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ADVANCED SYSTEMS FOR SHUTTLE LAUNCH PROCESSING

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#### ACKNOWLEDGEMENT

I would like to express my appreciation to NASA/ASEE for allowing me to spend these ten weeks working on the very interesting and challenging problem of identifying advanced technologies which could be effectively used in the design of a new shuttle launch processing center and to thank Mr. Richard Hurt for selecting me as a member of the group charged with that responsibility. I am very much indebted to Mr. Richard Dawson for orienting me around the Kennedy Space Center, providing me with a place to work, and helping me to focus the information that I gathered on advanced technologies on the unique problems faced by the space program. I would also like to thank other members of the team, Barbara Brown, Ben Bryant, Carl Delaune, Warren Lackie, Chuck Lostrocio, John Moore and James Sudermann for sharing their knowledge with me during all the meetings that we had and for making me feel welcome.

#### ABSTRACT

Four advanced technologies that could be used in a new shuttle launch processing center are described. The latest methods for high capacity data storage technology, disk arrays and magneto optical disks, are described and their advantages and disadvantages compared. A 3-D protein based optical memory, now being researched, is also described as a possible future technology for data storage. An overview of neural network technology is presented together with several commercial software development options now available for neural network applications. The feasibility of Asynchronous Data Transfer technology as the networking technology to integrate video, voice, and data in a new launch processing center is also considered. Different applications of expert system technology at KSC are enumerated together with a number of commercial expert systems development packages presently available.

## SUMMARY

This report describes the following advanced technologies which can play an important role in a new design for the shuttle launch processing center at KSC: high capacity data storage, neural networks, asynchronous data transfer and expert systems.

The latest high capacity data storage technology today consists of disk arrays and magneto optical disks. Each is capable of storing more than the 1.3 Terabytes of data that it is estimated constitute today NASA's requirements for launch related data. Disk arrays are more expensive than magneto optical disks but they provide faster access to data, although it is expected that the access speed for optical disks will decrease within a year or two. Disk arrays make all of the data available online, while a jukebox of magneto optical disks may provide only about 4 gigabytes of online data. It is quite possible that a storage system that combines both of these technologies, i.e. disk arrays for critical data that must be accessed quickly and optical disks for the rest, may provide a good solution for storing data in a new launch processing center.

Neural networks software has been successfully used for a variety of problems. This technology is most effective for problems where the relationships between cause and effect have not been explicitly identified but where there is sufficient historical data from which to learn these relationships. Neural networks can be retrained quickly to learn new relationships and therefore can also be effective for problems that frequently change. A number of software vendors provide reliable and effective development packages for neural network solutions which can execute on Dos, Windows, Mac, or Unix environments. Reasonable hooks from these products to databases are provided so that integration with a data storage system would be feasible.

Asynchronous transfer mode (ATM) is the latest technique developed for communication in computer networks and is expected to become the dominant networking technology in the future. Its main advantages are a transmission speed on the order of gigabits per second and a dedicated switched connection between sender and receiver nodes. These can allow the simultaneous transmission of audio, video, and data within the same network. Presently the main disadvantages of ATM are the lack of standards and the high cost of ATM products. It appears that at the present time most vendors are concentrating on offering ATM as a solution to the problem of limited bandwidth with existing networks. It is rare to find an application which integrates audio, video, and data. Increasing data bandwidth seems to be the bulk of today's demand for ATM products.

Expert systems technology has been successfully used since the 1970's for a wide range of problems. It is considered today by most people to be a proven technology. At KSC there are a significant number of expert systems projects underway or recently completed. A number of reliable software vendors was identified and their brochures provided. As with neural network software, hooks to databases are also available with expert system development software on a variety of operating systems and platforms making integration within an advanced launch processing center very feasible.

## TABLE OF CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page</u>
I	INTRODUCTION.....	1-1
II	HIGH CAPACITY DATA STORAGE TECHNOLOGY.....	2-1
2.1	Disk Arrays.....	2-2
2.2	Magneto Optical Systems.....	2-2
2.3	3-D Optical Memories.....	2-4
III	NEURAL NETWORKS TECHNOLOGY.....	3-1
3.1	Why Neural Networks Are Useful.....	3-1
3.2	Training a Typical Neural Network.....	3-2
3.3	Training Guidelines.....	3-5
3.4	Neural Network Software.....	3-8
3.4.1	Commercial Neural Network Software.....	3-8
3.4.2	Free Neural Network Software.....	3-9
3.4.3	Hardware Available.....	3-10
IV	ASYNCHRONOUS DATA TRANSFER TECHNOLOGY.....	4-1
4.1	Vendors of ATM Technology.....	4-1
4.2	Other ATM Issues.....	4-3
V	EXPERT SYSTEMS TECHNOLOGY.....	5-1
5.1	Expert Systems Projects at KSC.....	5-1
5.2	Commercial Expert Systems Development Software	5-3
VI	CONCLUSIONS.....	6-1

