ENCLOSURE 2

RESEARCH TRIANGLE INSTITUTE

Review of Nuclear Data Link
Conceptual and Programmatic Framework

for

Research Support Branch
Office of Nuclear Regulatory Research
Nuclear Regulatory Commission

prepared by

Energy Systems Department
Research Triangle Institute
Research Triangle Park, NC 27709

August 1980

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1.0 FINDINGS

The Research Triangle Institute (RTI) has completed a review of the report "Conceptual and Programmatic Framework for the Proposed Nuclear Data Link" [4] prepared by Sandia Laboratories. In this section are summarized RTI's findings in the form of some general observations and specific recommendations about various aspects of the Nuclear Data Link (NDL). Following the list of findings are more detailed discussions of the technical areas outlined in the Work Statement to which this report responds.

1. Sandia National Laboratory personnel have been interviewed as resources for this report. RTI has found them cooperative, competent to deal with the NDL design and genuinely interested in its success.

2. The NDL definition is still under development with many functional issues still unresolved. This is particularly true of the data display aspects of the Operations Center, the communications network configuration and the interface with other emergency resonse centers (TSC, SPDS, EOF).

3. The interaction of the NDL with the TSC, EOF and SPDS from the point of view of functional coordination, and particularly data display coordination, is not adequate at this time for fully defining the NDL communications link.

4. RTI agrees a the 32-bit super-mini computer provides the appropriate level of computer resources for the Operations Center data operations.

5. RTI believes the central data processing option is preferable to the distributed option as described by Sandia.

6. RTI recommends contacts with vendors and potential vendors of systems for the TSC, EOF and SPDS in order to assess their potential impact on the NDL design.

7. An Operation Center Computer with a multitask operating system, and preferably virtual memory capability, is very important to the NDL implementation. Use of vendor supplied packaged software should be maximized where its performance is adequate.

8. RTI is concerned that the data acquisition interface with the plant site has been chosen as the "stand-alone" system as opposed to the "standard" system. The latitude thus allowed the licensee in data acquisition implementation is very great, and implications for loss of data integrity are serious.

9. The stand-alone approach to data acquisition will have a higher total cost to the public and the variety of interface problems over the system life, as well as during construction, will be greater.

10. The supply of data to "vendors" from the data acquisition system may present problems to the data acquisition subsystem if not carefully defined.

11. RTI agrees that the transient signal monitoring approach suggested by Sandia [4] is the only feasible approach and is adequate.

12. RTI agrees that the leased telephone line is the appropriate communications medium from the standpoint of cost and performance.

13. Careful consideration should be given to minimizing the telephone line charges by selection of the network topology. Major potential cost savings are involved, but reliability is also a factor. AT&T has a network computer program, NERCE, applicable to this.

14. RTI recommends that the site and Operations Center hardware be standardized to one vendor to the greatest degree possible in order to maximize long-term viability of the system.

15. The long-term viability of the NDL is judged to be satisfactory from a hardware/software viewpoint if adequate staff is provided for maintenance and design evolution. Viability from the viewpoint of the Executive Mangement Team utilization of the NDL is unclear at this time and depends on a continuing program of familiarization and training over the NDL life.

16. The NDL design should be examined based on a life cycle cost analysis in order to better define cost, performance and reliability tradeoffs that exist.

2.0 TECHNICAL ACTIVITY

2.1 Background

The Nuclear Regulatory Commission is in the process of defining functional criteria for four emergency facilities [1] aimed at improving emergency preparedness at nuclear power plants. The need for these facilities became evident in the aftermath of the accident at Three Mile Island Unit 2, and their creation is expected to provide the following improvements:

1. management and coordination of all support personnel and organizations having a response role;

2. availability of information needed to assess and manage an accident at a nuclear reactor facility;

3. continuous assessment of actual and potential radiological consequences;

4. provisions (through State and local agencies) for early warning and frequent clear instructions to the local affected population; and

5. provision of continuing accurate information to the general public.

One concludes that a critical aspect of these facilities is that they provide rapid communication of reliable and accurate data to the various parties at several locations involved in a nuclear accident in such a manner that the tendency for misunderstanding and confusion naturally attending such accidents is eliminated or minimized. A second critical aspect of these facilities is that they maintain their functional viability over many years, essentially for the life of the nuclear power industry.

The four emergency facilities are [1]:

1. Safety Parameter Display System (SPDS),

2. Technical Support Center (TSC),

3. Emergency Operations Facility (EOF), and

4. Nuclear Data Link (NDL).

The relationship and requirements for these four response centers were summarized in Reference 2 and included here as Table 2-1. The data communica-

Table 2.1. SUMMARY OF NRC REQUIREMENTS FOR EMERGENCY RESPONSE FACILITIES [2]

System	Location	Time of Operation	Prime Users	Minimum Data Requirements	Primary Functions
SPDS	Control Rm.	Continuous	Reactor Operators	Subset of Data Specifically Listed in RG 1.97*	-Monitor safety status of important plant -Displayed overall safety status -Provide alert signal if any safety parameter approaches an unsafe condition
TSC	Near Control Room	During Emergency & Recovery Operations	Licensee Mgt. & Technical Support Staff/NRC Site Team	All Data Specifically Listed in RG 1.97* plus site-specific Type A data Duplicate SPDS Displays	-Plant mgt. & tech. support for control room -Info. source for EOF & NRC -EOF functons until EOF is staffed
EOF	Near Reactor (10 miles)+	During Emergency & Recovery Operations	Licensee Mgt. & Technical Support Staff/NRC Site Team	All Data Specifically Listed in RG 1.97* plus site-specific Type A data Duplicate SPDS Displays	-Overall mgt. of licensee emergency response resources -Coordinate & evaluate actions having potential environmental impact -Coordinate with local, state & federal agencies -Public information
NDL	Nationwide	Continuous	NRC Executive Mgt. Team & Tech. Staff	Subset of Data Specifically Listed in RG 1.97*	-Independent Assessment -Assist licensee -Review & approve certain proposed licensee actions -Be prpared to direct certain actions -Provide information

+ Given as 1-3 miles in Reference [2].

* Those variables which are exclusively type A, and therefore not specifically listed in RG 1.97, are not to be handled by common data acquisition processor.

tions between these facilities are further defined by Figure 2-1 [1]. Information for display by these four centers is derived from a subset of plant sensors defined by NRC Regulatory Guide 1.97 [3]. These items will be referred to in the following discussions.

