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SEISMIC NETWORK SYSTEMS STUDY

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13. ABSTRACT

This report presents design recommendations by Bolt Beranek and Newman for the data collection function of a worldwide seismic data network. Particular attention has been paid to integrating both ARPA Network packet switching technology and conventional leased channels. It appears not only feasible but attractive to employ such a mixed approach. The resulting communication system should be reliable, flexible, and cost-effective. Two detailed protocols included in this report specify the communications between four remote array sites and a central Communications and Control Processor (CCP) and the communications between the CCP and the seismic network mass storage facility.

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FINAL REPORT
SEISMIC NETWORK SYSTEMS STUDY



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## SUMMARY

In order to provide a large data base for research in
detection and identification of contained nuclear explosions
and to demonstrate the feasibility of an on-line system for
monitoring a nuclear test ban, ARPA plans to expand the existing
digital seismic network to provide more extensive worldwide
coverage.  This network will utilize state-of-the-art technol-
ogy, particularly in the area of data collection and storage.
Bolt Beranek and Newman Inc. (BBN) has been asked, under the
present contract, to work on the design of the on-line data
communication system integrating both ARPA Network packet
switching technology and conventional leased channels.

The approach taken has been to start with a broad system
definition and to make successive refinements of the design.
Under a previous contract [1], BBN described the system over-
view.  Under the current contract BBN has considered specific
alternatives to the previous design and has described the
interfacing of the packet switching links to the rest of the
system in detail.  Experience provided by previous work at
interfacing computers on the ARPANET has been combined with the
constraints existing in the seismic data network.

The main results of this work are the two communication
protocols included as appendices to this report.  Additional
results summarized in section 2.3.2.1 concern possible options
for specific components of the seismic data network.  The
protocols specify in detail the manner in which array sites use
the ARPANET to communicate with the Communications and Control
Processor (CCP) and how the CCP communicates with the Seismic
Input Processor (SIP) located at the mass storage site.  By

specifying what data is excha    ed between the various pieces of
the on-line data collectior    em the protocols effectively
define that system.

One general implication of the current work is the feasi-
bility of using packet switched and conventional technology in
a mixed communication network, even where various real-time
constraints may exist.  The overall seismic data network design
demonstrates the potential of the ARPA Network for providing
access to shared hardware and software resources.

The work done under the current contract suggests three
specific areas for further research and development.  First, the
protocols complete the input/output specifications of the
Seismic Private Line Interfaces (SPLIs).  The design of these
devices can, therefore, begin.  Second, a study should be
initiated to determine how the seismic data network will be
affected by various changes in structure or loading of the
ARPANET.  The design of a routine monitoring procedure to be
used by the CCP would be desirable.  Finally, the interface
between the individual research seismologist and the data base
has not yet been addressed.  The design and implementation of a
seismically oriented man-machine interface would capitalize on
the large data base which will exist on the mass storage
facility.

## 1. INTRODUCTION

In a continuing program to provide high quality digital seismic data for research in detection and identification of contained nuclear explosions, and to demonstrate the feasibility of an on-line system for monitoring nuclear test bans, ARPA plans to expand the existing digital seismic network to obtain more extensive worldwide coverage, particularly for long period data. Three additional small on-line digital arrays and 15 to 20 single point stations recording on digital magnetic tape are to be operational in 1975. The resulting seismic data collection network will produce a formidable library of valuable digital seismic data which must be organized and made available to the seismic research community.

Under a previous contract, BBN prepared a recommendation [1] for an overall system design for the world-wide seismic data handling system. The design included use of state-of-the-art techniques in the rapidly developing areas of communication, processing and data storage.

The objectives of the present contract have been to update the recommended system design to account for changes in the seismic network configuration or developments in the relevant technology and to provide more detailed design and perhaps breadboard implementation of parts of the system as directed by the project officer.

For system analysis purposes it has been convenient to think of the seismic network as serving or performing three interrelated functions: 1) data capture, 2) event processing, and 3) seismic research. Three phases or levels of design have

also been defined.  Phase I consists of examining optional
configurations to arrive at comparative estimates of costs,
schedules, and capabilities.  Phase II consists of defining
recommended formats, protocols, and flow charts.  Phase III
consists of designing and implementing experiments to test or
develop techniques required by the recommended design.

As directed by the project officer, the work carried out
by BBN under the present contract has focused primarily on the
Phase I and Phase II design of the data capture function.

## 2.  TECHNICAL DISCUSSION

### 2.1  Purpose of the Investigation

The work carried out and reported on in the following sections was part of a larger effort to design and implement the seismic data collection and analysis network mentioned in section 1.

In addition to providing data to support seismic research, this network should demonstrate the feasibility of an on-line system for monitoring nuclear explosions which will be essential for implementation of any underground nuclear test ban.

The primary goal of BBN's work has been to design the communication system for the on-line data collection system integrating both ARPA Network packet switching technology and conventional channels leased from the common carriers.  The design objective was to develop a cost-effective communication system flexible enough to adapt to changes in the deployment of sensors.  BBN has also assisted with the application of other state-of-the-art technology in the seismic data network.

### 2.2  Technical Background - ARPA Network Communications

The ARPA Network [2,3] provides a flexible, reliable, and economically attractive means for dissimilar, geographically distributed computers (Hosts) to communicate via common-carrier circuits.  Each Host connects into the network through a small local computer called an Interface Message Processor (IMP); each IMP is connected to several other IMPs via wideband (typically 50 kilobit) communication lines.  The IMPs, all of which are virtually identical, are programmed to store and

forward messages to their neighbors based on address information
contained in each received message.  The route that a message
will take through the network is determined dynamically and
depends on network loading as well as IMP and line failures.

The store-and-forward logic and the error control pro-
cedures implemented in the IMP subnetwork (which attempt to
insure correct delivery of a message by retransmitting a section
of a message when an error is detected) are optimum for
asynchronous and very bursty communication between various nodes
in the network.  Many of the major resources connected to the
ARPANET as Hosts also assume interaction over a bursty communi-
cation system with other Hosts which are tolerant of large data
rate variations and variable transmission delays.  Real-time
data sources and real-time recording systems such as the seismic
observatories and the VELA link, however, cannot tolerate
variable-speed bursty system components.  An important function
of the seismic communication system design, therefore, is to
interface these two classes of resources in the seismic data
network.

The general approach to this problem is to provide large
buffers at both ends of each communication link which use the
ARPA Network to implement an apparently non-bursty channel.
These buffers are used to smooth out the variations in message
delivery time.  Messages are delivered a fixed delay behind
real-time, the delay being specified by the amount of buffering
provided.  When transients in the bursty part of the system
exceed the delay time, of course  the on-line subsystems will
see a condition consistent with a transient phone line outage
which they are designed to tolerate.  The delay is specified

so as to reduce the probability of this occurring while keeping
the required buffer space within reasonable bounds.

## 2.3  Description of Work

## 2.3.1  Data Collection System Overview

The structure of the on-line seismic data collection net-
work is shown in Figure 1.  There are six array sites which are
the sources of the on-line seismic data.  The destinations for
this data are (1) the Seismic Input Processor (SIP) at The
Computer Corporation of America (CCA), (2) the 360/40A at the
Seismic Data Analysis Center (SDAC), and (3) the VELA Links at
SDAC.  Rather than have each source be concerned with each of
the destinations, each source simply sends its data to a central
site, Communications and Control Processor (CCP), in a con-
venient form.  The CCP takes care of any required reformatting
and transmission to the individual destination sites.  The CCP
also provides a central site for overall seismic network
control, performance monitoring, and maintenance.

Two of the array sites (ALPA and LASA) are connected to
the CCP over conventional leased channels.  The remaining source
sites are connected utilizing ARPA Network connections.  The
NORSAR 360/40A is interfaced as a local Host on the NORSAR TIP
while the station controllers at IRAN, KSRS, and Site II are
interfaced to Satellite IMPs (SIMPs) by means of Seismic
Private Line Interfaces (SPLI).  These devices act as Hosts on
the ARPANET and provide a convenient approach to interface
computers (i.e., the station processors) which are designed to
communicate over standard modem interfaces.  The 360/40A at
SDAC and the SIP at CCA are connected as local Hosts on the
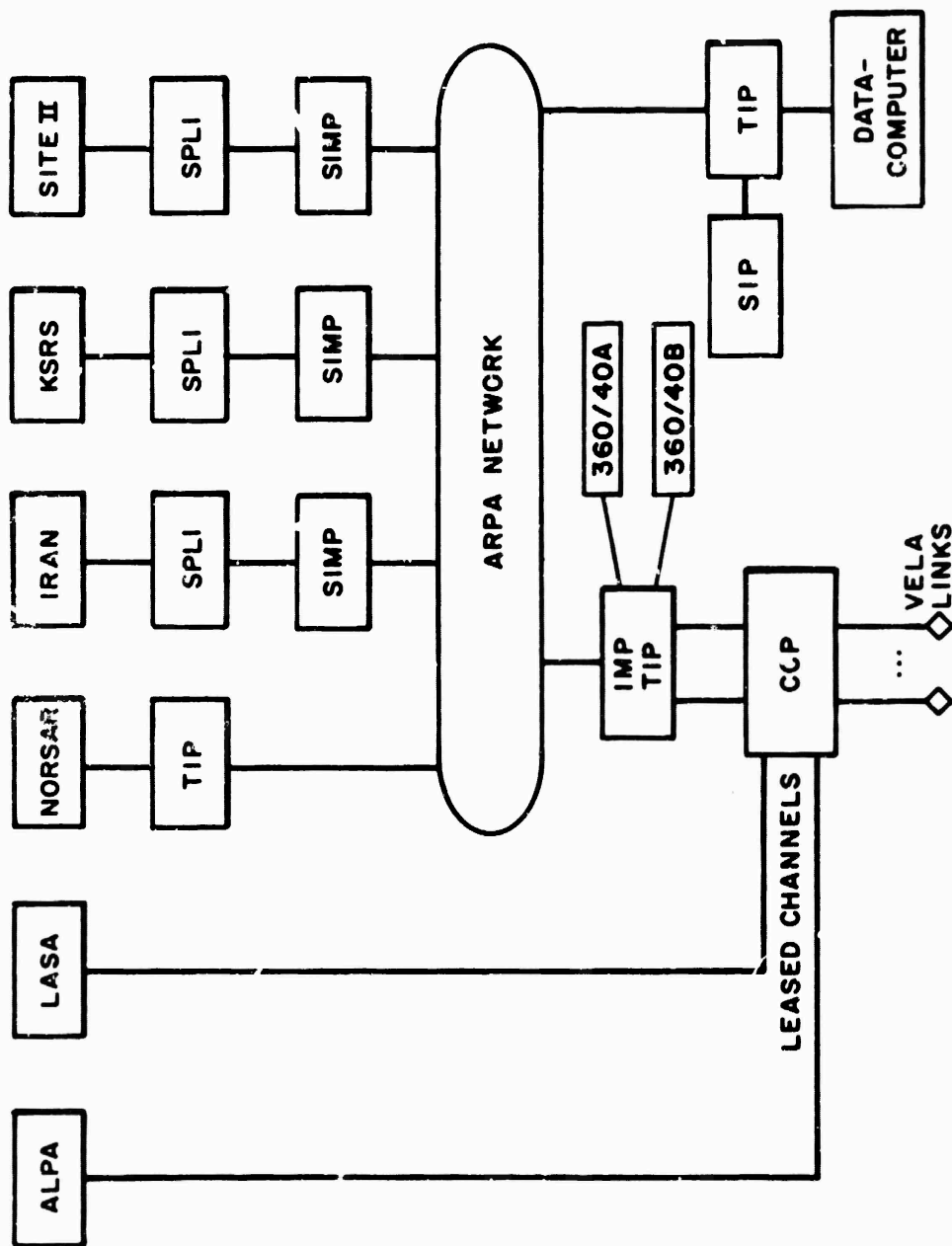
Figure 1   Data Collection System Overview

ARPA Network.  The VELA links consist of a number of 4800 baud
leased channels.

## 2.3.2  Results

### 2.3.2.1  Phase I Results

Several trade-offs not considered in the previous network
design [1] were considered under the current contract.  Options
involving the areas of data communication and man-machine inter-
action were presented to the project officer and are summarized
below.

LASA:  In light of the planned reconfiguration of the LASA
seismic array, a study was carried out to determine the most
appropriate method of providing LASA ARPANET access.  Alterna-
tives involving either use of the LDC 360/44 as a Very Distant
Host (VDH) or the acquisition of a new minicomputer to replace
the 360/44 and provide a VDH interface were presented to the
project officer.  It was subsequently decided that connecting
LASA to the CCP via a standard leased line would be more cost-
effective than either of the alternatives mentioned above.