## LIST OF ILLUSTRATIONS

<u>Figure</u>	<u>Title</u>	<u>Page</u>
2-1	Raid Configuration .....	2-3
2-2	Jukebox Configuration .....	2-4
3-1	An Illustration of a Neural Network .....	3-1
3-2	A Typical Artificial Neuron .....	3-2
3-3	A 2-layer Feedforward Network .....	3-3
3-4	Training Data .....	3-4
3-5	Network Response .....	3-5
3-6	Binary Data Preparation .....	3-6
3-7	Continuous Data Preparation .....	3-7

## INTRODUCTION

A new design for a Shuttle Launch Processing Center requires the identification of advanced systems available today and those that may become available in the near future. The complexity of a shuttle launch processing center is such that many different subsystems need to be carefully integrated into its design. Many different design issues also need to be considered such as: System Architecture, Computers, Networking, Software, Data Storage and Retrieval, Operational procedures, etc.

Identifying advanced technologies that impact all of these design issues is a very large task. This report addresses only the following areas:

- High Capacity Data Storage Technology
- Neural Networks Technology
- Asynchronous Data Transfer Technology
- Expert Systems Technology

The sections below describe the information obtained in each one of the areas.

## HIGH CAPACITY DATA STORAGE TECHNOLOGY

The approach taken to obtain information about this technology was to first contact reputable commercial vendors of data storage technology and request information on the latest product they sold as well as new products that they planned to introduce in the near future (one or two years ahead). Second, research labs were contacted to find information on products still in the research or prototype stage. The following vendors were contacted. Telephone numbers are given to make it easier to make future contacts with these vendors if needed:

- **ANDATACO**  
800-3349191 John Aiken  
<http://www.andataco.com>  
Very good web page. Register first, and the select "tech info" and within that select "raid disk arrays".
- **FUJITSU**  
800-6264686
- **HEWLETT PACKARD**  
800-6377740  
<http://www.hp.com>  
Very good web page. Select "products" then select "computing" then select "information storage".
- **HITACHI**  
800-4482244 415-2447515 Toni Maglaya
- **IBM**  
800-4262255  
<http://www.ibm.com>
- **MAXOPTICS**  
800-8483092 Less Jones Customer Service  
408-9549700 Akyra Pagoulatos Marketing Manager  
no web page
- **SUN**  
813-2897228 George Perkins  
407-3800058 Phil Murray  
<http://www.sun.com>  
Very good web page. Select "product overview" then select "mass storage and peripherals" then select "disks".
- **TOSHIBA**  
800-9994273 714-4550417

According to these vendors and other technical reports (provided to my NASA colleagues), it is generally agreed that the latest technology for mass data storage today consists of disk arrays and magneto optical disks. Important information about each of these is given below.

## 2.1 DISK ARRAYS

These consist of a group of disk drives that are considered as one logical storage device and which work in cooperation to improve speed and reliability over individual disk operation. Such a technique is referred to as RAID, an acronym for Redundant Arrays of Independent Disks. This technique is ideally suited for environments with large amounts of data needed on line and where data must be protected from disks failures.

RAID improves the speed with which data can be accessed by storing different portions of data blocks on different disks. When the data is needed it can be accessed in parallel from all the different disks with resulting faster access. Reliability can also be improved by this technology by using block interleaved parity, where a parity bit is associated with every block of data. If a disk crashes data can be rebuilt using the rest of the data on the other disks. Most vendors provide "hot spare" capabilities so that disks can be replaced without having to turn the disk array system off. Most vendors also provide software to make it easier to manage storage space allocation.

A technical detailed description of this technology is provided in the "RAID Report". A copy of this report was included in a separate document given to my NASA colleagues together with all the brochures and other information obtained from the different vendors contacted.