The primary interest of the investigation reported here is an assessment of the Nuclear Data Link conceptual and programmatic framework as defined by Sandia National Laboratory [4] for the NRC. The obvious interaction of the NDL with the other response centers will bring these into consideration as well. The level of effort expended in this RTI investigation was quite limited, and was structured to include:

- examination of the Sandia recommendation for the NDL [4] and the other referenced documents,
- personal interviews with Sandia Laboratory staff who conducted the NDL definiton study,
- consultation with a vendor of computer hardware and software exemplary of that proposed by Sandia,
- contacts with Bell Telephone sales representatives,
- consultation with other RTI staff with applicable expertise,
- consultation with faculty at North Carolina State University with expertise in computer applications and nuclear power plants, and
- discussion with Mr. Ron Feit of NRC, the RTI contract officer.

This approach was taken in order to bring as much expertise as possible to bear on the assessment (or critique) of the proposed NDL within the period of performance of the contract.

2.2 Work Statement

The Research Triangle Institute (RTI) has examined the Conceptual and Programmatic Framework for the Proposed Nuclear Data Link [4], as well as related documents, in order to provide an independent review of the concept with specific objectives as follows:

1. A assessment of the headquarter's computer size to best accomplish the Nuclear Data Link mission taking into consideration both hardware and software.
2. An assessment of the communication interface design problems at the reactor sites.

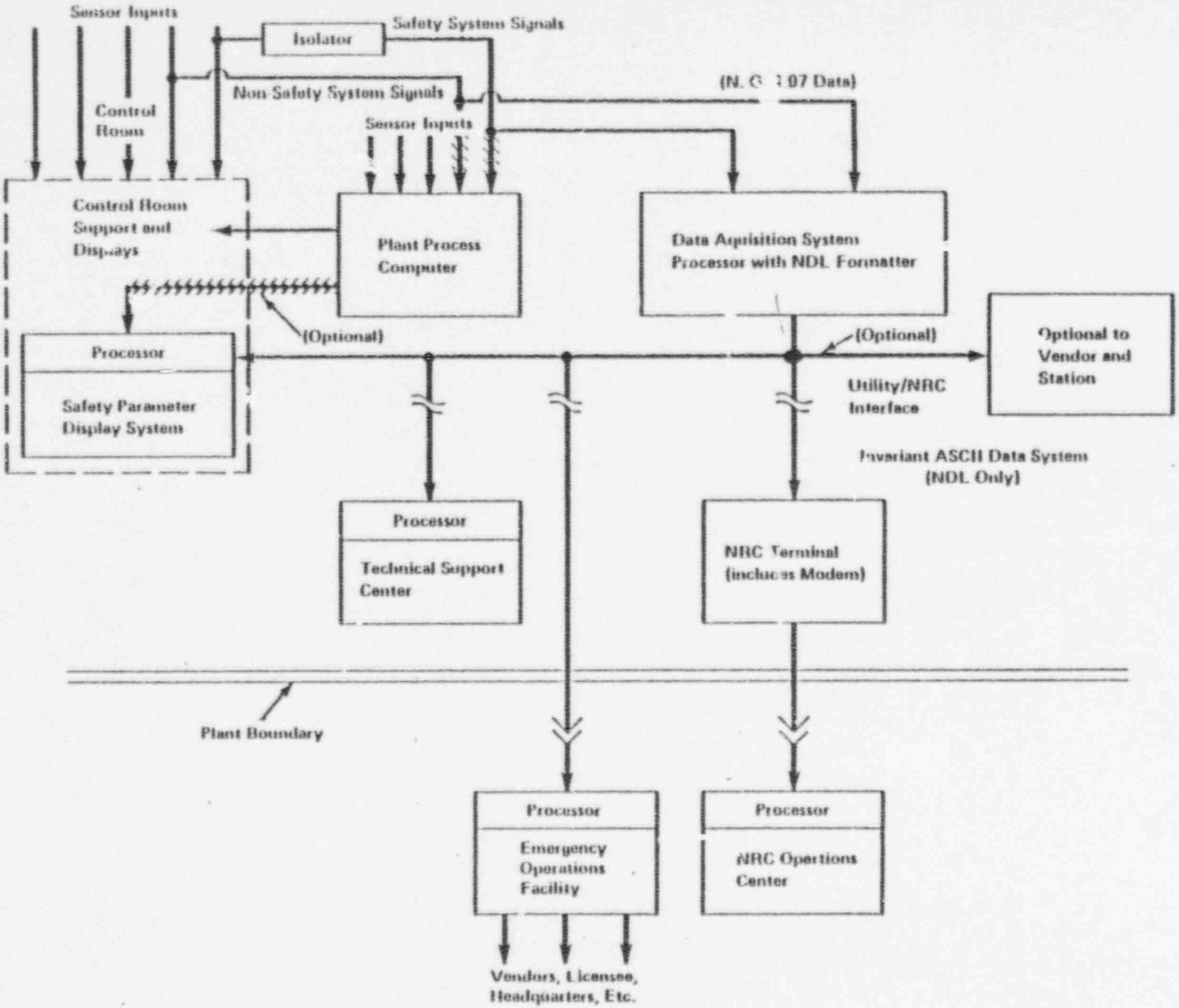

Figure 2-1. Functional Block Diagram of Emergency Response Centers [1]

3. An assessment of the potential problems of keeping the NDL operational after completion.

4. An assessment of the Sandia proposal to continually receive and store data using the headquarters computer versus the alternate concept of storing data at the site and transmission only during an emergency.

5. An estimate of the engineering (including software design) for the headquarter's computer system.

The following sections are organized to address these objectives in the above order. Additional related issues are included as appropriate.

The level of detail in this report is intended to reflect the approach taken and demonstrate the depth of the assessment by RTI. Extensive documentation of NDL background and technical tradeoffs is not feasible at the funded level of effort. Background is adequately covered by the references at the end of this report.

2.3 Work Element Discussions

2.3.1 Assessment of the NDL Operations Center Computer Requirements

The computer requirements are dependent on at least three major factors:

- volume and timing of data received from the sites,
- amount of data to be stored and the mode of short- and long-term storage,
- nature of the information display, the number of display formats, the speed of access to displays and the number of simultaneous displays.

The first point, data stream definition, is well defined, although some further modification as to number of sensors monitored may be made. Reference 4, Appendix A provides the "Preliminary NDL Specifications". From this specification and conversation with Sandia, the following are deduced.