NORSAR:  BBN was asked to explore the possibility of modifying
the current on-line seismic data network by replacing the
existing Trans-Atlantic Link (TAL) by an ARPANET connection.  A
detailed analysis of the resource availability (processor, core,
disk, and channel) in the Detection Processing (DP) systems at
SDAC and NORSAR indicated that this would be feasible.  Esti-
mates of the time and costs require  to make the necessary
changes were presented to the project officer.

NEPT: Several options concerning device types and interfacing
schemes were considered for the Network (Analyst) Event Pro-
cessing Terminal (NEPT) at SDAC. After considering storage
tube devices, conventional refreshed displays, and TV scan dis-
plays it was recommended that a conventional refreshed display
be employed. Such a graphic display could be interfaced as
1) a terminal on the SDAC TIP, 2) a mini-host on the SDAC TIP
or IMP, or 3) a peripheral device on the SDAC 360/40B. In
light of the expected use of the NEPT, either option (2) or (3)
was recommended. Cost estimates for the recommended options
were also presented to the project officer.

## 2.3.2.2  Phase II Results

The majority of the work done under the current contract
involved Phase II level design of communication formats and
protocols. The protocols specify the data exchange between
four of the array sites (NORSAR, IRAN, ASRS, and Site II) and
the CCP and between the CCO and the SIP. The protocols, in
their current form, are included in Appendices A and B. They
snould be considered as working documents and may be subject
to further revision. Various issues related to these protocols
are discussed in section 2.4.

## 2.4  Discussion of Results

## 2.4.1  Existing Constraints

A basic design decision for the on-line seismic data coll-
ection network has been that the data communication system should
be adapted to the existing site computer systems wherever possible.
Since these systems were originally designed to communicate
over conventional leased communication channels,

the resulting interfaces are not necessarily the most straight-
forward.  The data formats from the source computers (station
processors) also reflect the original leased channel assumption.
The communication system and protocols might be considerably
different if ARPANET communications had been assumed from the
start.

The other existing constraint has been the continuous
transmission fixed-delay constraint (see section 2.2) implied
by the VELA links.

## 2.4.2  Special Purpose Protocols

In order to effect communications between ARPANET Host
computers, several levels of communication protocols are re-
quired.  All Hosts must implement the Host/IMP protocol
described in BBN Report No. 1822 [4].  In addition, any pair of
Hosts that expect to communicate with each other over the net-
work must implement some mutually acceptable Host/Host protocol.
An elaborate Host/Host protocol for interconnecting processes in
large general-purpose computer facilities is described in [5].
Finally, progr as running in Hosts communicating with each other
must implement the protocol or language of the other user
program and/or operating system.

Since the seismic data collection function does not in-
volve communication with either large general-purpose computing
centers on the network or Hosts outside of the seismic network
(data collection and archiving require that the CCP communicate
with the SIP, not the Datacomputer system itself), special
purpose Host/Host protocols meeting the particular real-time
requirements of the seismic network have been proposed.  The

CCP resources that must be devoted to Host/Host protocol imple-
mentation using these protocols are significantly less than
required for a generalized Host/Host protocol.

### 2.4.3  Protocol Commonality

The initial versions of the protocols for the 3 different
array sources (NORSAR, IRAN, and the pair KSRS, Site II) were
developed and described independently.  It soon became apparent,
however, that a common seismic data input protocol was possible.
The merging of the three original protocols resulted in the
protocol included as Appendix A.  This common input protocol
should simplify implementation of data communication software
both at the remote sites and at the CCP.

A similar set of statements can be made concerning the
protocol in Appendix B which applies to CCP communication with
both the SIP and the 360/40A at SDAC.

### 2.4.4  Protocol Flexibility

Flexibility has been an important consideration in the
design of the current protocols especially in light of the
research nature of the seismic data network.  The protocols
should not constrain the deployment of channels in terms of
either the number of array sites or the number of long and short
period channels returned from the sites.  The protocols should
also allow any subset of the received data to be stored at the
seismic network mass storage facility.

Data is returned in terms of long and short period
channels, therefore, predetection processing can be done either
centrally, at the remote site, or at both.  Raw and processed

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waveforms are treated symmetrically in the CCP-Site protocol
and may both be present in the real-time data messages from
the sites.

The CCP to SIP protocol is extremely flexible. Periodic
control messages identify the specific channels which will be
included in subsequent data frames, and the destination file of
each channel. Data flow to the SIP can be modified under
command from the CCP operator.

Adaptation to changes in channel deployment at the remote
sites is straightforward, however it is not automatic and
source-initiated as in the case of the CCP-SIP protocol. If a
new site were to come on-line, the same protocol used for
NORSAR, IRAN, KSRS, and Site II would be employed. The format
particular to this new site would be defined and the CCP input
format definition tables and buffer allocation would be modified
to reflect the addition. A similar change would be required if
additional channels were returned from an existing site. The
elimination of an entire site or a reduction in the number of
channels sent to the CCP can be handled by considering the
changes as a temporary loss of the associated channels or by
modification of the CCP format definition tables and buffer
allocation as mentioned above.

## 3. CONCLUSIONS

It appears to be both feasible and cost-effective to
implement the on-line seismic data collection and storage
network using a combination of ARPA Network links and conven-
tional leased channels.  Initial steps toward the design of this
network can be found in section 2.3.2 and the Appendices.

Appendices A and B should be considered as working
documents.  Although these specifications incorporate the
latest design decisions related to the seismic data network,
they may require minor modification as hardware and seismic
data requirements become firm.

## 4.  RECOMMENDATIONS FOR FUTURE WORK

There are several projects which would be logical follow-
ups to the work reported on here.  These areas for future work
are listed below:

SPLI Design - Based on the attached protocols it appears
appropriate to begin final design of the SPLI devices for the 3
array sites.  This would involve a specification of the
required hardware capabilities and a detailed design of the
software.

System Throughput Analysis - The seismic data network will
utilize the ARPANET to transmit real-time data in a way pre-
viously not tried.  Assuming that there is sufficient bandwidth
available on the ARPANET links, there is every reason to believe
that the protocols mentioned previously will work.  It will be
important, however, for the seismic data network to anticipate
any changes in the ARPANET structure or load which will signi-
ficantly affect the seismic data subnetwork.  A study should be
made to determine what measurements and monitoring of the
ARPANET is appropriate and how it can be accomplished.

Seismologist Interface System - Given that a large and inter-
esting seismic data base will be accumulated by the on-line
system it is important to insure that this data can be
accessed easily by individual research seismologists.  The
research seismologist should not have to learn Datalanguage to
access data for his local computer.  Instead, we believe there
should exist an interface system which translates between a
language oriented toward the seismologist and Datalanguage.
The design of this system must begin as soon as possible if it

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is to be available when a significant volume of data accumulates
in the Datacomputer.  The design of the data access procedures
could also provide valuable insight into the design of file
formats that facilitate the necessary interaction between data
and status files and between raw data and processed data files.

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## GLOSSARY
of Acronyms and Abbreviations

| | |
|---|---|
| ALPA | Alaska Long Period Array |
| ARPA | Advanced Research Projects Agency |
| ARPANET | ARPA Network |
| BBN | Bolt Beranek and Newman Inc. |
| CCA | Computer Corporation of America |
| CCP | Communications and Control Processor |
| DP | Detection Processing |
| IMP | Interface Message Processor |
| IRAN | Iranian Seismic Array |
| LASA | Large Aperture Seismic Array |
| KSRS | Korean Seismic Research Station |
| LDC | LASA Data Center |
| NEPT | Network Event Processing Terminal |
| NORSAR | Norwegian Seismic Array |
| SDAC | Seismic Data Analysis Center |
| SIMP | Satellite Interface Message Processor |
| SIP | Seismic Input Processor |
| SPLI | Seismic Private Line Interface |
| TAL | Trans-Atlantic Link |
| VDH | Very Distant Host |

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## List of Figures

## 1. Introduction and Background

The overall design of a worldwide seismic data network utilizing ARPANET communications has been described in [1]. In that design six array sites enter raw and processed data by transmitting it to a central Communications and Control Processor (CCP). This document specifies in detail the communications formats and protocols between the CCP and four of these Sites--the Korean and Site II Seismic Arrays (KSRS and SITE II), the Iranian Long Period Array (IRAN), and the Norwegian Seismic Array (NORSAR).

The communication protocols described below build upon the Host-IMP Protocol [2] and are at the Host-to-Host level although they are not the standard Host-Host Protocol described in [3]. In spite of the fact that there is considerable variation among the array sites with respect to data format, rate, and type of ARPANET access, the overall communications requirement for each site is in essence the same. This document presents communications formats and protocols that could readily be used with new array sites in the network, each having its own individual peculiarities.

These protocols are designed to provide two unusual features in the ARPANET links. First, since the CCP is central to the operation of the on-line data collection system it must be designed to operate continously. To achieve a reliable seismic communications subnet it is desirable to connect the CCP to at least two IMPs (more precisely, an IMP and a TIP in the case of SDAC). With this arrangement, the CCP can be switched from one IMP to the other if

the  one on which it is operating is having troubles or is scheduled
for preventive maintenance.  Although such a duplex arrangement  has
not  yet  been  tried, such a scheme should be straightforward in the
current seismic data network application.

Second, because of the need to continuously retransmit and plot
waveforms  from several different sources with a known shift between
the individual waveforms, it is necessary  to  operate  the  ARPANET
links  in  the seismic network so that the data will be delivered to
its destination some constant period  behind  real-time,  i.e.   the
network  should  appear  to  be  an  "ideal (error free) delay line"
between the data source and  destination.   Although  this  mode  of
operation  is  somewhat unnatural on the ARPANET, it can be effected
by providing sufficient buffering for the data at both ends  of  the
communication  link.   There are tradeoffs, however, relating to the
length of outages (delays) that can  be  handled  and  the  size  of
buffers and bandwidth required to allow catchup.

The amount of data buffered by a Site will be approximately  10
seconds.   This  period was selected in order to (1) reduce the loss
of real-time data due to noise burst  errors,  retransmissions,  and
network delays, (2) to be frugal in the amount of space allocated to
buffering, and (3) to provide the option of a uniform  delay  across
all  six  of the array sites.  For array sites with a 4800 baud data
rate, 10 seconds of data equals 3K 16-bit words of  buffer  at  each
end.   Longer  delays  leading  to  larger  buffer sizes were judged
inappropriate since in many cases these will be core buffers.

It is possible, of course, that the network will be unavailable
for periods sufficient to overflow this 10 second buffer. Assuming
all of the data is recorded by the Site on tape, however, the data
which overflows the buffer is not actually lost. A copy of this
tape could be sent by mail to SDAC or selected portions of the data
could be transmitted over the ARPANET.

Two slightly different physical configurations will be used for
the ARPANET communications links between the overseas array sites
and the CCP. Figure 1 depicts the configuration that will be
employed by KSRS, SITE II, and IRAN. The station controller at each
of these array sites is interfaced to the ARPANET by means of a SPLI
(Seismic Private Line Interface). The SPLI is connected as a Host
using the VDH (Very Distant Host) Host-IMP Protocol [2] to the
nearest SIMP (Satellite IMP) by means of a leased line. This SIMP
will be located at a satellite communications ground station (the
Kum San ground station for KSRS and the Asadabad ground station for
IRAN). Communications over the Atlantic will be via the SIMP
located at the Etam, West Virginia ground station. KSRS and SITE II
will be linked to the continental U.S. ARPANET by means of the SIMP
at the ground station in Jamesburg, California.