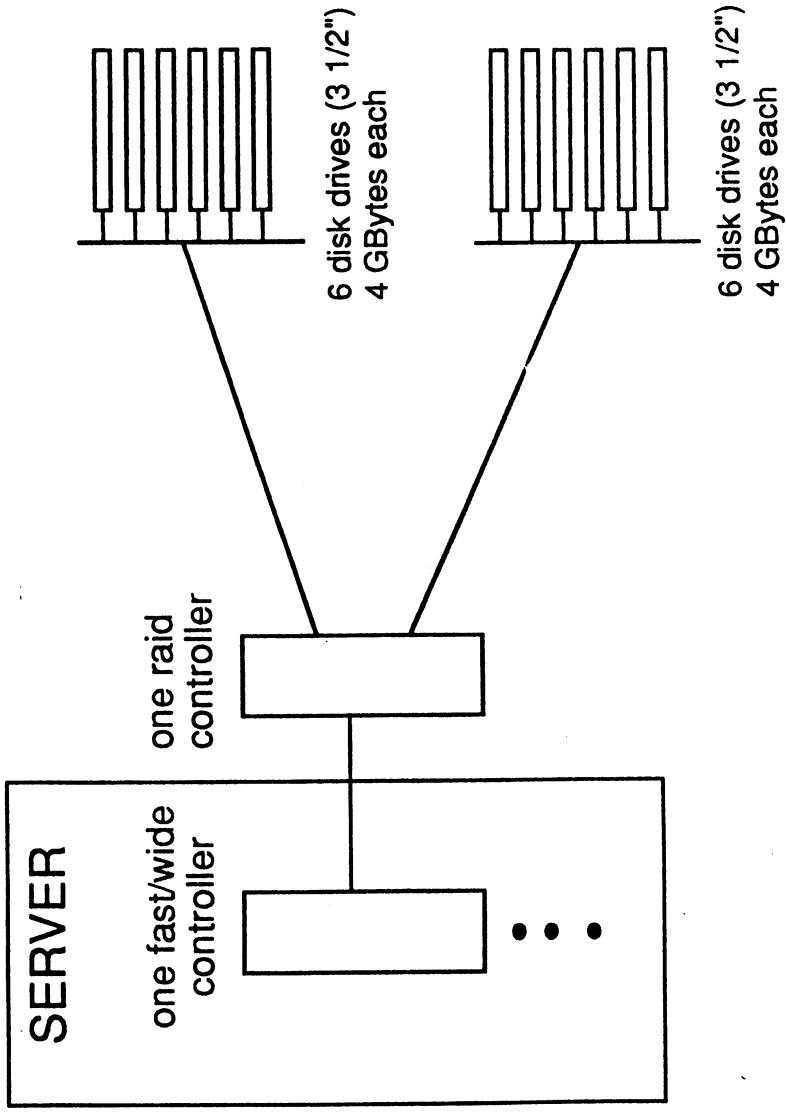
Figure 2-1 shows a typical configuration for a RAID and indicates how the configuration could be extended to provide for 1 Terabyte of data storage.

RAID is available from many of the vendors contacted - Andataco, Fujitsu, Hitachi, IBM, and SUN. Typical disk seek times of 10 milliseconds and latency times of 5 milliseconds were reported in the brochures obtained from the different vendors. The RAID storage capacity can be extended considerably. For example a SUN SPARCcenter 2000 connected to 15 Model 200 array cabinets can provide access to 4.86 Terabytes of data storage. The cost of this type of storage is approximately \$0.45 per Megabyte, not including the server. For example a 180 Gigabyte system would cost \$80,000 today.

## 2.2 MAGNETO OPTICAL SYSTEMS

These consist of a group of magneto optical read/write disk drives. These drives can be grouped, in "jukeboxes" and considered as one logical storage device to provide large amounts of storage space. Most vendors also provide software to make it easier to manage storage space allocation.





48 GBytes X 20 controllers = 1 TeraByte of storage

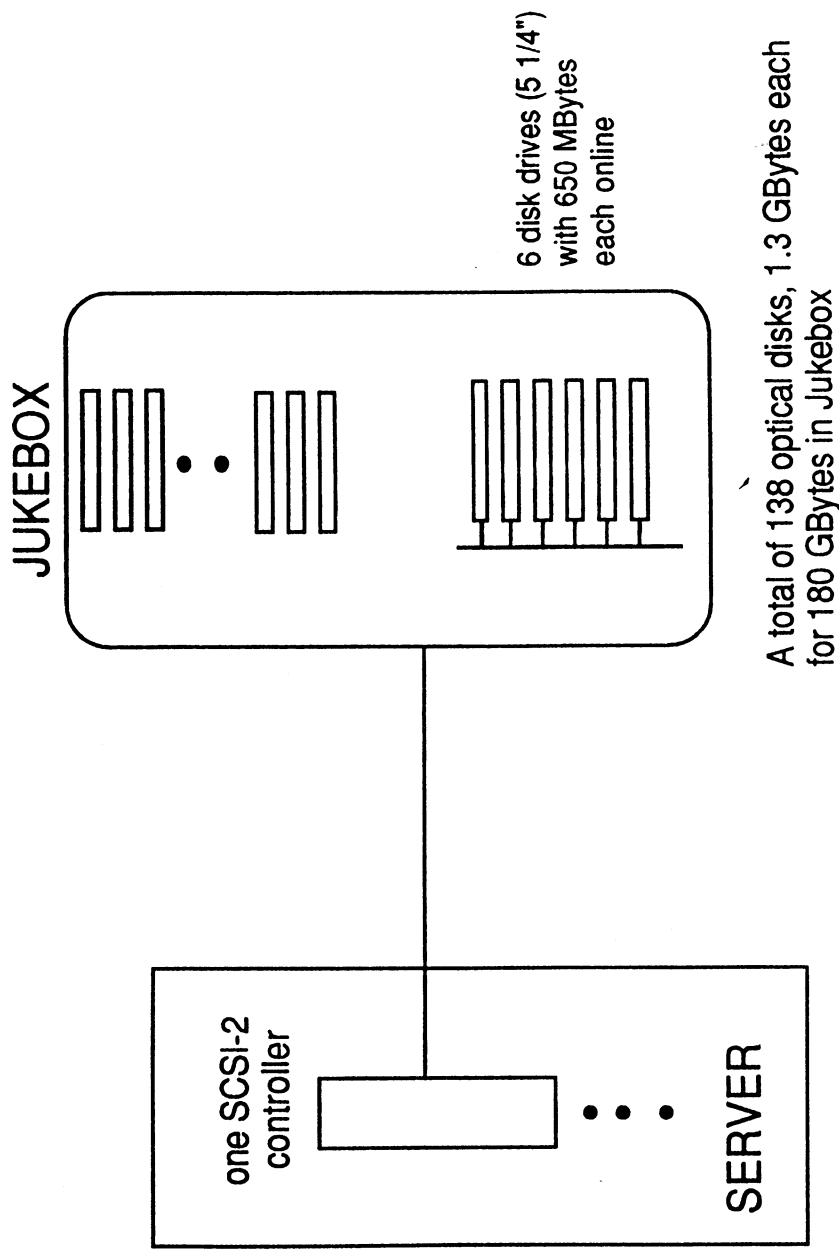
Can increase # of controllers, # of racks per raid controller and # of drives per rack