Maximum Number of Reactors on NDL = 200

Maximum Number of Sensors per Reactor = 140

Average Number of Characters Transmitted Per Sample = 18

Average Sample Rate = 1/min.

This implies an average of 336 bits per second (bps) transmitted. This rate is easily handled by conventional telecommunications equipment and lines. Transmission rates to 9600 bps are conventionally available. Sandia suggests 4800 bps over leased telephone lines, probably one line per reactor site (e.g., the three Browns Ferry units would be handled on one line). With four reactors per line, the line capacity would be only 28 percent utilized, allowing possible increase in the number of sensors and overhead for communication diagnostics as required.

There is a cost tradeoff between data rate, equipment cost and leased line cost. For example, 1979 prices for one vendor's modems are:

T202T-L1/2 full duplex, asynchronous, 1800 bps	$ 460
T20C1-L1/2/4/5 full duplex, synchronous, 2400 bps	$1,285
T208A/B-L1B full duplex, synchronous, 4800bps	$2,685

The maximum cost difference would be between 1800 bps and 4800 bps with 200 reactors and a line for each, amounting to $890,000. The apparent saving of cheaper modems, would be offset by reduced telephone line charges if multiple reactors are served by a single line operating at the higher rate. The savings in modem costs are one-time savings, whereas the line charges are annual. For example, the line charge for a 1000 mile line is $873/month regardless of data rate. Increasing the rate from 1800 to 4800 bps increases hardware cost by $3,005 (a $1,700 multiplexer must be used for the 4800 bps configuration) but reduces line charges by $1,746/mo. Therefore, where multiple reactors occupy a site, higher transmission rates and lower line costs are potentially attractive. Careful examination of the communication system should be carried out in detail since cost savings are possible. The issues of transmission error rates and standardization of hardware also must be considered in making these tradeoffs.

The aggregate data rate seen by the Operations Center computer based on the above numbers is 67200 bps with 200 reactors. This can be handled by conventional computer hardware configured as shown by Figure 2-2. This complement is assembled from hardware and software compatible modules manufactured by Digital Equipment Corporation. It is provided here as an aide to discussion only and not as a recommendation. This system is based on a VAX11-780 32 bit main processor, three PDP-1134A front-end processors to handle data communications and necessary display, storage and communications peripherals. The plant site data acquisition and communications system is shown as a "standard" system [4]. The central processor must handle the

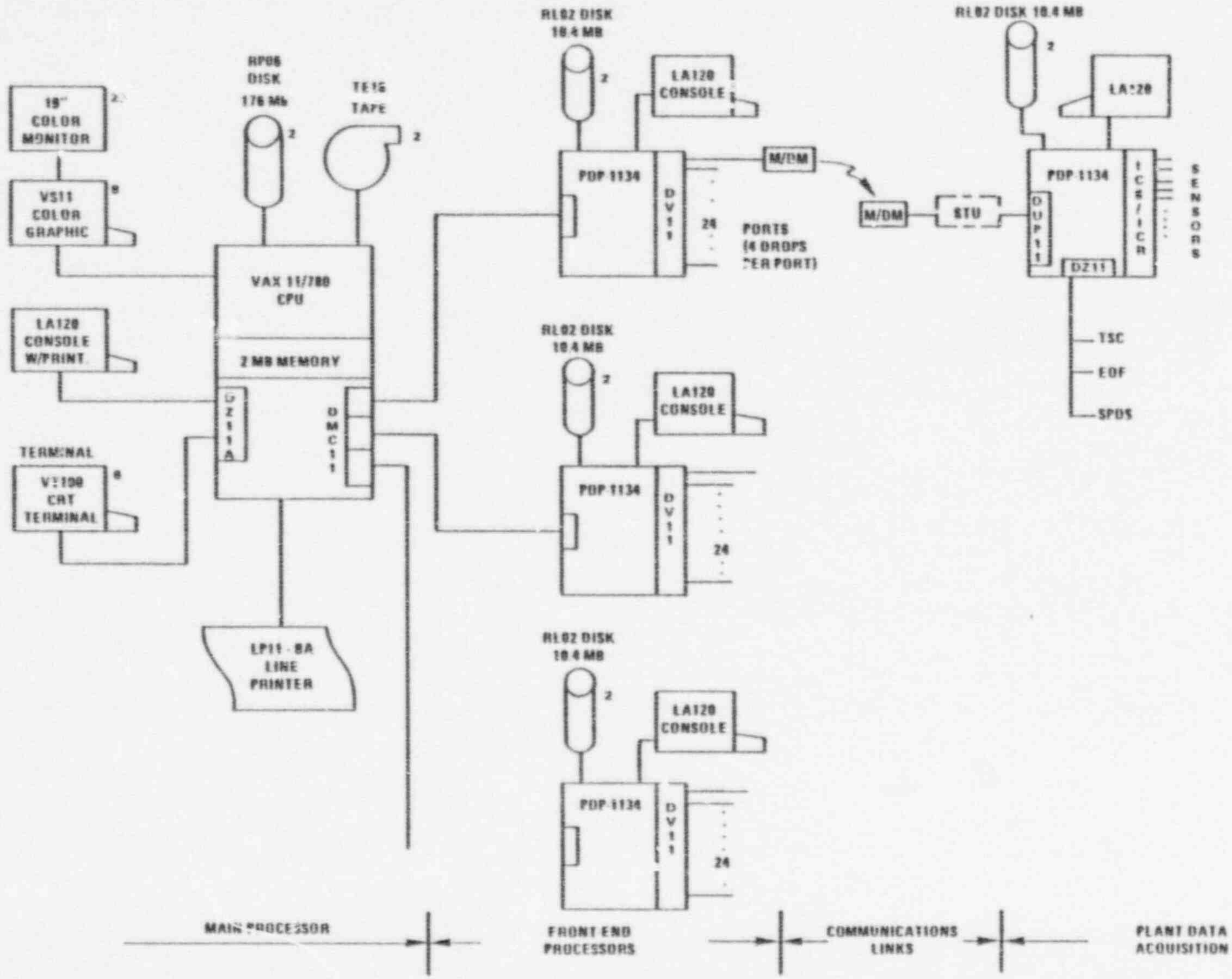

Figure 2-2. Example NDL Hardware System (DEC Equipment)

aggregate data stream and store the data in a manner suitable for retrieval and display. Checks of the data for consistency and validity are also necessary and represent additional load on the central processor. Assuming that the front-end processors handle data formatting, error handling, retransmission requests, polling, etc., the central processor load can be examined.

