in accordance with the priorities of the instantaneous demands of the service users. This goal could be accomplished by converting all communication modes to packets, locating a packet switch at each node in the transmission system and employing a reservation type flow control system based on service priorities as was proposed about 1976 for the AUTODIN II program. In the proposed flow control system, the user was required to indicate the type and expected duration of each session at its beginning. Knowing the priority of the user and the data rate associated with the type of session, the switch would reserve enough system resources along selected routes to accommodate the expected throughput. If higher priority users requested service, earlier reservations would be cancelled or user-to-user throughput rates reduced in order to reserve the necessary resources for the higher priority user.

Before such an ultimate solution to the overall TSP problems can be placed on line, the NCS and the DCSO will have to live for many years in the world of digital circuit multiplexing and digital circuit patching at a multitude of data rates. The current efforts to digitize signals in T1 carrier format and to switch them using DPAS hardware employing time slot interchange techniques that can cross connect at the DS0 and DS1 level will accelerate as the digital DCS evolves. A super-DPAS equipment cross-connecting the next generation of commercial DS-3 signals (third level multiplex) at a 44.736 Mb/s is in development. A new standard for DS-3 multiplexers called SYNTRAN uses synchronous multiplexing to eliminate asynchronous multiplexing (via pulse stuffing) as used with current DS-3 multiplexers. Synchronous multiplexing would have the advantage of making individual signals at the DS2, DS1, and DS0 level directly accessible by a DPAS without the need for demultiplexing the various stages of pulse stuffing multiplex.

The proposed TSP rules state that restoration of broadband or multiple service facilities is permitted, even though it might result in restoration of services assigned lower priorities (or no priority at all) along with, or sometimes ahead of, some higher priority level services. If broadband services are assigned service priorities equal to the highest embedded priority, there may not be enough alternate broadband routes to restore all essential services because of the lower priority services bundled within the broadband signals. The proposed TSP rules permit restrictions on the number of services that may be assigned any given priority which could result in some important DCS services being forced into a lower priority because of the configuration of the multiplexing equipments.

In the interest of facilitating the restoration of DoD services, the allocation and engineering elements of DCA will need to bundle high priority services to optimize their probability of survival under wartime damage conditions. For example, two ADPCM signals at 32 kb/s are being multiplexed on a single 64 kb/s channel. The signaling for groups of 11 ADPCM channels is carried in a twelfth channel producing a 384 kb/s bundle within a T1 digroup. Thus six DSO 64 kb/s channels must be restored simultaneously to maintain the same delays, the same channel order, and the proper signaling channel assignments.

Similar problems occur in rate converters such as the Digital Communications Efficiency Model (DCEM). In this system, the number of bits per sample is lengthened or shortened according to the speech activity at any given instant of time. TASI (the analog version of speech interpolation) also requires simultaneous restoration of all channels to keep speech segments from several talkers in sequence on an end-to-end basis. Here again bundling of like priorities will be required.

The circuit and trunk file structure of the WWOLS data base is basically compatible with the increasing number of multiplex levels. For example, circuit designators (CCSDs) are assigned cross-reference (or pseudo-trunk) numbers if they carry the composite output signal of a low-speed time division multiplex equipment which aggregates low-speed data and teletype circuits. Reference to the pseudo-trunk number in the trunk file reveals the individual low-speed channels carried under the circuit identifier. A direct extension of this system would assign circuit numbers to DS1 digroups and bundles of them at the DS2 and DS3 rates and cross-reference (pseudo trunk) numbers that could be referenced to find their component circuits. Again, the service priority of these pseudo-circuits and pseudo-trunks must be the highest service priority of any of its members. The size of the service priority fields in the data base will have to be expanded to hold priorities for all three time periods covered by the TSP system unless DCA feels that it cannot justify priorities for the post-attack/recovery period when many of the current services no longer survive. Changes to the WWOLS data base will also have their counterparts in the NCS, ACOC, SRCF, and station level data bases.

Assigning TSPs to virtual circuits is currently done by assigning class marks to users which limit the precedence of their calls, messages, and packets in switched systems. There may be no connection between these precedence levels and the priorities assigned to the physical interswitch trunks that form the switched networks. For example, AUTOVON interswitch trunks carry a 00 ("don't care") restoration priority even though the switches may directly serve very important C^2 customers, or act as a tandem switch in linking critical C^2 users at locations completely remote from the switch.