The physical configuration that will be used for the ARPANET
communications between NORSAR and the CCP is shown in figure 2. The
NORSAR Data Processing Center (NDPC) is interfaced as a Host to the
NORSAR TIP (Terminal IMP). The TIP is connected indirectly to a
SIMP located at the Goonhilly Downs ground station. Communications

over the Atlantic are again via the SIMP in Etam, West Virginia.

```
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                     !        !           !              !        !            !
                     !  SPLI  !-----------!   STATION    !--------!   TAPE     !
                     !        !           !  CONTROLLER  !        !   BACKUP   !
                     ----------           ----------------        --------------

                         !                                        (may not
                         !                                         exist
                         !                                         for IRAN)
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                     !        !
               ---   !  SIMP  !
               *     !        !
               *     ----------
               *         !
               *     ----------------
               *     !              !
               *     !  BROADCAST   !
               *     !  SATELLITE   !
               *     !  LINK        !
               *     !              !
               *     ----------------
               *         !
         ARPANET     ----------
               *     !        !
               *     !  SIMP  !
               *     !        !
               *     ----------
               *         .
               *         .
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               *     ----------
               *     !        !           --------------
               *     !  SDAC  !           !            !
               *     !  IMP   !           !   SDAC     !
               *     !  or    !-----------!   TAPE     !
               ---   !  TIP   !           !   BACKUP   !
                     !        !           !            !
                     ----------           --------------
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                     !        !
                     !  CCP   !
                     !        !
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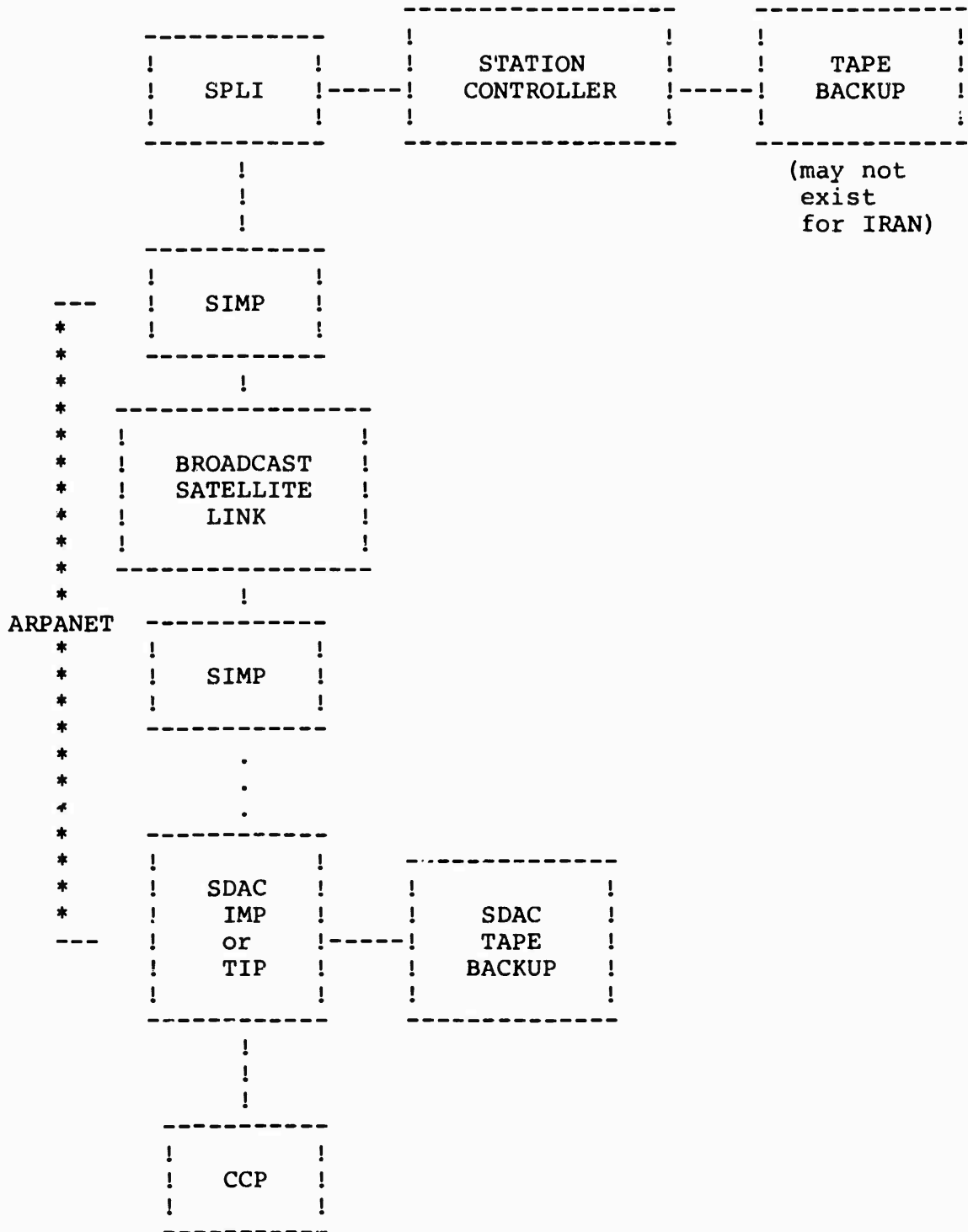
Figure 1. Site-CCP Data Link for Sites Connected to a SPLI

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        -------------        -------------        -------------
        !           !        !           !        !           !
        !  NORSAR   !        !   NDPC    !        !   TAPE    !
  ---   !  TIP      !------! !  360/40   !------! !  BACKUP   !
    *   !           !        !           !        !           !
    *   -------------        -------------        -------------
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    *            .
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    *        !         !
    *        !  SIMP   !
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    *        !               !
    *        !  BROADCAST    !
    *        !  SATELLITE    !
    *        !  LINK         !
    *        !               !
    *        -----------------
ARPANET          !
    *        -----------
    *        !         !
    *        !  SIMP   !
    *        !         !
    *        -----------
    *
    *            .
    *            .
    *            .
    *        -----------        -------------
    *        !         !        !           !
    *        !  SDAC   !        !   SDAC    !
    *        !  IMP    !------! !   TAPE    !
  ---        !  or     !        !  BACKUP   !
             !  TIP    !        !           !
             !         !        -------------
             -----------
                 !
                 !
                 !
             -----------
             !         !
             !  CCP    !
             !         !
             -----------
```
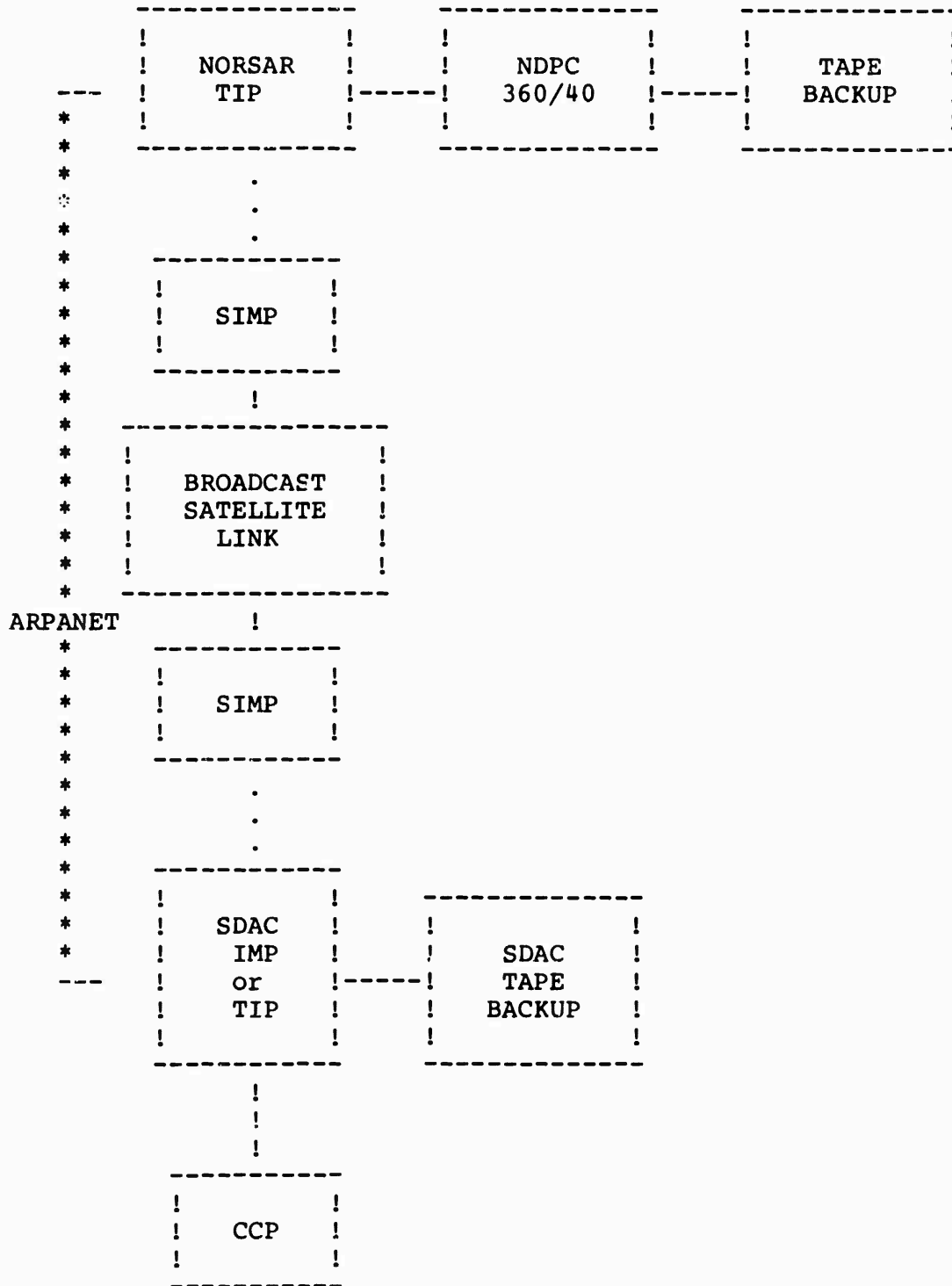
Figure 2. Site-CCP Data Link for NORSAR

## 2. Real-Time Data Transmission Formats

The format for ARPANET transmission of real-time data  between
the  overseas  seismic  sites  and the CCP is shown in figure 3.   It
consists of a 32-bit Host-IMP leader [2] followed by the  particular
real-time  message.    The  ARPANET  employs  RFNM  (Ready  For  Next
Message)  and  Incomplete  Transmission  messages  for  reliable,
efficient  communication.    The  message  ID  field in the leader is
constrained to be nonzero (see section 3) and is used to allow up to
four  messages  to  be  transmitted concurrently along an individual
data path.   This "pipelining" procedure decreases the time  required
to  empty  an output buffer that has been filling due to a data link
outage (see section 4.1).   The formats of the  particular  real-time
messages  are  exactly those specified to be used by the array sites
and are described in the following sections.

```
----------------------------------------------
!                      !                      !
!  HOST-IMP LEADER     !  REAL TIME MESSAGE   !
!                      !                      !
----------------------------------------------
         32 bits               m bits
```
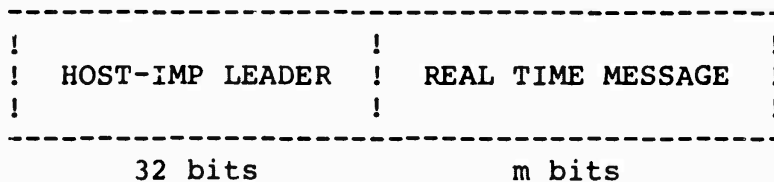
(a)  Format of Site-CCP Real-Time Messages

    (where: m=4800 from KSRS and SITE II
           m=816 from IRAN
           m=2400 for NORSAR)

```
-----------------------------------------------------------------------------
!        !             !             !            !            !          !
! ZERO   ! DESTINATION ! DESTINATION ! MESSAGE ID ! ZERO       !
!        !   HOST #    !    IMP #    !            !            !          !
-----------------------------------------------------------------------------
  8 bits     2 bits        6 bits       12 bits      4 bits
```
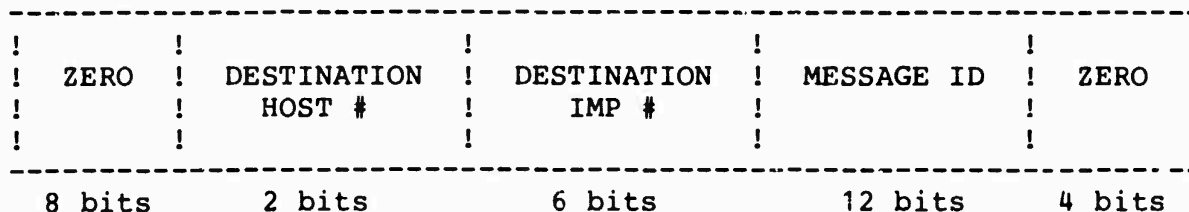
(b)  Host-IMP Leader for Real-Time Messages

Figure 3. Format of Site-CCP Real-Time Messages

2.1 Real-Time Data from KSRS and SITE II to the CCP

The real-time messages from the station controllers at KSRS and SITE II have the same format and are described in detail in [4]. Data frames are 4800 bits plus or minus 2 bits in length and will be transmitted by the station controller continuously at a rate of 1 frame per second.  The mode of transmission will be synchronous.

As shown in figure 4, each data frame consists of a 96-bit header, a real-time data portion, a block data portion, and a 32-bit plus or minus 2 bits portion which is hardware generated.  The header consists of 5 fields.  A 16-bit message SYNC field identifies the start of each 1 second data frame.  The 8 bits of the ID field constitute a single ASCII character used to identify the station controller.  The 8 bits of the status field individually convey information, primarily relating to requested data in the block data portion of the data frame.  Twenty bits in the middle of the header are currently undefined.  The last field of the header is the 44-bit time code field which contains the BCD time in eleven 4-bit subfields (year-tens, year-units, day-hundreds, ..., second-units).