Assume that the front end processor will compress each reactor sensor reading into a data set, to be transferred into the VAX memory by a Direct Memory Access (DMA) channel. The 18 characters are assumed to be compressed into five words. Each DMA transfer of 140 points then requires 700 words. Coming through a UNIBUS port on the VAX, this will require about 3.5 ms. With 200 reactors on line, the DMA will be busy seven milliseconds out of each minute. The internal bus of the VAX is over 10 times this fast, so memory loading due to DMA is negligible.

A simplistic view of event monitoring would be to assume that for each reactor each reading is checked against a table. If inside limits, a transfer to disk is initiated; if outside, a monitor task is activitated (using the system WAKE facility) and a disk transfer initiated. There is not a significant amount of calculation involved in this process. Assuming 100 instructions per sensor reading in the normal case, and a worst case instruction time of one microsecond (which does not consider the fact that the VAX has instruction look ahead, memory interleaving, and a cache), this calculation will require 2.8 seconds of CPU time each minute.

Using RP06 or RM03 disks on the VAX, a transfer of 700 words would require six blocks of 512 bytes each. Studies by Dr. Fornaro at NCSU on their VAX have shown that CPU overhead on simply structured data files is negligible compared to disk latency time. Assuming worst case conditions for the RM03 or RP06, we have an average 8.3 ms latency. Worst case is that it is impossible to concatenate disk writes onto consecutive blocks, and that the system must wait, on the average, one half rotation to have the disk in position for each of the six blocks in a message. For six blocks per plant, with 200 plants, latency requires 9960 ms per minute or about 16 percent of the time. Write time is also negligible. Based on these numbers, one can see that the VAX has adequate capacity to perform the monitoring of all 200 plants and has significant additional capacity for other functions such as data retrieval and display.

Data storage at the Operations Center for the required 30 minutes of data from each plant requires about 15 Mbytes with the previous assumptions of 200 reactors and 140 sensors per reactor. This is well within the disk capacity shown in Figure 2-2. The 2 weeks of data to be stored after an event for two plants (per the original specification) would require about 7.25 Mbytes. This is still well within the bulk storage capacity shown. The two RP06 disks provide redundancy in case of disk failure. Disks and other peripherals with moving mechanical elements are generally less reliable and subject to more maintenance than processors and other purely solid state elements. The TE16 tape drives can be used to archive data for long-term storage. Tapes are also useful as a software and data exchange medium with the software vendor and other computer centers.

The most strenuous requirement for CPU and peripheral resources will be associated with data display. However, these display requirements have not been defined sufficiently at this point to determine processor requirements. An opinion is, however, that the configuration suggested by Sandia [Ref. 4, pg. 78] is probably adequate, and is consistent with Figure 2-2. The data retrieval and storage requirements need to be more carefully defined before the final configuration is specified.

Cost of the NDL Operations Center computer was estimated by RTI using the configuration of Figure 2-2. Cost figures are broken down in Table 2-2. The total cost of $852,089 includes the front end processors and communications interface for up to 200 plants. Actually there is a maximum of 288 single plant interconnections possible, but it might be advisable to consider one PDP-1134 as a spare (or out of service for maintenance) so that 192 reactors could be accessed at one time. The hardware shown here assumes up to four drops (plant terminations) per hardware port at the Operations Center. This requires a communications protocol that is suitable to that arrangement and computer software to manage the communications. Such software is available, DECNET being the one for the hardware configuration shown.

2.3.2 Assessment of the On-site Communications Interface

There are a number of issues which impinge on the best selection of the communications interface at the plant site. Some of the issues of communications between the plant and the NRC Operations Center were addressed in Section 2.3.1, and these will be further considered later in this section.

TABLE 2-2. EXAMPLE OPERATIONS CENTER HARDWARE COMPLEMENT AND COST BREAKDOWN

I. Main Processor (1 Required)	
VAX 11/780 (SV-AXCVB-CA)	$217,300
1-MB Memory	
1-RP06 Disk (176 MB)	
1-TE16 Tape Cont. and Drive	
1-DZ11-A Asych. MUX (8 line)	
1-LA 120 Console	
VMS O/S	
Additional Peripherals	
1-MB Memory (MS780-DB)	$ 13,900
1-RP06 Disk (REP 06-AA)	$ 44,000
1-TE16 Tape Drive (TE16-AE)	$ 12,800
1-LP11-BA Line Pinter (LP11-BA)	$ 8,400
8-VS11-Color Graphics Term. (19", Single Image) (VS11-AP) @ $14,200	$113,600
6-VT100 CRT @ $2,050	$ 12,300
6-DMC11-AL Network Link @ $1,700	$ 10,200
6-DMC11-MA Network Link @ $1,200 ea.	$ 7,200
3-BC03N-A0 Cable @ $130	$ 390
	$222,790
DEC Software	
VAX-11/Fortran IV-Plus (QE100)	$ 5,800
DECNET/VAX (QED01)	$ 3,100
PDP-11 DATATRIEVE/VAX (QE105)	$ 2,600
	$ 11,500
Additional TV Monitors	
23-19" Monitors @ $300	$ 6,900
Main Processor Total	$458,490
+ Install SV-AXCVB-CA	$ 6,519
II. Front-End Processors (3 Required)	
PDP-1134A (SM-30MMA-CA)	$112,200
256 Kb Memory	
2-RL02 Disks (10.4MB)	
1-LA120 Console	
RSX-11M O/S	

(continued)

TABLE 2-2. (continued)

II. Front-End Processors (continued)	
<u>Interprocessor Communications</u>	
6-DMC11-AL/MA (included in main processor peripherals)	
6-DV11-AA Multiline Interface @ $5,200	$ 31,200
9-DV11-BA @ $4,250	$ 38,250
72-BC05D-25 Modem Cables @ $105	$ 7,560
<u>Software</u>	
Fortran-IV/RSX-11M (QP230)	$ 1,000
Decnet-11M (QJ684-AH)	$ 2,550
<u>Front End Processor Total</u>	$193,760
III. Modems (NRC Operations Center Only)	
<u>T208 A/B Modem @ $2,685</u>	
<u>Number depends on communications architecture, e.g.</u>	
72-T208 A/B	$193,320
36-T208 A/B	$ 96,660
IV. Total Cost (NRC Operations Center)	
<u>Main Processor + Installation</u>	$465,009
<u>Front End Processors</u>	$193,760
<u>Modems (72)</u>	$193,320
	$852,089

But first, the on-site data acquisition and communications interface are considered. Both data acquisition and communications interface are included as a single subject here because from a technical point of view they are inseparable, as is or will be apparent.