Figure 2-1. Raid Configuration

Magneto optical disks provide low cost on-line access to data and enables data to be stored for very long periods of time. Access speeds, however, are slower than for disk arrays. Presently there are 3 1/2 inch disks capable of storing 230 Megabytes and also 5 1/4 inch disks capable of storing 1.3 Gigabytes. It is predicted that by the end of 1995, 5 1/4 inch disks will be able to store 2.6 Gigabytes and that by the end of 1996, they will store 5.2 Gigabytes. Notice that since both surfaces on the disk are used to store information, only half of the storage per disk is available online. For example, today, a jukebox with 6 drives would provide approximately 4 Gigabytes of storage online as shown in Figure 2-2. Such a jukebox is capable today of handling 138 optical disks for a total of 180 Gigabytes of storage at a cost of approximately \$50,000.

Magneto optical disk storage systems are available from several of the vendors contacted - Fujitsu, IBM, Hewlett Packard, and Maxoptix. Typical disk seek times of 24 milliseconds, latency times of 12 milliseconds, and disk exchange times of 8 seconds were reported in the brochures obtained. However it is expected that access times will fall down in the near future to

about 10 millisecond when a direct overwrite feature is introduced. The storage capacity can be extended considerably to provide Terabyte ; of data by adding more SCSI controllers with their respective jukeboxes to the server. A 1.3 Gigabyte cartridge today costs approximately \$80.



Can increase # of controllers

Figure 2-2. Jukebox Configuration

### 2.3 3-D OPTICAL MEMORIES

This type of memory belongs to the category of future technologies. It is predicted that a working prototype might be available in 3 years and as a commercially available product in 8 years.

At the Center for Molecular Electronics at Syracuse University, Dr. Robert Birge is developing a 3-D memory using a photoreactive protein called bacteriorhodopsin. Writing to this type of memory is accomplished by the absorption of two laser beams at different wavelengths. Reading is accomplished by detecting the light emitted by the protein when excited by a laser beam.

This type of memory can be used to implement write-once-read-many (WORM) devices or also

to implement read-write-erase devices. Other advantages include room temperature operation, inexpensive material, and parallel operation.

Dr. Birge was very helpful when asked about this technology and provided copies of quite a few of his publications that describe his ongoing work. These papers have been included with the separate document given to my NASA colleagues.

### NEURAL NETWORK TECHNOLOGY

Neural networks are essentially a group of highly interconnected and relatively simple computational units as illustrated on Figure 3-1. Each of these computational units performs relatively simple processing of its inputs to produce a single output. The output of a unit is connected to the inputs of many other units through different weights.