The real-time data portion has two parts.  The first part is the short period data field.  This field is made up of 20 frames (corresponding to the 20 Hz sampling rate) each of which has NSP 12-bit data samples (NSP = number of short period channels).  The long period data field consists simply of NLP 16-bit data samples (NLP = number of long period channels).  The data format constrains

```
-----------------------------------------------------------------
!           !            !                !         !          !
!  HEADER   !  REAL-TIME !  WAVEFORM DATA  !  ERROR  !  IDLE    !
!           !  DATA      !  OR ASCII TEXT  !  CODE   !  CODE    !
!           !            !                !         !          !
-----------------------------------------------------------------
    96 bits      -----4672 bits---------      16 bits    14-18
                                                          bits
```

(a)  Real-Time Message Format from KSRS and SITE II

```
-----------------------------------------------------------------
!        !     !        !            !                !
!  SYNC  ! ID  ! STATUS !  UNDEFINED !  TIME CODE      !
!        !     !        !            !                !
-----------------------------------------------------------------
  16 bits 8 bits  8 bits    20 bits      44 bits
```
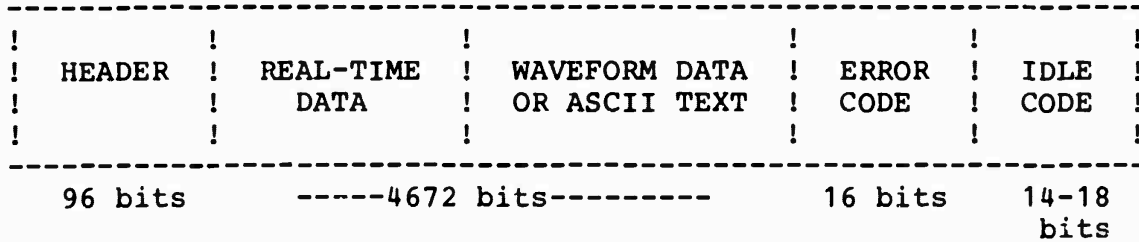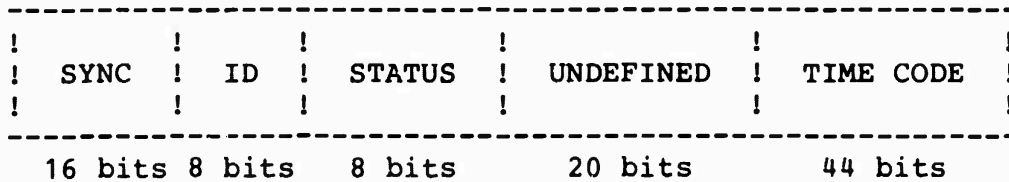
(b)  Format of Header in Real-Time Message from KSRS and SITE II

Figure 4.  Real-Time Message Format from KSRS and SITE II

the real-time data portion to be less than 4560 bits.  In  addition,
NSP must not exceed 19 and NLP must not exceed 30.

The block data portion of the one second data frame provides  a
field   in  which  specific  requested  data  can  be  transmitted.
Requested waveform data can be returned as  a  sequence  of  either
12-bit  or  16-bit  samples.   ASCII  data can also be returned as a
sequence of 8-bit characters.  Typically, the data associated with a
particular request will be multiplexed over a sequence of one second
frames because of the 4672-bit limit for both the real-time data and
the block data together in an individual message.  The block data is
described in more detail in [4].

The error and idle codes are hardware generated by the 4800 bps
modem  interface on the station controller.  The error code provides
a polynomial-type error check mechanism.  The idle code consists  of
a  sequence  of  14  to  18  zeros.   The  flexible  length  permits
variations between the clock in the 4800  bps  modem  and  the  time
standard of the station controller.

## 2.2 Real-Time Data from IRAN to the CCP

The format of the once-per-second real-time messages from   IRAN
is  specified in figure 5.  This format is derived from Addendum No.
1 to the Iranian Long Period Array Design Review [5].

| Length (words) | Contents | Description |
|------|----------|-------------|
| 1 | F09A (IN HEX) | SYNC |
| 1 | 'IL' (IN EBCDIC) | STATION CODE |
| 4 | One status byte* each for seven LP sites and one SP site | DATA STATUS |
| 3 | 0YYDDDHHMMSS | TIME CODE |
| 21 | 1 FRAME 21 CHANNELS | LP DATA |
| 20 | 20 FRAMES 1 CHANNEL | SP DATA |
| 1 | C8C8 (IN HEX) | END MESSAGE |

* Each data status byte will have the format:

| Bit On | Description |
|--------|-------------|
| 0 | Sync error (remote site to CRS) |
| 1 | Faulty or missing LP data |
| 2 | Calibration in progress |
| 3 | Deleted from beamforming by operator |
| 4 | Faulty or missing SP data |
| 5 | Extraneous data |

Figure 5.  Real-Time Message Format from IRAN

2.3 Real-Time Data Messages between NORSAR and the CCP

Real-time data is transmitted in both directions of the NORSAR-CCP data link. Figure 6 specifies the format of the real-time messages from NORSAR and figure 7 gives the format of the real-time messages sent to NORSAR by the CCP. These formats are essentially the same as those given in [6] except that the time specifications have been changed to 36-bit abbreviated station controller time codes [4], each consisting of 9 BCD 4-bit subfields (day-hundreds, day-tens, ..., second-units).

| Bits | Contents | Description |
|------|----------|-------------|
| 0000-0031 | Field 1 | Control Characters |
| 0032-0067 | Field 2 | Time (36-bit abbreviated format: DDDHHMMSS) |
| 0068-0211 | Field 3 | NORSAR Detection Log Reduction Groups |
| 0212-0291 | Field 4 | NORSAR LP Status and Repeat Indicators |
| 0292-1347 | Field 5a | NORSAR LP Data |
| 1348-1395 | Field 5b | NORSAR SP Channel Identification |
| 1396-1875 | Field 5c | NORSAR SP Data |
| 1876-2259 | Field 6 | NORSAR Offline Results |
| 2260-2323 | Field 7 | Program Coordination Data |
| 2324-2355 | Field 8 | Control Characters |
| 2356-2399 | Field 9 | Spare (encoded as zeros) |

Figure 6. Real-Time Message Format from NORSAR

| Bits | Contents | Description |
|------|----------|-------------|
| 0000-0031 | Field 1 | Control Characters |
| 0032-0143 | Field 2 | LASA Signal Arrival Queue File Entry |
| 0144-0179 | Field 3 | LASA Time (36-bit abbreviated format: DDDHHMMSS) |
| 0180-0235 | Field 4 | LASA LP Status and Repeat Indicators |
| 0236-1051 | Field 5 | LASA LP Data |
| 1052-1087 | Field 6 | ALPA Time (36-bit abbreviated format: DDDHHMMSS) |
| 1088-1151 | Field 7 | ALPA LP Status and Repeat Indicators |
| 1152-2063 | Field 8 | ALPA LP Data |
| 2064-2271 | Field 9 | LASA Off-line Results |
| 2272-2367 | Field 10a | Program Coordination Data |
| 2272-2343 | Field 10b | SP Data Request |
| 2368-2399 | Field 11 | Control Characters |

Figure 7. Real-Time Message Format to NORSAR

### 3. Format for Control Messages

The ARPANET message format for communication of commands and operator messages between the CCP and the Sites is shown in figure 8. This format was designed so that the protocol will use a Host-level acknowledgement scheme for reliable communication between the CCP and the Sites. It consists of a special 32-bit Host-IMP leader [2], a 16-bit message class identifier, and a variable length message body. This Host-IMP leader is special in so far as only its Destination Host Number field (bits 9-10) and Destination IMP Number field (bits 11-16) are ever nonzero. These control messages are distinguishable from real-time data messages by the fact that the message ID in the Host-IMP leader of the real-time messages is nonzero, while the message ID for control messages is always zero. The formats for each of the various classes of messages, shown in figures 9 and 10, are described below. The final sixteen bits in the message body contain a checksum for the entire message. A message is acknowledged only if it is successfully error-checked by the receiver. If an end does not receive such a Host-level acknowledgement within a specified time-out period after it sends a message, it will retransmit the message.

* Class 0 messages are sent from the CCP to either the KSRS SPLI or the SITE II SPLI containing command data to those Sites. The first forty-eight bits in each Class 0 message body contain a 44-bit time code identifier. The structure of this time code is identical to that used by the station controllers [4] and

```
 --------------------------------------------------------------
 !                   !                   !                    !
 !  HOST-IMP LEADER  !  MESSAGE CLASS ID !  MESSAGE BODY      !
 !                   !                   !                    !
 --------------------------------------------------------------
         32 bits             16 bits          < 8048 bits
```

(a)  Format of CCP-SPLI Control Messages

```
 ----------------------------------------------------------------
 !        !               !               !            !         !
 !  ZERO  !  DESTINATION   !  DESTINATION  !    ZERO    !
 !        !    HOST #      !     IMP #     !            !
 !        !               !               !            !         !
 ----------------------------------------------------------------
    8 bits     2 bits           6 bits         16 bits
```
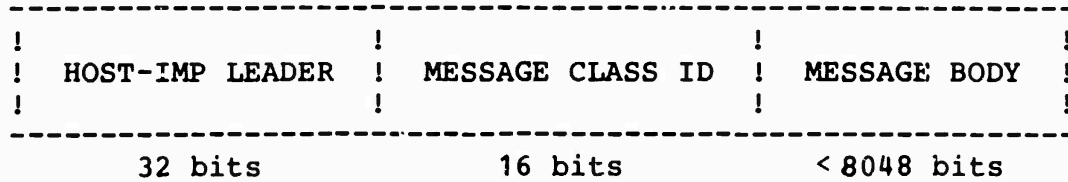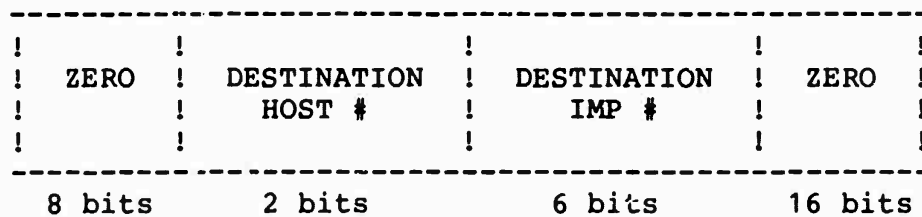
(b)  Host-IMP Leader for Control Messages

Figure 8.  Format of CCP-SPLI Control Messages

| Message Class ID | Definition of Fields in Message Body | Field Size (bits) | Message Interpretation |
|---|---|---|---|
| 0 | Undefined | 4 | Commands to Station Controller |
| | Time Code identifier | 44 | |
| | Message to KSRS or SITE II | – | |
| | Checksum | 16 | |
| 1 | | 0 | HELLO |
| 2 | | 0 | I-HEARD-YOU |
| 3 | Undefined | 4 | Message Acknowledgement |
| | Time Code of acknowledged message | 44 | |
| | Checksum | 16 | |
| 4 | Undefined | 4 | IRAN SPLI to CCP Operator Message |
| | Time Code identifier | 44 | |
| | ASCII Text | – | |
| | Checksum | 16 | |

Figure 9.  Classes of Control Messages from the CCP
to the SPLI

| Message Class ID | Definition of Fields in Message Body | Field Size (bits) | Message Interpretation |
|---|---|---|---|
| 1 | | 0 | HELLO |
| 2 | | 0 | I-HEARD-YOU |
| 3 | Undefined | 4 | Message |
| | Time Code of acknowledged message | 44 | |
| | Checksum | 16 | Acknowledgement |
| 4 | Undefined | 4 | CCP |
| | Time Code identifier | 44 | to |
| | ASCII Text | - | IRAN SPLI Operator Message |
| | Checksum | 16 | |

Figure 10. Classes of Control Messages from the SPLI
to the CCP

consists of eleven BCD 4-bit subfields (year-tens,  year-units, day-hundreds,  ...,  second-units).    Following  the  time code identifier is the command message which is described in section 3.1 and shown in figure 11.

* Class 1 (HELLO) and Class 2 (I-HEARD-YOU) messages have no body and  are  exchanged periodically to detect data link outages as described in section 4.

* Class 3 (Acknowledgement) messages are  sent  whenever  an  end successfully receives command or operator messages.   Each Class 3 message includes a 48-bit field which  specifies  the  44-bit time  code  identifier  of the message being acknowledged.   The final  sixteen  bits  contain  a  checksum  for  the  preceding forty-eight  bits  of this Class 3 message which is being sent. If an end does not receive a correct Class 3 message  within  a specified  time-out  period  after  it  sends  a  message,  it retransmits the message.