Sandia described two basic configurations for the on-site subsystem in Reference 4: (1) the stand-alone subsystem, or Option 2 in Appendix D of Reference 4, including the Site Transmission Unit (STU); and (2) the standard system, or Option 1. The stand-alone option is recommended by Sandia. A third option consisting of essentially no NRC equipment in the plant was also considered [Ref. 4, pg. 31] and rejected for the very valid reason that it did not provide an acceptable degree of control and uniformity in communications protocol. The following discussion centers around the stand-alone and standard choice.

First, observe that while Reference 4, page 31, indicates that the STU is a part of both options, the hardware implementation is significantly different. The point is that the STU does not exist as a <u>separate</u> hardware item in the standard option, since its functions can be performed by software and hardware integral to the data acquisition component. A separate modem is necessary in either case. The division of responsibilities between NRC and the licensees are adequately stated by Sandia and reproduced here as Table 2-3. More specifically, Appendix D of Reference 4 addresses the choice with considerable insight and summarizes the arguments with Table D-1 which is reproduced here as Table 2-4. Using those arguments as a base, the choice of plant subsystem needs to be examined further. Three basic factors are involved in the decision.

- Cost--the NRC would like to keep its own cost for the NDL down,
- Administrative--the NRC wants to maintain a posture of regulatory involvement only with the licensees and avoid any technical interference,
- Technical--the timeliness and integrity of the NDL data over the system life are essential to its usefulness by NRC in assessing the seriousness of an event.

Considering the first point, cost, Sandia estimated [Ref. 4, pg. 145] that the standard option "will cost the NRC approximately $10 million more than (the stand-alone option) for development and operation through FY83 . . . however, we believe that the total licensee costs to develop (the stand-alone

TABLE 2-3. DIVISION OF NRC/LICENSEE RESPONSIBILITIES

Option	Responsibilities	
	NRC	Licensee
1. Standard Data Acquisition System	1. Specify space, power air conditioning and signal-input requirements for the Data Acquisition System Verify licensee compliance with specifications	1. Provide space, power, operating environment, input signal interconnects, and appropriately isolated sensor signals.
	2. Design and procure combined data acquisition and communications control equipment.	2. Supply sensor calibration and conversion factors.
	3. Develop and verify standard and unique software to acquire, condition, format, and transmit data from each site.	3. Maintain calibrate and test sensors.
	4. Prove-in, operate, and maintain all data-acquisition and communications equipment.	4. Notify NRC of inoperative sensors, or of sensors under test.
	5. Document, maintain, and update software.	
	6. Respond to changes in sensor status.	
2. Stand-Alone Data Acquisition System	1. Specify standard data format and interconnect requirements. Specify sampling interval, accuracy, range, etc. Verify licensee compliance with specifications.	1. Develop, procure, and install a Data Acquisition System with output to meet data format and interface specification.
	2. Develop, procure, and install a standard Site Transmission Unit for each site.	2. Develop or procure, and verify software for data acquisition, conditioning, calibration, and formatting.
	3. Develop and verify software for transmission and communication protocol control.	3. Operate and maintain the Data Acquisition Sytem to assure data availability.
	4. Monitor system status.	4. Update Data Acquisition System software (or hardware) as required in response to sensor status or NDL expansion and modification.

TABLE 2-4. COMPARISON OF SITE INTERFACE OPTIONS [4]

Criteria	Option 1- Standard Data Acquisition System	Option 2- Stand-Alone Data Acquisition System
Cost (NRC, licensee, total)	Cost to NRC is higher; cost to licensee lower because of software and equipment standardization; Total cost is lower because licensees do not duplicate efforts.	NRC cost lower because it provides only the STU. Licensee's cost higher because he must furnish and develop the data acquisition system.
System reliability	Probably higher because NRC controls design, and because it is a standardized unit.	Since each site may have unique hardware and design, reliability over the long term depends on ability of licensee and vendors.
Expandability, with emphasis on deferred NRC functions.	Close cooperation of the NRC and unit designers will help incorporate features for expansion.	Depends on licensee resources and approach.
Testing and software verification	As a dedicated and centrally controlled system, it will be far the easier to isolate from the reactor and verify from the Operation Center.	May not be designed to test from the Operation Center.
Maintenance	As a standardized unit, should be stockpiled, repairmen can be specially trained, etc.	Depends on ability of licensee. Might have the on-going experience to repair the unit easily.
Interface with the site or NDL-STU	The more complex, requiring large number of physical connections and consequent detailed electrical and terminal definitions.	Requires a complex and detailed specification to provide basis for design and software. Connection its fairly simple using the RS-232-C interface.
Implementation difficulties	Probably more difficult from the NRC poit of view; more complexity of equipment; considerable detailed involvement with licensees.	Clear interface point with STU should simplify implementation. Still involves considerable involvement with licensees regarding specification implementation.

option) will greatly exceed the estimated NRC saving because of the large amount of duplicate work that will be done as each licensee implements his own data aquisition system." The $10 million figure is an acceptable estimate and RTI concurs in Sandia's conclusion of total cost. Since the licensees' customers will ultimately pay the cost of the NDL in any case, either as taxes to support the NRC or as revenue to the licensees who operate as regulated monopolies with guaranteed rates of return on investment, the least total cost NDL is the preferred one. Argument for the least cost system to NRC must be based on institutional issues between NRC, the Congress and the licensees.

The second factor, that of administrative posture by NRC towards the licensees, is a valid consideration. NRC is a regulatory agency and has no charter to operate nuclear power plants. NRC apparently is reluctant to place equipment in the plant because it would mitigate its regulatory posture. Three points are pertinent here. First, NRC is placing inspectors in all of the plants and stationing them in the control rooms. While this does not imply anything beyond a regulatory presence, the NRC presence at the plant site is established. Second, either the stand-alone or the standard option will require equipment in the plant, and so the difference is only a matter of degree. Third, the administrative problems associated with the stand-alone system can be as significant as for the standard option. The NRC/plant interface for the standard option is at the sensor isolation point. This means that NRC interacts with the plant to obtain information on the status of sensors (in or out of service, recalibrated, replaced, etc.,) which are primarily interchanges of technical information about hardware. The NRC/plant interface for the stand-alone system is a single serial, digital data line and would appear simpler from an administrative interaction point of view. However, sensor status is still necessary for NRC interpretation of the received data, and although some of this can be included in the data stream, some cannot (e.g., why is the sensor inoperative, when will it be returned to service, what are the alternatives for safety assessment in the meantime.) The important aspect of data integrity lost to NRC by the stand-alone option is that of priority in an emergency. Access to the data in either option is controlled by software, but in the stand-alone option the licensee defines the software. At least one manufacturer is reported to be developing a system in which all information functions for the TSC, SPDS, EOF and NDL data acquisition will reside in a single computer. It will be necessary for NRC to ensure that adequate processing capacity and software priority is provided by this licensee system in order to assure timeliness of the NDL data. This administrative (or regulatory) problem may be equal to or greater than that associated with the standard option. Moreover, computer-based systems tend to evolve and change on a near-continuous basis, and this implies that the administrative interface will remain for the life of the NDL for either option. As Sandia notes [Ref. 4, pg. 148], "the NDL must be able to deliver accurate and reliable data in an emergency. The transducers and data acquisition system . . . provide the basic data input. As a result, proper implementation of the NDL depends heavily on the design of the data acquisition subsystem."