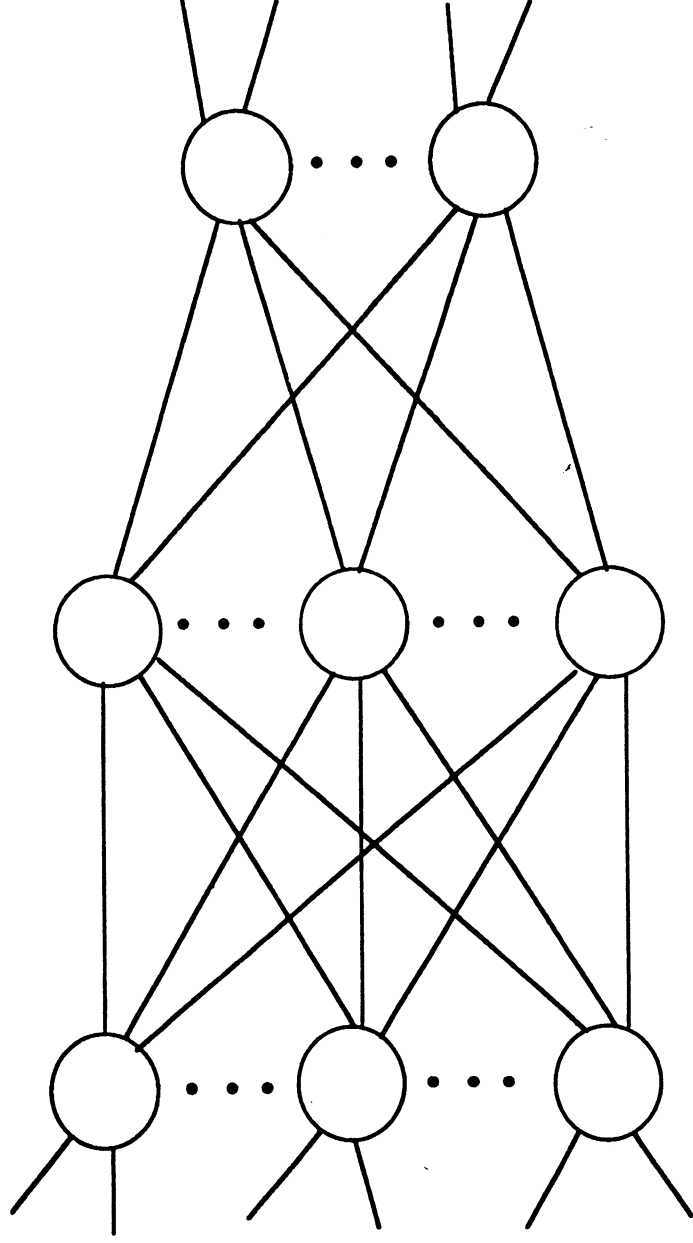


Figure 3-1. An Illustration of a Neural Network

Figure 3-2 shows a typical artificial neuron which adds all of its weighted inputs and uses a sigmoid output function to generate its output. Instead of a sigmoid function a threshold logic function is often used when binary functions are being implemented by neural networks.

#### 3.1 WHY NEURAL NETWORKS ARE USEFUL

There are several reasons why neural networks have been used to solve a variety of problems. Probably the most significant capability of neural networks is that of learning previously unknown relationships directly from raw data. Indeed, neural networks are best suited for problems for which data exists that associates a set of inputs and outputs but for which no explicit relationships between them has been established. A typical example of this is the

automatic recognition of printed characters.

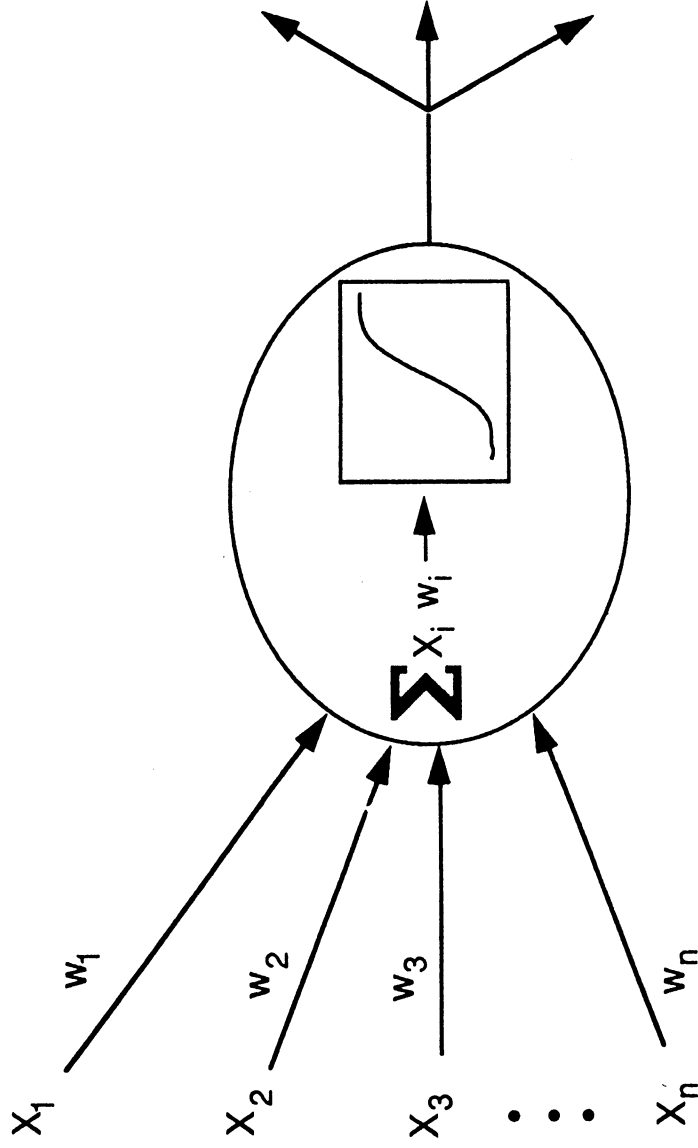


Figure 3-2. A Typical Artificial Neuron

Neural networks are capable of discovering nonlinear relationships from a training set and then apply these relationships to previously unseen data from that problem domain with very accurate results. This learning capability makes neural networks adaptable and very useful in environments where the relationships between input and output change over time.

Another important capability of neural networks is that they are fault tolerant. As individual neurons fail the performance of the entire network does not drop suddenly to zero but instead it slowly degrades in proportion to the number of failed units. This is in stark contrast to traditional algorithmic solutions where a single bit failure can have catastrophic results.

Finally, neural networks can function in parallel. The corresponding increase in speed that results from this can be used in applications requiring real-time responses.