* Class 4 messages are used to send operator messages between the IRAN  SPLI  and  the  CCP.   As for Class 0 messages, the first forty-eight bits in each Class 4 message body contain a  44-bit time  code  identifier  and  the  final  sixteen bits contain a checksum.

```
              --------------- < 689 bits*----------------
              ----------------------------------------------
              !          !          !              !           !
              !  START   !  BODY OF COMMAND  !  TERMINATION  !
              !  CODE    !          !           CODE         !
              !          !          !              !           !
              ----------------------------------------------
                7 bytes       < 73 bytes*        7 bytes
```
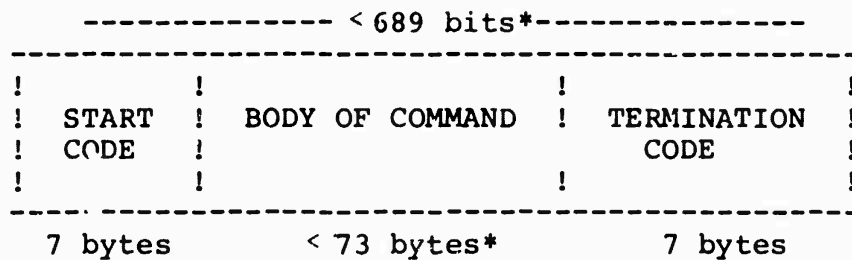
* except for "MESS" command which can contain text of up to 150
  lines of 72 characters each

```
        ------------------BODY OF COMMAND------------------
        -------------------------------------------------------------
        !         !        !          !       !        !            !
        ! COMMAND ! REQUEST ! FUNCTION ! TYPE ! OPTION ! PARAMETERS !
        ! CODE    !   ID    !  CODE    ! CODE !  CODE  !            !
        !         !        !          !       !        !            !
        -------------------------------------------------------------
```

(ASCII CHARACTERS)
------------------

```
START
CODE          -------------------------------------------------
              ! SOH ! SOH ! CR  ! CR  ! LF  ! NUL ! NUL !
              -------------------------------------------------


COMMAND
  CODE        ---------
              ! / ! / !
              ---------


REQUEST
  ID          -----------------------------------
              ! H ! Q ! Q ! Q ! Q ! Q ! , !
              -----------------------------------


TERMINATION
   CODE       -------------------------------------------------
              ! CR  ! CR  ! LF  ! NUL ! NUL ! EOT ! EOT !
              -------------------------------------------------
```
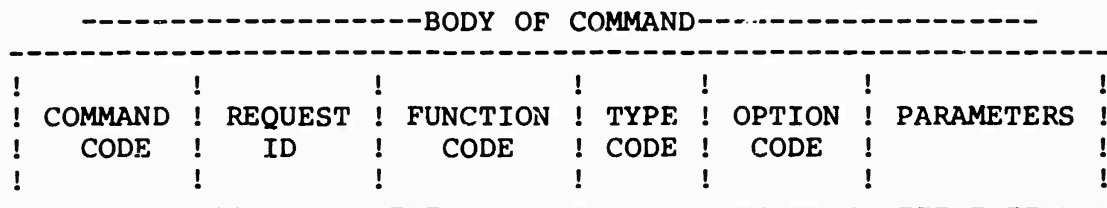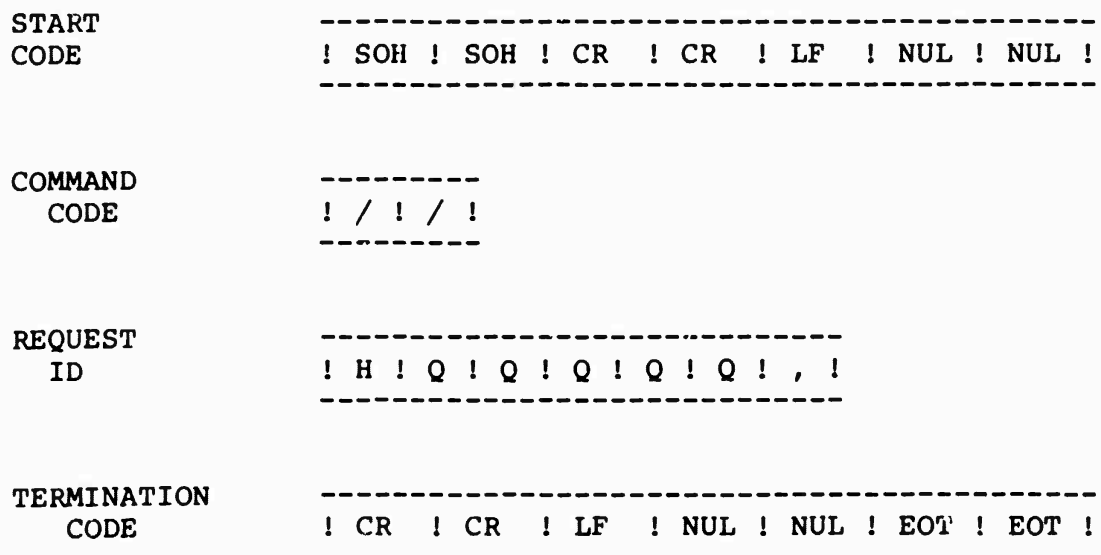
Figure 11.Command Message Format to KSRS and SITE II

3.1 Commands to KSRS and SITE II

The command messages to the station controllers at KSRS and SITE II have the same format and are described in detail in [7]. The length of each command will be less than 86 ASCII characters except for the "MESS" (message) command. The "MESS" command can contain a text message of up to 150 lines of 72 characters each, which is equal to 86400 bits. The restriction that an ARPANET message must be no longer than 8095 bits implies that lengthy "MESS" commands will be transmitted by using a sequence of as many as eleven Class 0 messages. The Host-level acknowledgement protocol, however, prevents these messages from arriving out of order. Each command will be sent as a stream of ASCII characters. The SPLI to station controller interface will be consistent with the current 75 bps modem data link.

As shown in figure 11, each command consists of a 7 character start code, a body, and a 7 character termination code. The request ID in the command body is a 7 character field. The first 6 characters of this field are included as part of the block data portion of the station controller to SPLI data frames (see section 2.1), so that a command and its corresponding response can be associated with one another. The first of the six characters must be "H". The remaining five are arbitrary, but must be alphanumeric.

The function code field specifies the operation to be performed as a result of the command. The type and option code fields may not

be present in a command.  However, if they are present, they specify
the operation of the command in more detail.  The parameter field of
a command either specifies parameters to be modified by the  command
or,  in  the  case  of the "MESS" command, includes the text message
that 's to be transmitted.  Like the type and  option  code  fields,
the parameter field may not be present for every command.

3.2 Operator Messages between the IRAN SPLI and the CCP

As mentioned earlier, a Class 4 message body  will  contain  an
operator message from either the IRAN SPLI to the CCP or vice versa.
Taking  into  account  the  Host-IMP  leader,  the   message   class
identifier,  the time code identifier, and the checksum (112 bits in
all), each Class 4 message may contain  up  to  8095-112=7983  bits,
i.e. 997  characters of ASCII text.  Longer operator messages can be
sent as a succession of Class 4 messages.  These  messages  will  be
received   in   the  proper  order  on  account  of  the  Host-level
acknowledgement protocol (see section 3.1).

4. Detailed Operation of the Communications Link

4.1 Transmission of Real-Time Data

The seismic sites will generate real-time data blocks at a rate
of one per second.  These blocks are buffered in a 10 second buffer.
If this buffer is full when a new data  block  arrives,  the  oldest
record  in the buffer is replaced by the new data.  Output from this
source buffer to the network should be initiated whenever  there  is
data  to  be  sent.   Normally. this  will be at a rate of once per
second.  When a RFNM (Ready For Next Message) for a previously  sent
message is received at the source, the buffer allocated to that data
block can be released (if it is still assigned).  If  an  Incomplete
Transmission  is  received in response to a previously sent message,
that message should be retransmitted by the  site  if  it  is  still
available in the source buffer.

At the destination (the CCP) there are two analogous  processes
which manipulate the destination buffer.  The process which receives
real-time data from the network discards messages which arrive late,
i.e.,  that  cannot  be delivered with the required 10 second delay.
Data with a bad  software  checksum  may  also  be  discarded.   The
checksum  is  included primarily for end-to-end error detection, but
would also allow easy implementation of  end-to-end  acknowledgement
in  the  future  (see section 4.3).  Time-of-day clocks at the array
sites and the CCP are both calibrated to an absolute  time  standard
(such  as  WWV)  so  that  the  source  and  destination  can remain

synchronized.

The destination buffer is filled with 10 seconds of  data  when the  data  link is initialized.  The source buffer only fills up due to network delays resulting from retransmissions,  channel  outages, lost  messages  (or  acknowledgements),  etc.  When  more  than one message is available for transmission at the source, several message IDs  will  be  used  so  as  to  clear  out  the source buffer, i.e, catch-up, as  quickly  as  possible.  This  "pipelining"  procedure improves  the  network  throughput  for  real-time  data.  The  IMP subnetwork, however, imposes a constraint on the throughput which is possible.  In  particular, only 4 messages can be transmitted prior to receiving a RFNM for the first message.

If the network delays are short, the  10  seconds  of  buffered data  will be sufficient for lossless real-time communication with a fixed delay.  Some types of errors, however, can cause gaps to occur in  the  data.  Loss  by  the  ARPANET  of a part of a message, for example, can cause a gap of up to 60  seconds  to  occur  while  the source  IMP  times out the associated acknowledgement.  The only way around this problem is to buffer up to one minute of  data  both  at the  source  and the destination.  This would, of course, imply that all data would be delivered 60 seconds late rather than  10  seconds late.  Since  this  type  of error is expected to be rare (probably less than once per day), the added delay and cost of buffering  were considered  inappropriate.  This data should always be available on tape and could be accessed via the network if desired.

4.2 Flow of Commands and Operator Messages

In contrast to the real-time messages, the commands and operator messages employ a reliable communication protocol which requires message acknowledgement or timeout and retransmission of unacknowledged messages. The Class 3 Acknowledgement message for a particular message is sent to the sender by the receiver to indicate that the received data arrived correctly as evidenced by recomputing the associated checksum. If the data is lost or arrives with a detectable error, no Host-level acknowledgement is returned, the sender eventually does a timeout, and the message is retransmitted. A 60 second timeout would probably be appropriate here.

In addition to the specification of reliable transmission for commands and operator messages, these control messages also require a simple implementation of flow control not required for real-time data. In each direction, control messages are sent over a single logical channel (the Host-IMP Leader message ID is zero--see section 3). This implies that no pipelining is possible for these messages. In particular, a RFNM must be received for the previous message (in a given direction) before the next message (in that direction) can be transmitted. Although this scheme limits the throughput for transmission of commands and operator messages, it also has the positive effect of minimizing the buffer space required for messages in transit.

The CCP or Site will eventually receive either a RFNM or an Incomplete Transmission message from its IMP or SIMP for each of the

messages which it transmits [2].   These Host-IMP messages are discarded because of the Class 3 Host-level acknowledgement procedure.  Although Incomplete Transmission messages could be used to improve throughput of control messages, the added complication was judged inappropriate.

4.3 The Question of End-to-End Acknowledgement of Real-Time Data

The communication protocol described above does not include any mechanism for Host-to-Host acknowledgement of real-time data messages.  A message is assumed to be delivered correctly by the source when a RFNM from the destination is received.  What the RFNM actually implies is that the first packet of the associated message has been transmitted to the Host-IMP interface by the destination IMP.  Whether the rest of the message made it through the interface and was received correctly by the destination Host is not known.  To add error checking to the overall communication path, a Host-to-Host acknowledgement scheme for real-time messages similar to that used for control messages would be required.   A  Host-level acknowledgement message would be used for this purpose.  The time code on the real-time messages could provide the unique identifier required for handling messages arriving out of order and duplicate messages.

One unfortunate side effect of the end-to-end acknowledgement of real-time data, however, is that it increases the data link vulnerability to long outages due to lost messages.  If a Host-level

acknowledgement   or   the   RFNM for a Host-level acknowledgement were
lost, the system would be stuck for up to 60 seconds while  the  CCP
IMP  timed out the RFNM.  Since the positive acknowledgement creates
this problem and adds  to  the  complexity  of  the  real-time  data
protocol, it was not included in the design.  Such a mechanism could
be added at some later time if it were deemed appropriate.

4.4 Error Recovery and Initialization

    To decide that the data link between the CCP and  the  Site  is
working  properly,  a  scheme  is used analogous to that used with a
very distant Host, the VDH-to-IMP circuit test procedure [2].  Every
R  seconds both the CCP and the Site independently send each other a
Class 1 (HELLO) message.  Whenever the CCP or the  Site  receives  a
HELLO  message, it must respond with highest priority by sending the
other  a  Class  2  (I-HEARD-YOU)  message.   The  I-HEARD-YOU  is  a
Host-to-Host  acknowledgement of the corresponding HELLO.  If either
end of the data path sends more than T  consecutive  HELLOs  without
receiving  an  I-HEARD-YOU acknowledgement, it declares the Site-CCP
data path to be dead.  After declaring the path dead,  it  does  not
send  or  receive  any  messages  for 2RT seconds to allow the other
party also to declare the path dead.