Integrating the TSPs of virtual circuit users with the TSPs of the transmission system in a meaningful and practical manner will present a major challenge to DCA. The switched networks whose routing algorithms support MLPP are already in compliance with the TSP system philosophy of assigning priorities to users. Each caller or originator of messages or packets is assigned a precedence level which determines the priority the switched network will give to his requests for service. Voice network routing algorithms will normally select the first idle trunk, or preempt the lowest priority call if necessary to complete a call of higher precedence. Data switches will queue low precedence traffic behind high precedence traffic for processing and transmission. Thus the switch takes no notice of the service priority for restoration of the particular trunk in an interswitch trunk group to which it directs outgoing traffic.

There may be a disconnect as the calls, messages, or packets attempt to enter the transmission system if the interswitch trunks are all assigned low or "don't care" priorities. When damage occurs in the transmission system and the technical controllers restore physical circuits in priority order (or the restoration is done by an intelligent automated DPAS network control system, References 14, 15 and 16), other services may be restored at the expense of the low or "don't care" priority interswitch trunks of the switched network. The switches may then no longer have the resources to support essential users who are not collocated with the damaged facilities.

If an interswitch trunk terminates at a damaged facility, there is no way it can be restored short of reconstituting the damaged facility. But if it only transits the damaged facility, it may be able to be restored by patching it around the damaged facility if it carries a high enough restoration priority. Without the rerouted trunk, the switch may be able to route calls around the damage via other surviving trunks, but it will do so at the expense of completing other calls if its trunks are not restored. The switch has no control over the restoration of its network resources, whereas an intelligent automated DPAS network control system may be able to restore these resources in seconds to minutes if the damage to the transmission system is not so extensive as to partition the network into isolated enclaves.

Thus some minimum number of interswitch trunks between each set of connected switches will require a high service priority for restoration. In the current DCS where manual patching procedures create long delays in circuit restoration, the interswitch trunks to be assigned high restoration priorities should be selected, if possible, so that they follow non-redundant routes over different media, such as satellite, microwave/tropo, cable, etc. In an automated circuit restoration environment, spreading the high priority circuits over routes traversing different media is no longer essential. What is essential is that there be some matching of the distribution of switched network subscriber service priorities with the distribution of service priorities for restoration of the transmission services (circuits) connecting the switches.

SECTION 7 - A PLAN FOR THE DCS VERSION OF ISDN IS NEEDED

Actions are underway to determine what form the ISDN should take in the DCS (Reference 17). Although the ISDN may not mature until the mid-90s, it is timely to evaluate the developments currently underway in the commercial and international arenas (Reference 18) for potential inclusion in the DCS. If ISDN follows its present course, it will become the major commercial communications system of the developed world. DCS dependence on commercial facilities, increased user service demands, and the goal of a single integrated DCS make it crucial for DCA to stay abreast of ISDN developments. Also, DOD policy mandates the procurement of commercially developed equipment in lieu of unique and specially developed military equipment unless there are valid and important military requirements that cannot otherwise be satisfied.

The DCS is presently transitioning from an analog system to a digital system. Large procurements are involved to accomplish this transition. All DCS programs need to consider the possible effects of ISDN to avoid procuring equipment that lacks the versatility to transition to ISDN.

Important considerations include the following:

1. Unique DSN services that may not be supported by ISDN (some examples from Reference 19 follow)
    a. Toll Restriction
    b. Abbreviated Dialing
    c. WATS Access
    d. Trunk Call Back Queuing
    e. Off-Hook Service
    f. Out of Service Code
    g. Off-Hook Queuing

2. ISDN services presently not supported by the DCS (some examples from Reference 19 follow)
    a. 384 kb/s and 1536 kb/s unrestricted transfer of user information at the S/T reference point.
    b. User-To-User Signaling
    c. Closed User Group
    d. City-Wide Centrex
    e. Direct Dial In and Terminal Selection
    f. Calling Line Identification Presentation and Restriction
3. Services existing in the DSN and ISDN need to be compared for possible differences and incompatibilities.
4. DOD/NSA security issues and requirements need to be addressed
5. Interfaces between DCS and commercial ISDN need to be examined