The third factor in plant subsystem choice is the technical one. Viewed from a purely technical perspective, the stand-alone and standard options are actually the same if the data acquisition processor has adequate capacity. Either one of the options can provide the data required. On-site hardware maintenance requirements for the standard option will be somewhat higher, but design features still to be determined for the STU and for the overall communications network may obviate some of the differences. For example, some diagnostic operations might be initiated from the Operations Center so that routine maintenance would be reduced. The functions and hardware of the STU are still being defined, but if it were defined as in Appendix C of Reference 4 the functional elements would differ only in capacity from the data acquisition system of the standard option (i.e., both contain a processor, memory, printing terminal, modem.) In the final analysis, the basic technical issue may be the definition of the on-site system in terms of whether or not it requires on-site maintenance and operational support.

A separate but related issue in the communications area is the selection of the communications network topology for the NDL. The baseline design of Reference 4 calls for a dedicated, four-wire duplex line from each STU to the Operations Center. RTI's early reaction was that a less expensive and more reliable topology might be in order. Subsequent conversation with Terry Unkelhaeuser at Sandia indicates that Sandia's investigation has been more detailed than shown by Reference 4 and is currently being documented [5]. In order to illustrate the tradeoffs in cost and reliability, Figure 2-3 shows a network for five reactors on the West Coast (only one of those at San Clemente has an operating license). The lines designated A, B, C, D, and E would constitute a simple radial network and each reactor would be dependent on the

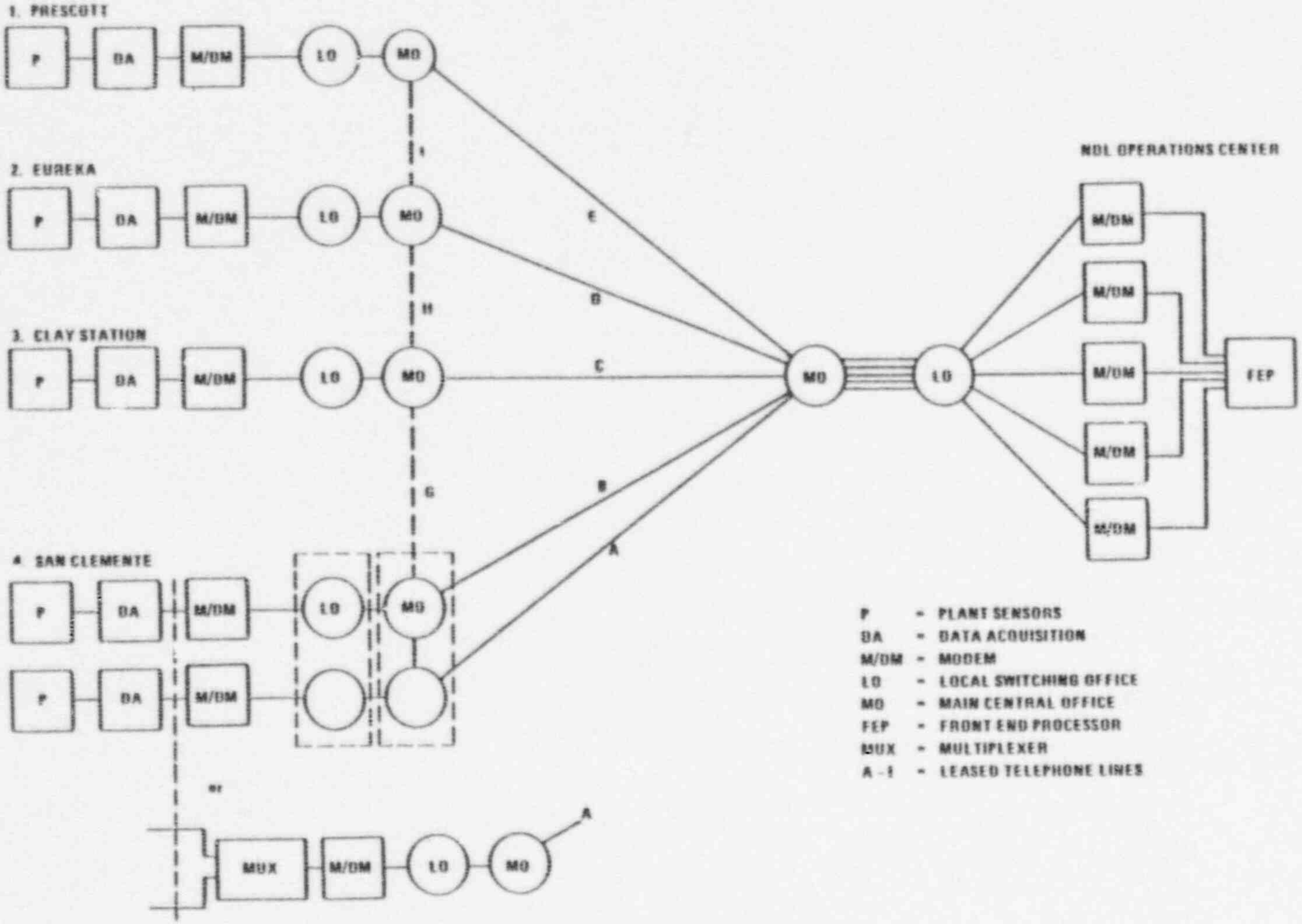

Figure 2-3. Communications Topology Example

elements between the plant, P, and the Operations Center, FEP. There is actually only one main office (MO) and local office (LO) serving the San Clemente site, and so it is possible to eliminate the long-line B by multiplexing the two reactors onto one line. Saving the line cost in this manner means that if the multiplexor or modem fails, two plants rather than one are unavailable. A second network possibility is the multidrop in which the lines A, G, H, and I are used and considered a single long-line for costing purposes. Each reactor site is then a "drop" off the line and so is the Operations Center end of the line. This can save cost on leased line charges as shown below. Finally, the line E can be added to the A, G, H, I line to form a ring network.