    After an end waits 2RT seconds, it attempts to reinitialize the
path.  This  is done by sending only HELLO messages every R seconds
until X consecutive HELLOs have been acknowledged  by  I-HEARD-YOUs.
After  X  HELLOs  in  a row have been acknowledged, the data path is

declared alive.  After  the  data  link  has  been  declared  alive,
regular   messages   can   be   sent  in  addition  to  the  periodic
HELLO/I-HEARD-YOU pairs.

The value of R is initially 2, the value of T  is  5,  and  the
value  of  X is 5.  The Network Control Programs for the CCP and the
Site should  be  designed  so  that  it  is  easy  to  change  these
parameters.

Since the CCP can be on either the SDAC IMP or  the  SDAC  TIP,
the  Site must be prepared to try both Host addresses when trying to
bring up the data path.  It can do this by  sending  the  HELLOs  to
both Host addresses simultaneously.

At system startup the data path will be assumed  to  have  been
declared dead,  and  the  procedure  for waiting 2RT seconds before
sending HELLO messages will be used for initialization.

## 5. References

[1]  BBN Report No. 2632 - Final  Report  -  A  Study  of  the  Data
     Collection,  Processing, and Management for a Worldwide Seismic
     Network, September 1973.


[2]  BBN Report No. 1822, Specifications for the Interconnection  of
     a Host and an IMP, April 1973.


[3]  McKenzie, A., Host/Host Protocol  for  the  ARPA  Network,  NIC
     8246, January 1972.


[4]  Texas Instruments Inc., Specification for Station Controller to
     HDT Communication Formats, Drawing No. 138658.


[5]  Texas Instruments Inc., Iranian Long Period Array Design Review
     Addendum No. 1, April 1, 1974.


[6]  Teledyne Geotech, REF 110S,N -ISRSPS Program Reference  Manual:
     Section 1-3-2, Rev. 8/31/71; Section 1-4-3, Rev. 6/08/72.


[7]  Texas Instruments Inc., Specification  for  Station  Controller
     Command and Response Formats, Drawing No. 140521.

BBN Report No. 2865    Appendix B

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## 1. Overall Link Operation

A protocol for the on-line transmission of seismic data between the Communications and Control Processor (CCP) at SDAC and the Seismic Input Processor (SIP) at CCA is described in this document. This protocol is consistent with both the initial specification of the Datacomputer files presented by R. Lacoss [1] and the subsequent file descriptions developed by E. B. McCoy [2].

Both the CCP and SIP are interfaced as Hosts on the ARPANET and communicate at the Host-to-Host level although not via the standard Host-Host Protocol [3]. As shown in figure 1, both the SIP and the Datacomputer are Hosts on the CCA TIP. The SIP will provide buffering to handle outages of the Datacomputer and will permit higher rate transfers to the Datacomputer. The buffering at the SIP is provided by a large disk with a capacity of on the order of 24 hours of data. Normally the SIP will buffer on the order of one hour of data before transferring it to the Datacomputer at a rate of about 100 kbaud. Larger amounts of data will be buffered, of course, when the Datacomputer crashes or when it is scheduled for preventive maintenance.

When the SIP successfully transfers the data from its disk to the Datacomputer it will send a message that will be stored in a table in the CCP. These transfers will occur typically every hour and so a table of SIP-to-Datacomputer transfer status for a day or two will be quite small.

```
        --------------------
        !                  !
        !   DATACOMPUTER   !
        !                  !
        --------------------
                !
                !
                !
        -----------       ----------       --------------
        !         !       !        !       !            !
        !   CCA   !-------!  SIP   !-------!    SIP      !
        !   TIP   !       !        !       !   DISK      !
        !         !       ----------       !  BUFFER     !
        -----------                        !            !
                !                          --------------
                !
                !
        ---------------
        !             !
        !   ARPANET   !
        !             !
        ---------------
                !
                !
                !
        -------------       --------------
        !   SDAC    !       !            !
        !   IMP     !       !    SDAC    !
        !   or      !-------!    TAPE    !
        !   TIP     !       !   BACKUP   !
        !           !       !            !
        -------------       --------------
                !
                !
                !
        -------------
        !           !
        !    CCP    !
        !           !
        -------------
```
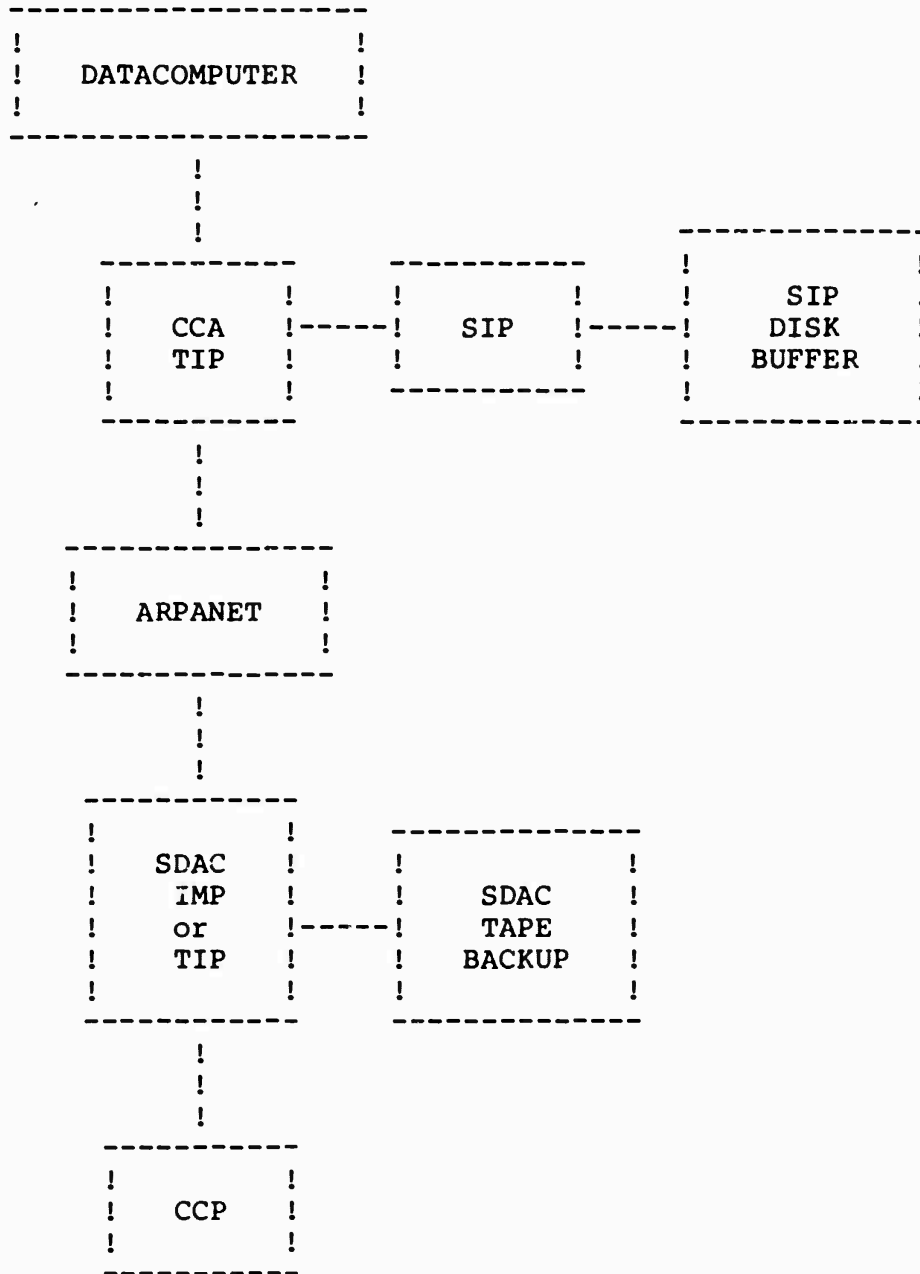
Figure 1. CCP-SIP Data Link

At the SDAC end of the data link, buffering must be provided by the CCP to handle the uneven data flow caused by the asynchronous nature of the ARPANET.  Tape backup also must be available at SDAC in case of a network outage or failure of either the SIP or Datacomputer.  It is recommended, however, that a continuous backup recording capability be provided by SDAC.  Everything which is transmitted to the SIP would be recorded at SDAC and kept for a week before the tapes are recycled.  These tapes would be used off-line at the Datacomputer to fill in any data missed during data link failures.

Three kinds of data are to be sent from the CCP to the SIP:

* Waveform data consisting of Long Period (LP) and Short Period (SP) real-time seismic data and beams will be sent in one second data blocks arranged by site.

* Status information concerning the data transmitted from each site will be sent to the SIP prefixed to the waveform data.

* A file directory control message, taking effect either immediately or at a preset time (e.g. midnight) and of course at initialization, will specify the interpretation of subsequently received data blocks (e.g. which channels are being sent and the files into which they should be placed).

A detailed description of the formats of these messages will be presented in the following section.

## 2. Data Formats

### 2.1 Waveform Data and Status Information

Once each second, the CCP sends to the SIP a message containing one second of seismic waveform data preceded by status information concerning that data from each of the sites. A variable number of raw data channels and beams may be sent from each site, so the message must be interpreted according to the most recent file directory control message (discussed below) received by the SIP from the CCP. Each one second data block is formed with a given delay for each of the sites, but the differential delay for each channel and beam within a site must again be interpreted according to the current file directory control message.

The format in which the waveform data is sent to the SIP by the CCP is shown in figure 2. The data is arranged by site so that this data format can be used to send specified data from the CCP to the SDAC 360/40. For sites not sending both long period data and short period data the corresponding data fields (described below) will not be used. Within each site field this status/data message logically consists of five fields: the time code; the status of the long period data; the status of the short period data; the long period data; and the short period data.

\*   Each one second data block from a site is prefixed with a time code. The structure of this field (shown in figure 3) is identical to the 44-bit time code used by the station

```
-------------------------------------------------------------------
!        !          !        !           !         !            !
!  LASA  !  NORSAR  !  KSRS  !  SITE II  !  IRAN   !   ALPA     !
!        !          !        !           !         !            !
-------------------------------------------------------------------
```

(a) One Second Status/Data Message Compiled by Site

```
             ---------------------------SITE---------------------------------
-----------------------------------------------------------------------------
!            !             !             !            !             !
! TIME CODE  !  LP STATUS  !  SP STATUS  !  LP DATA   !  SP DATA    !
!            !             !             !            !             !
-----------------------------------------------------------------------------
```

(b) Structure of the One Second Status/Data Message from a Site

Figure 2. Logical Form of the One Second Status/Data Message

```
          ----------------------48 bits----------------------
      ------------------------------------------------------------
      !            !    !   !       !     !   !     !   !     !   !     !   !
      ! UNDEFINED  !  Y !  Y !   D  !   D !  D !   H !  H !   M !  M !   S !  S !
      !            ! 10 !  1 !  100 !  10 !  1 !  10 !  1 !  10 !  1 !  10 !  1 !
      !            !    !   !       !     !   !     !   !     !   !     !   !
      ------------------------------------------------------------
                          (4 bits each)
```
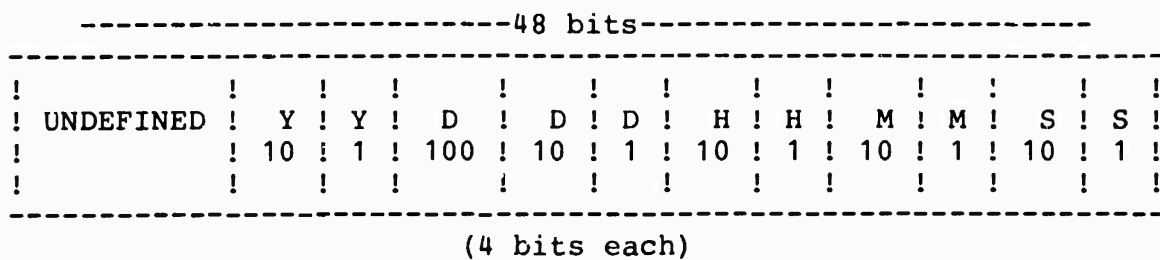
Figure 3. Detailed Structure of the Time Code Field

controllers [4] and consists of eleven BCD 4-bit subfields (year-tens, year-units, day-hundreds, ...  , second-units).