DCA has established a DOD ISDN Systems Working Group which has the primary responsibility for developing the DOD ISDN Network Migration Plan (Reference 17). The Network Migration Plan will address all relevant issues associated with the implementation of ISDN by the DOD. It is recommended that the work of this group be accelerated and that their migration plan be approved as early as possible in draft form to provide needed planning and design guidance. Even though it is extremely likely that the specific ISDN implementations will change, the basic concepts, goals, and services will not. Lack of ISDN guidance will cause confusion and potentially allow funds to be improperly utilized. An approved ISDN concept will provide much needed guidance to DCS Program Managers/MILDEPs and have the entire DCS moving in a common direction towards ISDN. The Air Force has a program underway which will include some form of ISDN capability in a base switch. It is possible that this program could develop the necessary data on which to develop a consensus of what the ISDN should be in the DCS. Otherwise, ISDN planning for the DCS is subject to all the vagaries of the commercial activity. At the present time there is no definite consensus, even in the United States, as to what it will be in the near-term. For this reason, an agreed concept of the DCS ISDN and the way in which the DCS will interface with the commercial ISDN is a critical step in improving the effectiveness of current and future DCS ISDN activities.

SECTION 8 - A PLAN FOR IDS SURVIVABILITY/ RECONSTITUTION IS NEEDED

The Integrated Data System (IDS) will be composed of I-S/A AMPE, BLACKER, and DDN using leased and Government-owned transmission facilities of the DCS. Figure 8-1 illustrates the planned architecture of the IDS with a focus on the security related aspects. I-S/A AMPE, the Inter-Service/Agency Automated Message Processing Exchange will be based on trusted (A1) processors and would occupy the "host" boxes in Figure 8-1. The monitoring and control of the various I-S/A AMPEs would be performed by the DCOSS NCF. BLACKER is composed of Blacker Front Ends (BFE, KI-111), the Blacker Access Control Centers, the Blacker Key Access Control Centers, and the Blacker Key Distribution Centers. DDN, the Defense Data Network, is composed of DISNET and MILNET packet switches, and DDN monitoring centers. All subscribers including I-S/A AMPEs will have a BLACKER Front End connecting them to the network. The backbone transmission provided by the DCS is supported by the DPAS, TRAMCON and other technical control operations support systems, through the DCOSS Subregional Control Facilities (SRCFs).

Planning for the IDS is itself in a state of flux and the concept presented above may still evolve. Some work is in progress on IDS reconstitution in DCEC R600. Broader issues including security considerations need to be addressed in connection with further IDS planning and with planning to provide IDS survivability.

"Survivability" measures the resistance of a system to sustaining damage from enemy attack, along with its ability to perform in a partially damaged state and its ability to restore some of its destroyed capabilities (a Worldwide Digital System Architecture (WWDSA) definition that is generally accepted). Survivability goes hand in hand with "Responsiveness"