### 3.2 TRAINING A TYPICAL NEURAL NETWORK

There are many types of neural networks. Among the ones most commonly described in the literature and included in the commercial software packages are: Multilayer Feedforward

networks, RCE networks, Radial-basis Function networks, Hopfield networks and Self-Organizing networks. Among these, 2-layer feedforward networks are probably the most popular because it has been shown that they are theoretically capable of implementing any association between input and output and because there is a well defined training method (Backpropagation) for them.

A typical 2-layer fully connected feedforward network is shown in Figure 3-3 with an n-dimensional input and m-dimensional output.

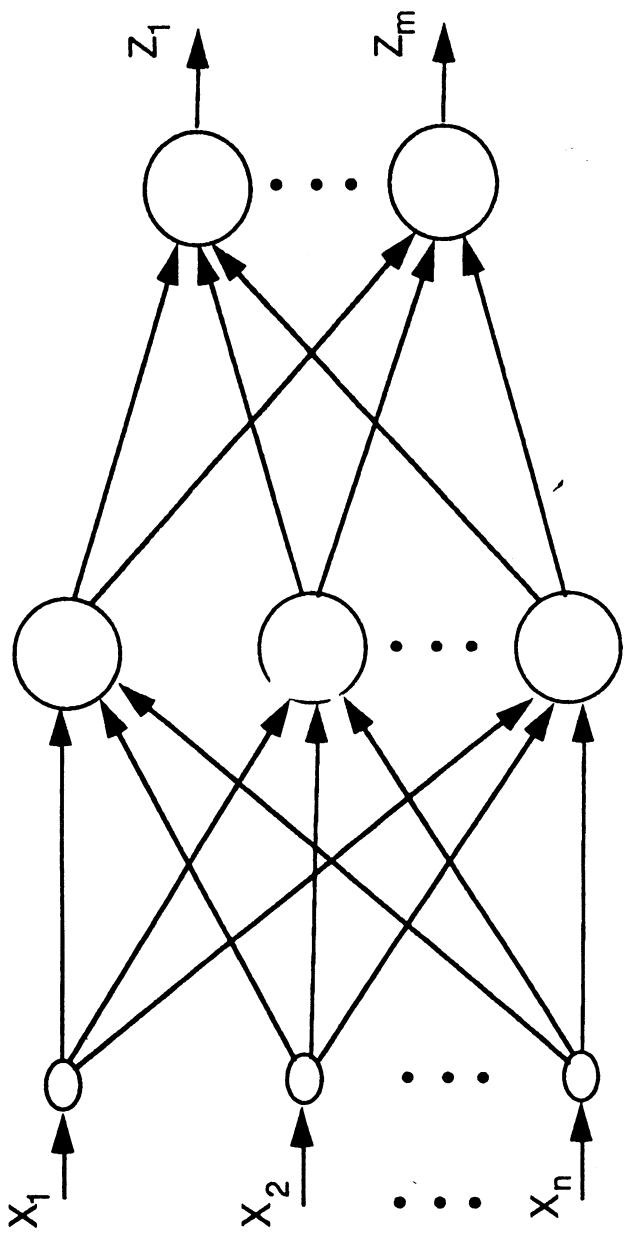
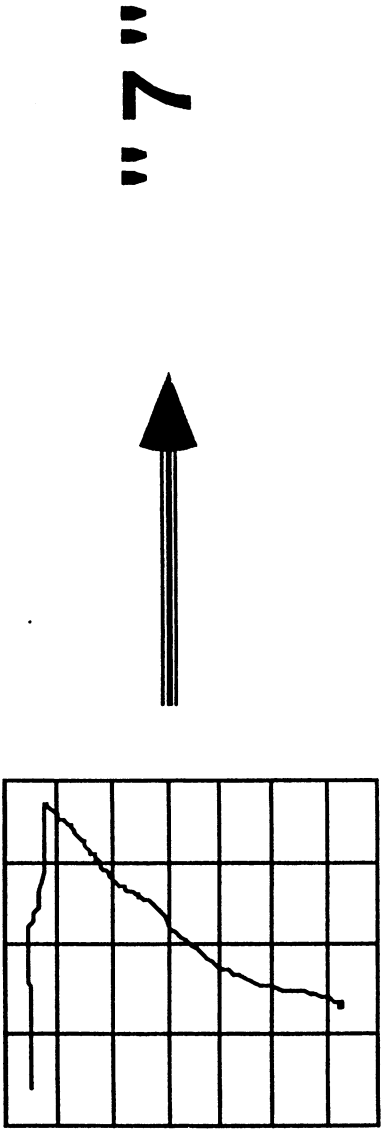


Figure 3-3. A 2-layer Feedforward Network

Training a network usually consists of finding the weight values so that previously known associations between input and output can be duplicated by the network. This implies that training requires a set of input data for which correct outputs are known. The learning that the network does through this method is called supervised learning. The correct weights can be found by an iterative procedure called backpropagation. Training also normally requires manually changing the number of neurons in the hidden layer and sometimes increasing the number of layers.