* The status information for the one second block of long  period data used from each site will specify:

** the availability of data from  an  individual  channel  or beam

** that the data for a particular channel or beam is bad

** that a particular seismometer is either  being  calibrated or otherwise tested

To indicate these conditions, a 4-bit  status  field  (see figure  4)  is assigned to every beam and channel that is being used from a site as specified in  the  file  directory  control message  described  below.  Three  bits  are  used as flags to specify  the  above  conditions,  and  the  fourth  remains unassigned.

* The status information for the one second block of short period data  used  from  each  site  will  be given in the same format described above for the long period data status information.

* The format of the one second block of  Long  Period  data  used from  a  site  is shown in figure 5.  It consists of one 16-bit data sample from every selected seismic  channel,  followed  by specified  16-bit  beams  formed  for  that  site.    The

```
        ------------------LP OR SP STATUS--------------------
      --------------------------------------------------------
      !          !       !        !         !       !         !
      ! CHANNEL 1 !  ... ! CH N   ! BEAM 1  !  ...  ! BM M    !
      !  STATUS   !      ! STATUS ! STATUS  !       ! STATUS  !
      !          !       !        !         !       !         !
      --------------------------------------------------------
                        (4 bits each)
```
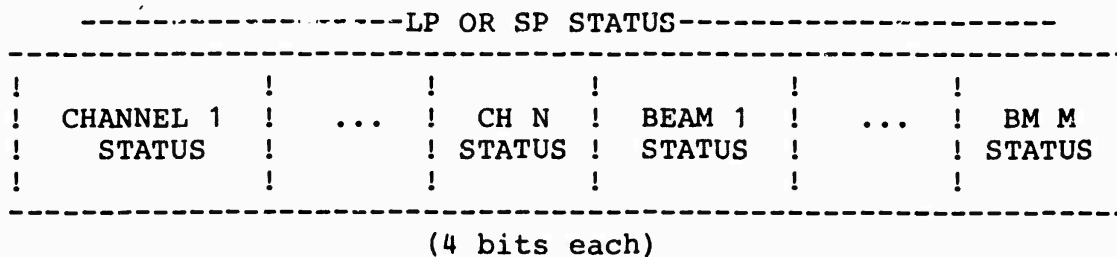
(a) The Ordering of the Status Fields given for either Long Period
    or Short Period Channels and Beams

```
          ------------------STATUS FIELD-------------------
      ------------------------------------------------------------
      !           !           !            !              !
      ! AVAILABLE ! BAD DATA  ! CALIBRATED ! UNASSIGNED    !
      !           !           !            !              !
      ------------------------------------------------------------
                        (1 bit each)
```
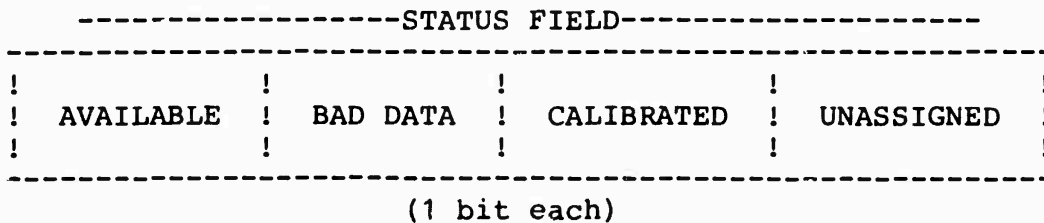
(b) Definition of an Individual Channel or Beam Status Field


           Figure 4.  Format of Status Information in One Second
                       Status/Data Message

```
            -----------------------LP DATA-----------------------
      ------------------------------------------------------------
      !          !        !      !       !         !      !       !
      ! CHANNEL 1 !  ...  ! CH N ! BEAM 1 !  ...   ! BM M !
      !   DATA    !        ! DATA ! DATA  !         ! DATA !
      !          !        !      !       !         !      !       !
      ------------------------------------------------------------
                          (16 bits each)
```
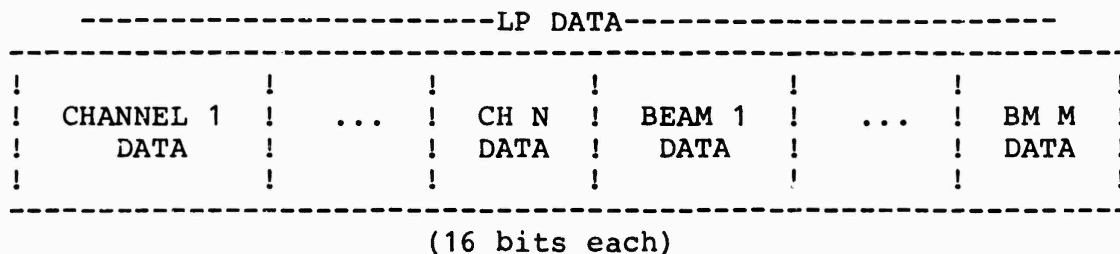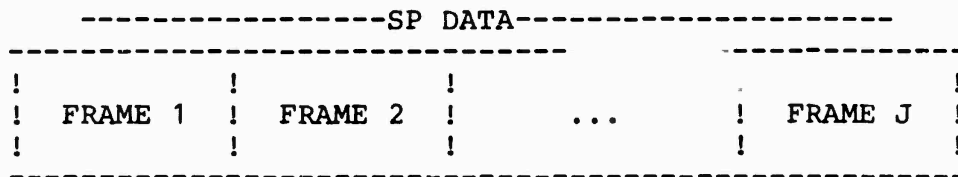
(a)  One Second of Long Period Data from an Individual Site

```
            -----------------SP DATA----------------------
      ------------------------------------      -------------
      !          !          !         !        !           !
      ! FRAME 1  ! FRAME 2  !   ...    !        ! FRAME J   !
      !          !          !         !        !           !
      ------------------------------------------------------
```

(b)  One second of Short Period Data Frames from an Individual Site
     (J samples per second, where J=20 for all sites other than LASA
     where J=10)

```
            --------------------SP DATA FRAME--------------------
      ------------------------------------------------------------
      !          !        !      !       !         !      !       !
      ! CHANNEL 1 !  ...  ! CH N ! BEAM 1 !  ...   ! BM M !
      !   DATA    !        ! DATA ! DATA  !         ! DATA !
      !          !        !      !       !         !      !       !
      ------------------------------------------------------------
                          (16 bits each)
```
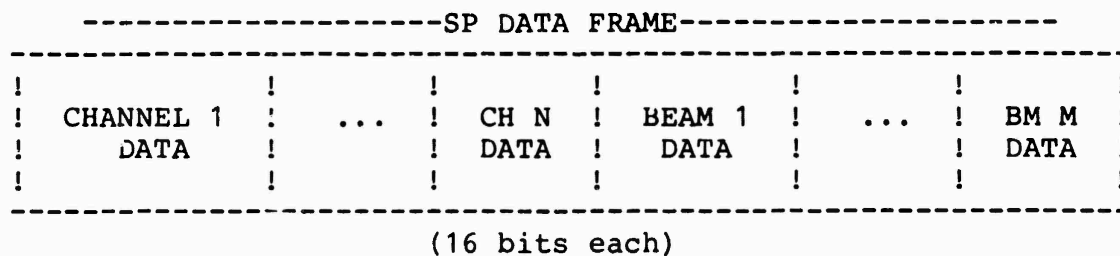
(c)  One Frame of Short Period Data from an Individual Site


               Figure 5.  Format of Waveform Data in One Second
                          Status/Data Message

interpretation of the ordering of these data  samples  is  done
using the file directory control message described below.

* The format of the one second block of Short  Period  data  used
  from  a  site  is also shown in figure 5.  It is divided into J
  time frames, where J is the number of samples given each second
  by  that  site.  J is equal to 20 for all sites other than LASA
  where J equals 10.  Each frame  consists  of  one  16-bit  data
  sample  from  every  selected seismic channel  at  the  site,
  followed by specified 16-bit beams formed for that  site.   The
  interpretation  of  a frame of data from a site is accomplished
  using the file directory control message described below.

2.2 File Directory Control Message

During initialization of the data link or at any  time  at  the
start  of  a  new file, a file directory control message is used for
three purposes: identifying the  channels  and  beams  contained  in
subsequent  waveform  data  messages;  specifying  the  differential
delays of these channels and beams  with  respect  to  the  standard
times  of  their  sites;  and designating the Datacomputer file into
which an individual data sample is to be entered.

* Each channel and beam in the entire seismic network is assigned
  a  unique 16-bit identifier.  (Using four 4-bit BCD fields, for
  example, this would accommodate 10,000 channels and beams.) The
  file  directory  control  message  contains  identifier-labeled
  48-bit subfields (see figure 6) corresponding to  each  of  the

```
-----------------------------------------------------------------
!        !          !       !           !        !         !
! LASA   ! NORSAR   ! KSRS  ! SITE II   ! IRAN   ! ALPA    !
!        !          !       !           !        !         !
-----------------------------------------------------------------
```

(a)  Logical Form of the File Directory Control Message
     Compiled by Site


```
          -----------------------------SITE-----------------------------
-------------------------------------------------------------------------
!           !              !              !                  !
! TIME CODE ! # OF SUBFIELDS ! LONG PERIOD  ! SHORT PERIOD   !
!           ! FOR THIS SITE  ! SUBFIELDS    ! SUBFIELDS      !
!           !              !              !                  !
-------------------------------------------------------------------------
                              (one for each   (one for each
                              LP channel      SP channel
                              and beam)       and beam)
```

(b)  Structure of the File Directory Control Message from
     a Single Site


```
-----------------------------------------------------------------
!                  !                    !                     !
! CHANNEL/BEAM ID  ! DIFFERENTIAL DELAY ! DESTINATION FILE #  !
!                  !                    !                     !
-----------------------------------------------------------------
                   (16 bits each)
```

(c) Definition of the File Directory Control Message Subfield
    given for each Channel and Beam




Figure 6. Format of the File Directory Control Message

channels and beams included in the  status/data  message.    For
Long  Period  data,  subfields  are  given corresponding to the
channel and beam samples within each site  field  of  the  Long
Period  waveform  data.    For  Short Period data, subfields are
given for all the channels and beams sampled  within  one  time
frame  from  each  site.    This ordering is the same, of course,
for every frame.

*    Each  identifier-labeled  subfield  also  contains   a    16-bit
     differential delay for that channel or beam with respect to its
     site.    (These delays should probably be given in twentieths  of
     a second, and will most likely not exceed thirty seconds.)

*    The sixteen bits following the delay in each subfield are  used
     as a file number by the SIP, specifying which Datacomputer file
     is to receive the data from this identified  channel  or  beam.
     (Only  ten conceptual seismic files at the Datacomputer have as
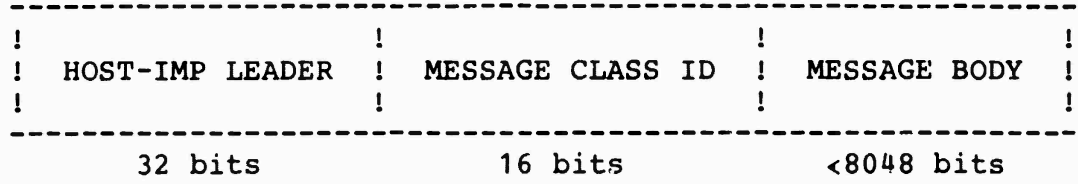     of yet been specified [1].)

As for the status/data message described above, the  file  directory
control  message  is arranged by site (see figure 6a).   In order for
the SIP to interpret this message correctly, the  number  of  48-bit
subfields  given  for  each  site  is  specified  in  a 16-bit field
following the time code in each site field  (see  figure  6b).    The
time  code  of when this message was sent is given in a 48-bit field
(see section 2.1).   Using this ordering-correspondence  scheme,  the
number of seismic channels or beams referenced from each site may be
easily altered.   The choice of files into which  specified  data  is

entered  is  also readily controlled.  These changes should probably

take effect at a preset time (e.g. midnight), but this protocol also

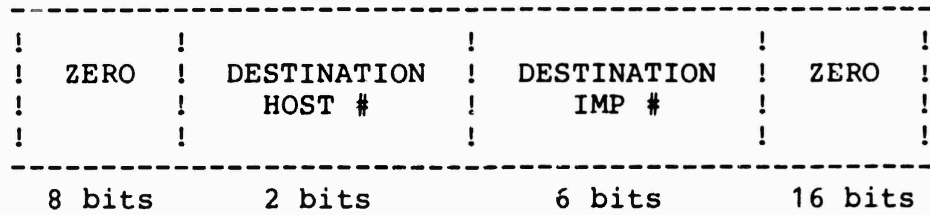provides for such changes to be made at any time.