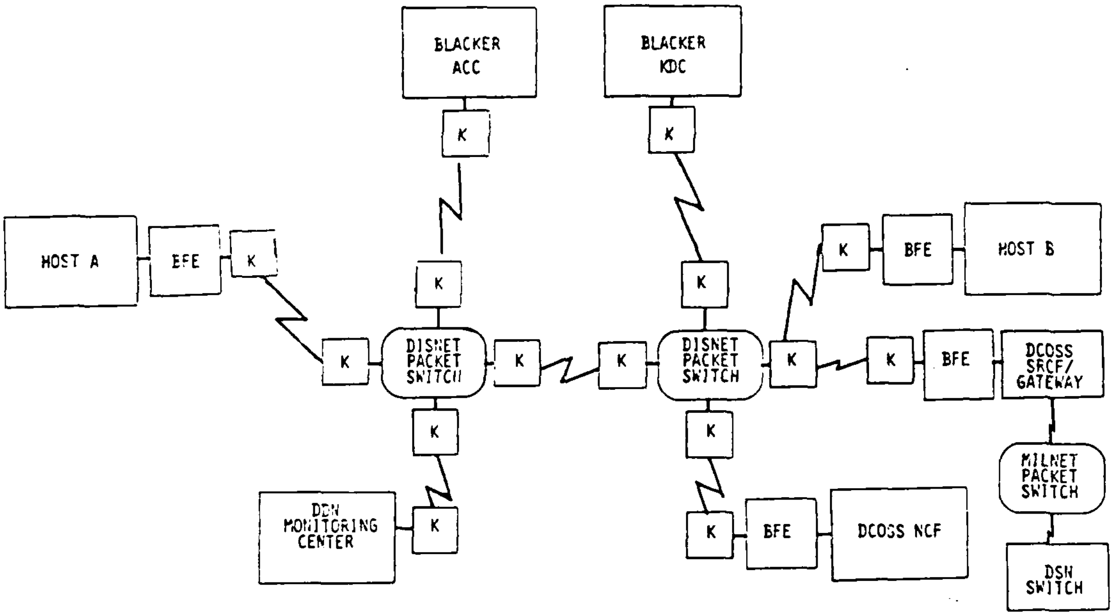


Figure 8-1. A Generic View of the IDS Archicture

Legend:	ACC	Access Control Center
	BFE	Blacker Front End
	DCOSS	*Defense Communications Operations Support System*
	K	Encryption device
	KDC	Key Distribution Center
	NCF	Network Control Facility

which measures the ease with which a system can adapt to changing conditions, for example, its ability to extend its boundaries, reconfigure its connectivity, accommodate traffic peaks, and interoperate with other systems (another WWDSA definition). Thus inherent invulnerability, the plan for restoral, interoperability, and the plan for reconstitution are key criteria for measuring IDS survivability.

A key issue in planning for IDS survivability is determining what mission needs are required to survive at each of the five defined levels of stress: Peace-time; Crisis, Pre-Attack and Theater Non-Nuclear War; Early Trans-Attack; Massive Nuclear Attack; and Post-Attack. In particular, which of the user needs for interactive or batch data communications and for the formal message service need to survive along with the needs of critical C^2 subscribers and at what throughput, error rate and permissible delay.

Another key issue is what assets may be used to ensure survivability: DCS, private networks, commercial networks or other Government-owned networks. This consideration drives requirements for interoperability among the assets, for commonality of protocols and for agreements on procedures. In connection with the use of other assets, a decision is needed on the application or relaxation of the stringent security requirements of the IDS. The issues herein are:

1. A need for a security policy statement tied to each of the five levels of stress
2. The impact of using the commercially available off-the-shelf computer security (COMPUSEC) and Communications Security (COMSEC) products and their compliance with the policy in item (1).

The first level of IDS survivability is provided by control of the transmission plant in which the DPAS units will automatically switch connections to restore the backbone transmission. Other technical control solutions are also available at this level. The next level is provided by the DDN packet switches themselves and the dual- or triple-homing I-S/A AMPEs.

Plans for another level of survivability to perhaps use the public switched networks are under consideration in DCEC R600 as mentioned above. These plans are incomplete at the time of writing.

Scenarios, both post-attack and crisis, need to be defined and described to reflect both general threats and threats currently defined by NSA. The existing tasking may satisfy the requirement for scenarios against the general threats. Further tasking at higher levels of classification will be required to complete the necessary scenarios.

An earlier plan for IDS Reconstitution employed an automated modem to allow the host a choice of standard use of DDN or dial up on DSN. Among other things, this required a control line that bypassed the IPLI (predecessor to BLACKER) apparently violating established security directives.

It is clear that a coordinated plan for IDS survivability is needed now while the IDS design can still be modified. The plan for IDS survivability must address, at a minimum, all of the issues raised in the above paragraphs. The following factors/items should also be considered in the IDS survivability plan:

1. Quality of service may not be critical in the IDS reconstitution as long as the minimum mission needs are met.

2. A wide variety of assets (commercial off-the-shelf (COTS) to minimize cost) may be used to make the IDS survivable.

   They include:

   a. Dispersed node locations
   b. Mobile nodes (switches and users)
   c. Technologies/techniques in the access area such as dual homing and VSAT
   d. Technologies/techniques in the backbone area such as multirate switches, multimedia links, dial-up circuits essentially using DSN /ISDN or Public Data Networks (PDN), and sophisticated gateway based systems.