An example of a training set of data is given in figure 3-4. The number of training examples required depends on the size of the network and the accuracy desired. Also a percentage of the training data collected (10% is given as a guideline) is set aside for testing the network and is not used for training.



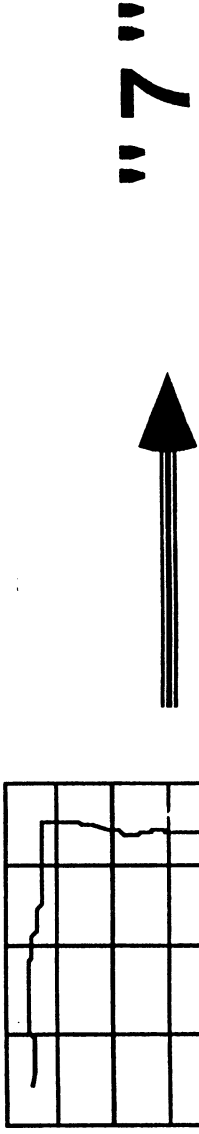
actual network input                      desired network output

$X_1$	$X_2$	...	$X_{28}$	$Z_1$	...	$Z_7$	...	$Z_{10}$
1	1	...	0	0	...	1	...	0

Figure 3-4. Training Data

Backpropagation uses the training examples to change the weights so that the error between the desired network output and the actual output is minimized. It is possible however to have a small training error but a large error when the test set is used. In many of these cases the problem is that the number of neurons in the hidden layer is too large. Thus the test set results and the training set results must be used in combination to arrive at the best network architecture - one that would perform well not only on the training set but also on the test set.

If the network has been trained properly, it will be able to correctly identify inputs that were not included in the training set. This is illustrated in figure 3-5. When this occurs the network has not memorized the training set but instead it has learned the basic relationships that exist in that problem domain between input and output and has stored those relationships in the weights of the network.



actual network input                      actual network output

$X_1$	$X_2$	• • •	$X_{28}$	$Z_1$	• • •	$Z_7$	• • •	$Z_{10}$
1	1	• • •	0	0	• • •	1	• • •	0

Figure 3-5. Network Response

### 3.3 TRAINING GUIDELINES

Guidelines for collecting network training data and for preparing the data for input to the network have been published in several books. The one by Jeannette Lawrence "Introduction to Neural Networks" is especially helpful on this topic.

When selecting a training set the following guidelines can be used:

- The number of training examples should be greater than the number of hidden neurons divided by the error criteria.
- Save about 10% of the training data for testing the network.
- Noise may be added to the original training data to increase the size of the training set.
- If implementing a network to classify data into different categories, include examples from each category. Include "border" examples for training and testing. If the network is to approximate a continuous function, include data throughout the entire range.
- Make sure that no contradictions exist in the training data. Also make sure that data that covers a long period of time has not been affected by extraneous factors.



Before the data collected for training can actually be used by the network, it must be transformed into a number. If the data can be represented by binary values then this number will be 0 or 1 (sometimes the binary numbers used are -1 or 1). Network inputs that represent attributes of a problem that can take on symbolic values are usually represented by binary values as illustrated in Figure 3-6.