The cost for leased private lines associated with the radial, multidrop and ring are summarized by Table 2-5. Note that the multidrop network costs only about one-third as much as the radial network for the four sites considered. All sites are dependent on line A, however, and the reliability would appear reduced. However, at some small cost in modem hardware, a capability for connection through the long-distance direct-dial network can be provided as a short-term back-up so that not much reliability will be sacrificed. Also, while Figure 2-3 does not illustrate it, four modems at the operations center are eliminated at an estimated cost of $10,740. However, the present value of the savings of $4,590 per month ($55,080/year) is almost $370,000 (assuming 10 year life, discount rate of 8 percent). Line charge savings are thus the more important aspect.

The ring network provides two paths to any site by connecting through either line A or line E. Thus, if line G is disabled, sites 1, 2 and 3 communicate through E, I, H and site 4 through A. The line cost savings is only $2,509/mo. but this has a present worth of over $202,000. The ring network might also employ the dial-up back-up, though less reliability gain is provided.

Some software complexity is added by the multidrop and ring networks and this must be considered. Also, the example of Table 2-5 is probably an extreme in that most nuclear reactors lie east of the Mississippi River and most of the lines would be shorter than those of the example and savings would be less. Also, the number of multidrops on a single line is limited by the transmission rate and by the software considerations so the maximum reduction in the number of long lines is probably a factor of three or four.

TABLE 2-5. EXAMPLE TELEPHONE LEASED LINE COSTS

I. AT&T Private Line Rates*

Over 100 miles, less than 1,000 miles:
$252.54/mo. + $0.69/mo. for each mile over 100

Over 1,000 miles:
$873.54/mo. + $0.42/mo. for each mile over 1,000

Each local drop on line: $26.30/mo.

*Schedule 2. Lines from rural to urban area.

II. Estimate Mileage for Four Sites (site to Washington, DC)

Site	No. Reactors	Mileage
1. Prescott, OR	1	2,875
2. Eureka, CA	1	3,000
3. Clay Station, CA	1	2,875
4. San Clemente, CA	2	2,750

III. Radial Network Charges

Site 1: $873.54 + 0.42 (1,875) + 2 (26.30) = $1,713.64
Site 2: $873.54 + 0.42 (2,000) + 2 (26.30) = $1,766.14
Site 3: $873.54 + 0.42 (1,875) + 2 (26.30) = $1,713.64
Site 4: $873.54 + 0.42 (1,750) + 2 (26.30) = $1,661.14
$6,855.00/mo.

IV. Multidrop Network Charges (4,000 total miles)

All Sites: $873.54 + 0.42 (3,000) + 5 (26.30) = $2,265.00/mo.

V. Ring Network Charges

All sites: $2,265 + 8.73.54 + 0.42 (2,875) = $4,346.00/mo.

What the example points out is that the dollars involved are not inconsequential and that optimization of the network for cost and reliability is worth some effort. A computer program called NERCE is available at AT&T and they will run it where reasonable chance of business is apparent.

2.3.3 Assessment of Long Term Viability of the NDL.

"Long term" in the case of the NDL is taken to be at least 20 years and perhaps 50 years. It must be recognized that over that period evolution in nuclear plant design, regulatory concerns, computer hardware and software capability, and public opinion may cause many, if not continuous, revisions of the NDL.

Long term viability depends on two broad areas of consideration: (1) the long term viability of hardware and software and (2) the ability to maintain trained staff who have the necessary proficiency to function effectively in an emergency using the NDL as their information source. The hardware and software viability is easier to manage than the personnel viability. Hardware and software diagnostics can be manually and/or automatically initiated and problems diagnosed and repaired. The operation of the computers and communications lines can be verified by specified procedures. Given the high reliability of electronic devices, the viability of the system equipment is not viewed as a serious technical problem. There are several considerations which can improve the long term viability of the NDC, however.

1. Purchase of hardware and utility software from a reputable vendor who is likely to be in business for a long time is advantageous. This allows the NDL to take advantage of updates in software and hardware with minimal impact on performance. It also provides maximum availability of spare parts, and access to vendor field maintenance organizations as appropriate.

2. Standardization of hardware even at some added initial cost in order to reduce the complexity of maintenance problems and spare parts inventories. Communications between processors and peripherals are carried out at very high speeds and with complex protocols. Isolation of problems between different vendors equipment is often more time consuming and may require sophisticated in-house maintenance personnel at NRC. Maintenance staffs with adequate training are expensive and turnover can be significant if salaries are not kept competitive.

3. Use of commercially available software packages as opposed to specialized software should be maximized. Use of Higher Order Languages as opposed to macro or assembler languages should be maximized. Over the long life of the NDL, changes in the system

and changes in personnel associated with the NDL are inevitable. Higher Order Languages are largely self documenting if properly used and documentation will become very important as personnel change. Adherence to these ideas will reduce future costs associated with system evolution by allowing use of purchased software packages and reducing applicati_ıs programming effort.

The question of long term viability of staff is a more difficult one. The NDL is perhaps analogous to the airport fire department. It may exist for years without a crash occurring with nothing to do but polish the brass and make practice runs. Yet, many lives may denend on high proficiency of personnel when the rare crash occurs. Keeping the personnel interested in their job and technically proficient in the face of turnover is not trivial. In the case of the NDL, the very high skill leval required of maintenance personnel and system operators probably means they are not the NRC staff w ' will be called on for judgments about plant safety in an emergency (i.e., the Executive Management Team.) Therefore, a cadre of NRC staff trained to know the NDL capability, to communicate effectively with the system operators and to judge the plant situation will be even harder to maintain. These people will not even have the maintenance and enhancement of the NDL to hold their interest over the years.

The question arises as to what will be the function of the NDL, particularly the Operations Center, on a dav to day basis beyond receiving and storing 30 minutes of history for each reactor. This question has not been addressed by NRC so far as RTI knows, and it lies at the root of the long term viability question. Unless a training program is established and maintained and proficiency monitored, no one will know the viability of the NDL after a few years without an accident. Several obvious functions that can be carried by the NDL/OC to aid in maintaining viability are

- development of accident scenarios for training of NRC emergency management staff,
- development of correlations between measurements as indicators of unsafe operating conditions,
- archiving of data from various operating excursions for use by NRC and licensees,
- enhancement of data displays through application of human factors engineering to improve communications between NRC and licensee staff.