3. Control of the IDS will be critical when connectivity is disrupted during increasing stress scenarios and reconstitution of an orderwire is a first order of business.

4. A security policy statement is needed corresponding to the five levels of stress. In compliance with such a policy commercial off-the-shelf equipment should be considered.

Glossary of Technical and Operational Acronyms

ACOC	Area Communications Operations Center
ADPCM	Adaptive Differential PCM
AMI	Alternate Mark Inversion
AO&M	Administration, Operations and Maintenance
ADMDCD	Advanced Development Model Digital Conference Director
AMPE	Automated Message Processing Exchange
AUTODIN	Automatic Digital Network
AUTOVON	Automatic Voice Network
BFE	Blacker Front Ends
CCITT	International Telegraph & Telephone Consultative Committee
CCS	Common Channel Signaling
CCSD	Circuit Designator
CD	Conference Director
CEPT	European Conference for Administration of Telecommunications Ports
CIK	Crypto Ignition Keys
CINC	Commander in Chief
CONUS	Continental United States
COTS	Commercial off-the-shelf
DACS	Digital Access Cross-Connect System
DCA	Defense Communications Agency
DCA-EUR	Defense Communications Agency - Europe
DCD	Digital Conference Director
DCEC	Defense Communications Engineering Center
DCEM	Digital Channel Efficiency Model
DCOSS	Defense Communications Operations Support System
DCRC	Digital Compression Rate Converters
DCS	Defense Communications System
DCSO	Defense Communications System Organization
DDN	Defense Data Network
DECS	DSCS ECCM Control System
DOD	Department of Defense
DPAS	Digital Patch and Access System
DSCS	Defense Satellite Communications System
DSI	Digital Speech Interpolation
DSN	Defense Switched Network
DS0	Digital Signaling Rate 0 - 64 kb/s
DS1	Digital Signaling Rate 1 - 1.544 Mb/s
DS2	Digital Signaling Rate 2 - 6.312 Mb/s
DS3	Digital Signaling Rate 3 - 44.736 Mb/s
DSVT	Digital Subscriber Voice Terminal
DTN	Defense Telecommunications Network
ECCM	Electronic Counter Counter Measures
EOC	Early Operational Capability
FCC	Federal Communications Commission
FOC	Final Operational Capability
FSVS	Future Secure Voice System

Glossary of Technical and Operational Acronyms (Cont'd)

GP	General Purpose
GSL	Gaussian Signal Level
IDS	Integrated Data System
IEEE	Institute of Electrical and Electronics Engineers
IPLI	Internet Private Line Interface
ISDN	Integrated-Services Digital Network
I-S/A	Inter-Service/Agency
ITIP	Integrated Transition Implementation Plan
JCS	Joint Chiefs of Staff
JRSC	Jam Resistant Secure Communications
KMC	Key Management Center
LCT	Low Cost Terminals
MILDEP	Military Department
MLPP	Multi-Level Precedence Preemption
MRVT	Multiple Rate Voice Terminals
NATO	North Atlantic Treaty Organization
NCA	National Command Authority
NCC	Network Control Channel
NCF	Network Control Facility
NCS	National Communications System
NOSC	Naval Ocean Systems Command
NRZ	Non Return to Zero
NSA	National Security Agency
NSEP	National Security Emergency Preparedness
OMNCS	Office of the Manager NCS
PCM	Pulse Code Modulation
PBX	Private Branch Exchange
QD	Quantizing Distortion
RADC	Rome Air Development Center
RIT	RED Interface Terminals
RP	Restoration Priority
SCP	Secure Conferencing Project
SRCF	Sub-Regional Control Facility
STP	Signaling Transfer Point
STU	Secure Terminal Unit
SVIP	Secure Voice Improvement Program
SVS	Secure Voice System
TASI	Time Assignment Speech Interpolation
TCCC	Terrestrial Critical Control Circuit
TCF	Technical Control Facility
TDM/FDM	Time Division Multiplex/Frequency Division Multiplex
TRI-TAC	Tri-Services Communications System
TSP	Telecommunications Service Priority
TTY	Teletypewriter
VF	Voice Frequency
VSAT	Very Small Aperture Terminals
WESTPAC	West Pacific
WWDSA	World-Wide Digital System Architecture
WWOLS	World-Wide On-Line System

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