### 3. CCP-SIP Messages

The ARPANET message format for communication between the CCP and the SIP is shown in figure 7.  This format was designed so that the protocol will use a Host-level acknowledgement scheme for reliable communication between the CCP and the SIP.  It consists of a special 32-bit Host-IMP leader [5], a 16-bit message class identifier, and a variable length message body.  This Host-IMP leader is special in so far as  only  its  Destination  Host  Number field  (bits 9-10) and Destination IMP Number field (bits 11-16) are ever nonzero.  The formats  for  each  of  the  various  classes  of messages, shown in figures 8 and 9, are described below.

The restriction that an ARPANET message must be no longer  than 8095 bits  necessitates  the  use  of  some scheme for partitioning longer messages that are  sent  from  the  CCP  to  the  SIP.  A straightfoward  approach  is  to  divide  each  logical message into acceptably-sized pieces, giving all pieces a  message  label  and  a numerical ordering.  This protocol employs the 44-bit time code (see section 2.1) of the message as the label,  and  uses  the  preceding 4-bit  field  to  represent  the piece number.  The number of pieces which the SIP must wait to receive before reassembling  the  message is  determined  from  the  Class 4 message (see figure 8) previously received from the CCP.  (The control messages themselves specify  in each  of  their  pieces  the  total  number  of pieces of which they consist.)

```
----------------------------------------------------------
!                  !                  !            !           !
! HOST-IMP LEADER  ! MESSAGE CLASS ID ! MESSAGE BODY !
!                  !                  !            !           !
----------------------------------------------------------
       32 bits            16 bits            <8048 bits
```

(a) CCP-SIP Message Format

```
----------------------------------------------------------
!        !            !              !          !          !
!  ZERO  ! DESTINATION ! DESTINATION ! ZERO     !
!        !   HOST #    !    IMP #    !          !          !
!        !            !              !          !          !
----------------------------------------------------------
   8 bits    2 bits        6 bits        16 bits
```

(b) CCP-SIP Host-IMP Leader

Figure 7. CCP-SIP Message Format

| Message Class ID | Definition of Fields in Message Body | Field Size (bits) | Message Interpretation |
|---|---|---|---|
| 1 |  | 0 | HELLO |
| 2 |  | 0 | I-HEARD-YOU |
| 3 | Message Class ID of acknowledged message | 16 |  |
|  | Undefined | 4 | Message |
|  | Time Code of acknowledged message | 44 | Acknowledgement |
|  | Checksum | 16 |  |
| 4 | Number c  this piece | 4 | File Directory |
|  | Time Code when this message was sent | 44 | Control |
|  | Number of pieces in this message | 8 | Message for |
|  | Number of pieces in Status/Data message | 8 | Reinitialization |
|  | Immediate File Directory Control Message | – | or Starting |
|  | Checksum (last piece only) | 16 | New Files |
| 5 | Undefined | 4 | Close Files--- Use Next |
|  | Time Code | 44 | Class 4 Message To Start |
|  | Checksum | 16 | New Files |
| 6 | Number of this piece | 4 | File Directory |
|  | Time Code when this message was sent | 44 | Control |
|  | Number of pieces in this message | 8 | Message for |
|  | Number of pieces in Stat ıs/Data message | 8 | Starting |
|  | Future File Directory Control Message | – | New Files |
|  | Checksum (last piece only) | 16 | at Preset Time |
| 7 | Number of this piece | 4 |  |
|  | Time Code | 44 | One Second |
|  | One Second Status/Data Message | – | Status/Data |
|  | Checksum (last piece only) | 16 | Message |

Figure 8. Classes of Messages from the CCP to the SIP

| Message<br>Class ID | Definition of Fields<br>in Message Body | Field<br>Size<br>(bits) | Message<br>Interpretation |
|---|---|---|---|
|  | Undefined | 4 | Datacomputer |
| 0 | Time Code of last data transferred | 44 | Transfer |
|  | Checksum | 16 | Completed |
| 1 |  | 0 | HELLO |
| 2 |  | 0 | I-HEARD-YOU |
|  | Message Class ID of<br>acknowledged message | 16 |  |
| 3 | Undefined | 4 | Message |
|  | Time Code of<br>acknowledged message | 44 | Acknowledgement |
|  | Checksum | 16 |  |

Figure 9. Classes of Messages from the SIP to the CCP

The final sixteen bits in the last piece of each message contain a checksum for the entire message. Each message is acknowledged by the SIP only after the entire message has been reassembled, error-checked, and correctly stored on the SIP disk. If the CCP does not receive such a Host-level acknowledgement within a specified time-out period, it will retransmit all the pieces.

Figures 8 and 9 depict the eight classes of messages used in CCP-SIP communication.

*   Class 0 messages are sent to the CCP by the SIP whenever it has successfully transferred the data from its disk to the Datacomputer. A Class 0 message contains the time code of the last data sample that was transferred to the Datacomputer by the SIP.

*   Class 1 (HELLO) and Class 2 (I-HEARD-YOU) messages have no body and are exchanged periodically to detect data link outages as described in section 5.

*   Class 3 (Acknowledgement) messages are sent to the CCP by the SIP whenever it successfully receives and incorporates messages (other than HELLO and I-HEARD-YOU) from the CCP. Each Class 3 message includes a 16-bit field which specifies the message class identifier of the message being acknowledged. The following forty-eight bits contain the 44-bit time code (see figure 3) of the acknowledged message. The final sixteen bits contain a checksum for the preceding sixty-four bits of this

Class 3 message which is being sent.    If  the  CCP  does  not receive  a  correct Class 3 message within a specified time-out period after it sends a message, it retransmits the message. Class 3 messages are likewise sent to the SIP  by  the  CCP  to acknowledge the receipt of Class 0 Datacomputer transfer status messages.

* Class 4 messages are used for either  reinitializing  the  data link   or   defining  a  new  format  for  Datacomputer  files. Following an outage or a  Class  5  Close  Files  message  (see below),  the  CCP must send a Class 4 message to the SIP.  This message is labeled with the time code of when it was  sent  and contains  information  as to the size of subsequent status/data messages, as described above.  It also includes  the  immediate file  directory control message (see section 2.2) being used by the SIP.  Only after the  SIP  successfully  acknowledges  this Class 4 message does the CCP continue data transmission.

* Class 5 (Close Files) messages are sent by the  CCP  to  inform the  SIP  of a change in either which data is being sent or the files into which data should be placed.  When the SIP  receives a Class 5 message it must immediately close all files.  It will open new files to accept future data in a format  specified  by the  Class  4  file directory control message it next receives. To insure reliability, the Host-level acknowledgement procedure requires that the CCP receive a Class 3 Acknowledgement message from  the  SIP  before  it  sends  the  file  directory  control

message.    Furthermore,    this    Class    6    message    must   be
acknowledged to have been successfully incorporated by the  SIP
before   the   CCP   continues data transmission according to this
file directory control message.

* Class 6 messages have   exactly   the   same   format   as   Class   4
  messages,    but    are    used   by   the   SIP   at   a   preset   time
  (e.g. midnight) to update the current  file   directory   control
  message   being   employed   by   the SIP.   A Class 6 message takes
  effect at the beginning of a new file, and thereafter  is   used
  by the SIP in interpreting incoming messages.

* Class 7 messages contain the one   second   status/data   messages
  (see  section 2.1), each piece being labeled with the time code
  specific to the one second data  block   which,   together,   they
  contain.

## 4. Backup Recording

Tape backup must be  provided  by  SDAC,  at  least  to  handle possible  outages  of  the  CCP-SIP  data  link.  It is recommended, however, that all the data sent to the SIP be saved at  SDAC  for  a week  on  tape.    This  would insure the integrity of the data files despite any losses by the Datacomputer.   These tapes could be mailed to CCA in order to update the Mass Store.

A "lost data scenario" might go as follows:  Each  second,  all data  sent  to CCA is also recorded on tape at SDAC.  When some data is lost due to a network outage, an  indication  of  the  lost  data (start time, stop time) is presented to the CCP operator and is also recorded in a CCP lost data table.   This table has sufficient  space for  the  maximum number of outages that could possibly occur during one tape's worth of data.   (If a tape holds 5 hours of data, one can impose the restriction that outages less than one minute apart cause the entire minute's worth of data to be marked, thus  no  more  than 300  entries  are required in the lost data table.) When a full tape is unmounted, the CCP operator can request to see the old lost  data table  and  decide  whether  or  not to send the recorded data (more likely a copy of it) to CCA.

## 5. Detailed Operation of the Data Link

### 5.1 Normal Operation

A one second status information and waveform data message, or a file directory control message, is produced by the CCP and placed in the output buffer to the SIP.  It is held there for retransmission by the CCP if a correct acknowledgement for it is not received from the SIP within a specified time-out period.  In the case of a data link outage, it will be stored on tape to prevent the loss caused by the overflowing of the output buffer.  It is recommended that all the data also be saved on tape at SDAC for a week in order to protect against any losses incurred at the SIP end of the data link.

A checksum is computed for the message, and then it is divided into pieces (see section 3) which are sent over the ARPANET.  To accomplish this, the Network Control Programs of the CCP and SIP must both implement the standard Host-IMP protocol described in detail in BBN Report No. 1822 [5].  When all the pieces are received by the SIP it reassembles the message.  A checksummed acknowledgement (i.e. one containing a checksum on itself) for the message is sent to the CCP by the SIP only if no error has been detected by the message checksum and the data is safely stored on the disk.  If the CCP does not receive a correct acknowledgement for the message within a specified time-out period, it retransmits all the pieces.  Occasional duplicate messages received by the SIP do not cause any problem since if it is a data message, the data will

simply be recorded over the first copy.

The CCP will eventually receive either a RFNM (Ready  for  Next Message)  or  an Incomplete Transmission message from its IMP or TIP for each of the  message  pieces  which  it  transmits  [5].    These Host-IMP  messages  are  discarded  becaus  of  the Class 3 Host-level acknowledgement    procedure.    Although    omplete    Transmission messages could be used to improve throughput, the added complication was judged inappropriate.  RFNM and Incomplete Transmission messages are likewise discarded by the SIP.

As indicated in section 4, the CCP  keeps  a  table  specifying those  messages  that  are  not successfully transferred to the SIP. This occurs when the data link is down for a period  for  which  the CCP  output  buffer  is not sufficient.  The CCP process which writes messages to the output buffer is in this case required to  overwrite the oldest message stored.  Tape backup, however, prevents any loss.

When the SIP successfully transfers the data on its disk to the Datacomputer it sends the CCP an appropriate Class 0 message.  These transfer status messages give the time code of the last data  sample transferred  and are recorded in a table in the CCP.  It is probably not necessary to store more than a  day  or  two  of  this  kind  of information, so the table will be quite small.

5.2 Error Recovery and Initialization

    To decide that the data link between the CCP and SIP is working
properly,  a  scheme  is  used  analogous  to  that used with a very
distant Host, the VDH-to-IMP circuit test procedure  [5].   Every  R
seconds  both  the  CCP  and the SIP independently send each other a
Class 1 (HELLO) message.  Whenever the CCP or SIP receives  a  HELLO
message,  it must respond with highest priority by sending the other
a Class 2 (I-HEARD-YOU) message.  The I-HEARD-YOU is a  Host-to-Host
acknowledgement  of  the  corresponding HELLO.  If either end of the
data path sends more than T consecutive HELLOs without receiving  an
I-HEARD-YOU acknowledgement, it declares the CCP-SIP data path to be
dead.  After declaring the path dead, it does not  send  or  receive
any  messages  for  2RT  seconds  to  allow  the other party also to
declare the path dead.

    After an end waits 2RT seconds, it attempts to reinitialize the
path.   This  is done by sending only HELLO messages every R seconds
until X consecutive HELLOs have been acknowledged  by  I-HEARD-YOUs.
After  X  HELLOs  in  a row have been acknowledged, the data path is
declared alive.  After the end declares the path alive,  a  Class  4
(reinitialization  control)  message  (see  section 3)  followed by
regular data messages can be sent by the CCP,  in  addition  to  the
periodic  (every  R seconds) HELLO messages.  If a control message is
received by the SIP before it  has  declared  the  link  alive,  the
message should not be acknowledged.

The value of R is initially 2, the value of T  is  5,  and  the
value  of  X  is 5.  The Network Control Programs of the CCP and SIP
should be designed so that it is easy to change these parameters.

Since the CCP can be on either the SDAC IMP or  the  SDAC  TIP,
the  SIP  must be prepared to try both Host addresses when trying to
bring up the data path.  It can do this by  sending  the  HELLOs  to
both Host addresses simultaneously.

At system startup the data path will be assumed  to  have  been
declared  dead,  and  the  procedure  for waiting 2RT seconds before
sending HELLO messages will be used for initialization.

## 6. References

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[4]   Texas Instruments Inc., Specifications for  Station  Controller
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[5]   BBN Report No. 1822, Specifications for the Interconnection  of
      a Host and an IMP, April 1973.