2.3.4 Assessment of the Distributed Versus Centralized Data Processing Options

Sandia presented two options for "data processing" [Ref. 4, pg. 55 and Appendix C]. In the centralized option the NDL/OC continuously receives data from the reactor site, reformats it for insertion in the data base and checks the sensor values to determine if an event is indicated. In the distributed option, the data are examined by the site-based equipment (STU) to determine if an event has occurred. If so, the STU begins to transmit the 30-minutes of history and current readings to the Operations Center.

There are no strong technical requirements that argue for distributed processing. Average data rates for the system are low and even with multidrop networks the leased lines provide adequate capacity. Therefore, storage and processing on-site are not required by the communications network. The capacity of the Operations Center front-end processors and main processor are adequate to handle the data and provide other functions, so that additional on-site processing is not requried.

Because of the large number of sites in the communications network and the hardware included in that network (modems, STUs, telephone company communications links, etc.), maintaining continuous, reliable communications will be one of the larger continuous efforts in the NDL operation. It is imperative that the communications lines be kept in service and the only way that condition can be verified is to transmit information across them. Therefore, the information may as well be actual plant data since the data do not stress the communications capacity.

There are some reasons for wanting to have some limited storage and processing capability at the sites. In the first place, a limited capability is needed to handle the communications protocol, allow for retransmission and diagnose errors. If multidrop or ring networks were implemented, the communications protocol is more complicated and higher on-site capability is needed. Also, given the potential for all communication to be disrupted temporarily, then some storage (and the processor required to manage it) would be useful on-site to preserve data that would otherwise be lost. Another option, of course, would be for the data acquisition processor to store such data.

The argument for on-site processing and storage can be turned around to say that should an event occur at a plant while the communication link is interrupted, it would be advisable to have as much recent plant history as possible at the Operations Center. This argues for continuous data transmission and processing at the Operations Center.

Finally, it should be noted that the Operations Center will have to be capable of receiving data and inserting it in a data base, managing that data base, generating displays from the data and processing messages. All of these are required during the period of an event, and since they must exist, the Operations Center will be more viable and more reliable if those functions are carried out on a continuous basis.

In summary, there are valid reasons for providing a limited data processing and storage capability on-site, but the normal mode of NDL operation should be central data processing and storage with continuous (i.e., each data sample set as acquired) transmission of data to the Operations Center.

2.3.5 Assessment of Estimates of Operations Center Engineering Costs

Estimation of manpower for implementation of the NDL is a difficult task because the system definition is still evolving. A significant portion of the cost is associated with definition of functional requirements and software development to implement those requirements. Software cost estimating is a notoriously imprecise procedure unless definition is first done in considerable detail. RTI feels its level of involvement is not sufficient at this point to make an accurate, independent cost assessment. RTI has reviewed with Sandia personnel the basis for their estimates and offers here some comments based on intuitive judgments.

The Sandia estimate of cost [Ref. 4, Table V-2] is reproduced as Table 2-6. In Table 2-6, the total project manpower is 116 manyears. Conversations with Sandia indicate that six manyears was estimated for an NDL-Phase 2 concept study, leaving 110 manyears directly for the NDL system. Additional documentation provided by Sandia relating to the breakdown of this 110 manyears is provided as Table 2-7 (slight differences in figures are due to round-off). These estimates are totals for three years including estimates of non-Sandia (contractor) manpower. A manyear of Sandia time was estimated at $70K and a contractor manyear at $60K. In computing dollar costs for manpower a contingency factor of 1.5 is included. Thus, for personnel costing $60-70K,

TABLE 2-6. ESTIMATED NDL COSTS

Category	Cost Estimate ($K)				
	FY80	FY81	FY82	FY83	Total
I. Engineering and Proj. Mgt.					
Manpower (manyears)	1,350 (20)	3,100 (42)	3,500 (44)	900 (10)	8,850 (116)
Travel	100	700	550	100	1,450
Sub-Total	1,450	3,800	4,050	1,000	10,300
II. Equipment					
Operations Center	850	450	0	0	1,300
[illegible]U's	50	1,300	250	0	1,600
Sub-Total	900	1,750	250	0	2,900
III. Operation and Maintenance	--	300	1,800	2,230	4,330
IV. Contingency	500	2,100	2,300	500	5,400
TOTAL	2,850	7,950	8,400	3,730	22,930

TABLE 2-7. SANDIA MANPOWER ESTIMATE FOR NDL

Function	Sandia	Contractor	Total
Operations Center	13.6 (20.4)	12.1 (18.3)	25.8 (38.7)
Site-Based Equipment	10.9 (16.4)	12.2 (18.3)	23.1 (34.7)
Reactor Experts	5.5 (8.3)	2.5 (3.7)	8.0 (12.0)
Technical Program Mgmt.	2.8 (4.1)	2.5 (3.7)	5.3 (7.8)
NRC Interface	5.5 (8.3)		5.5 (8.3)
Project Engineers	21.8 (32.7)		21.8 (32.7)
System Documentation	2.8 (4.2)		2.8 (4.2)
Oper. Document, Training	2.8 (4.2)		2.8 (4.2)
Q/A, Hardware Software	2.8 (4.2)		2.8 (4.2)
Purchasing	2.8 (4.2)		2.8 (4.2)
Clerical		2.5 (3.7)	2.8 (4.2)
Install		7.3 (11.0)	7.3 (11.0)
	71.3 (107.0)	39.2 (58.7)	110.5 (165.7)

(Includes Contingency of 50%)

the total manpower estimate is about 165 manyears if the contingency is included and expressed as manpower. These figures are given in parentheses in Table 2-7. Table 2-7 shows that by far the largest efforts were estimated for the Operations Center, 25.8 (38.7) manyears, the Site-Based Equipment 23.1 (34.7) manyears, and project engineers, 21.8 (32.7) manyears.

Based on discussion with Sandia after examining these and other breakouts, it is RTI's feeling that the manpower estimates are conservative, particularly when the contingency is included. The estimated cost might conceivably be reduced if, as the system becomes better defined, options are taken which will keep software complexity down and maximize the standardization of hardware, particularly in the plant interface.

ENCLOSURE 3