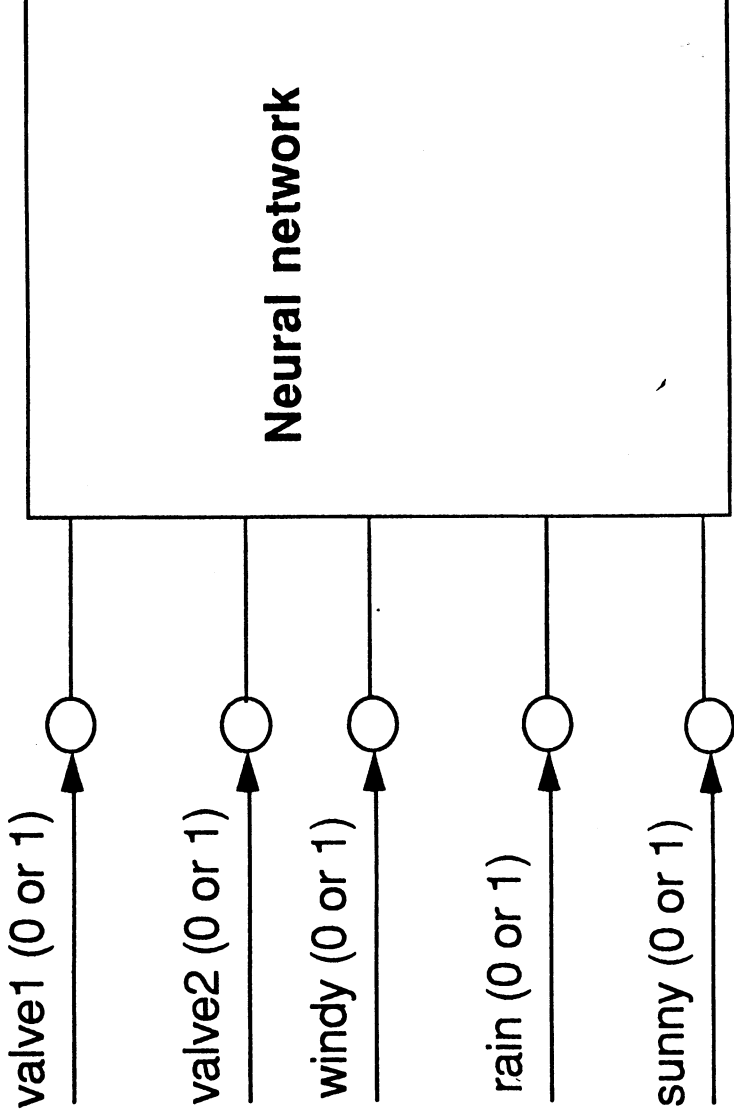


Figure 3-6. Binary Data Preparation

Network inputs that represent attributes of a problem that can take on numerical values are usually represented by continuous values between 0 and 1 as illustrated in Figure 3-7.

When the value range of a given attribute is very large, using the change recorded for that value instead of the actual value is better. This should be done only if it has been determined beforehand that it is the change in value that is significant for the problem at hand. Along the same lines, some data would need to be transformed using methods like Fourier's to reduce the dimensionality or to eliminate meaningless time variations in the original data.

If the goal of the neural network is to make a prediction based on what has happened in previous time periods, the network inputs should be set up as separate set of inputs for each of the time periods included in the data.

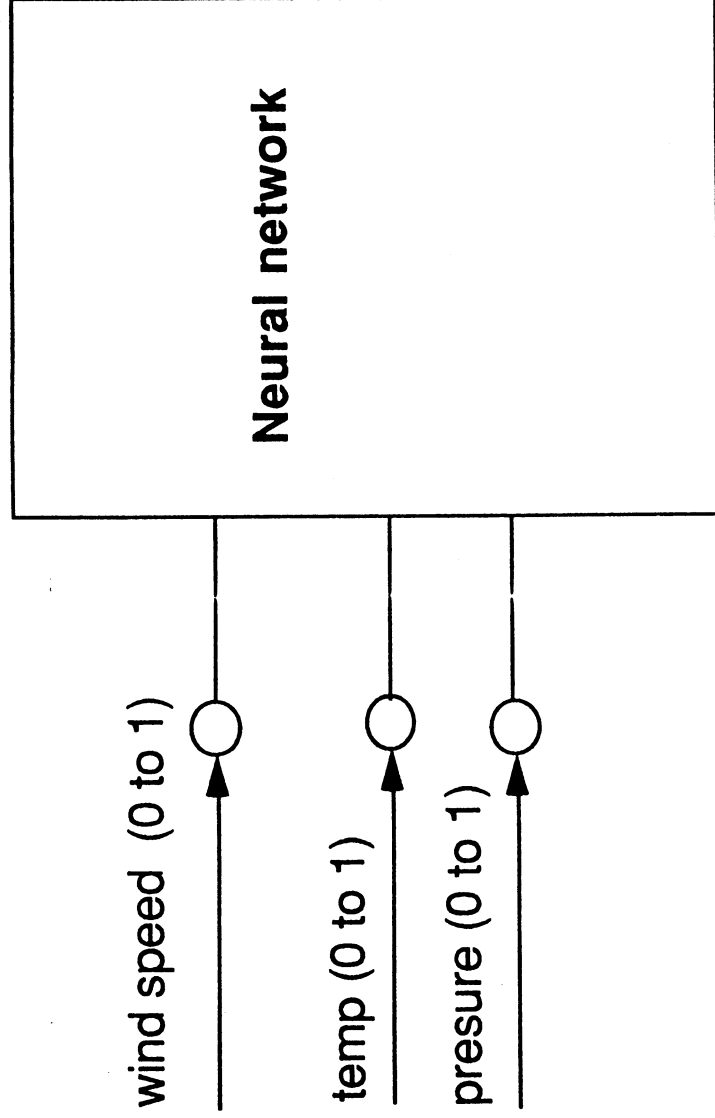


Figure 3-7. Continuous Data Preparation

After the data has been prepared, selecting the number of hidden layers and neurons in those layers is the next step in the training process. There are no clear guidelines on the number of hidden layers. Some suggest that one hidden layer is preferable because it is theoretically sufficient and improves training speed. Others suggest two hidden layers because the network architecture would fit the problem more effectively by allowing the first hidden layer to detect local features and then the second hidden layer to use these local features to detect global features.

The number of neurons in the hidden layers should be selected small at the start. After the network is trained it should then be tested. A few hidden neurons should then be added and the network retrained and retested. This process should be continued as long as the test performance continues to decrease. This should ensure that the network does not memorize the training set but that instead learns the general relationships that exist between input and output.

Other guidelines that are useful for training include the following: The learning rate should be smaller in the last layers than the front layers; initialization of the weights should be uniformly distributed within a small range; the training examples should be presented to the network in a random fashion and not according to categories.

### 3.4 NEURAL NETWORK SOFTWARE

There is a fair number of neural network simulation packages available. Some are commercial products from relatively small companies and others are available free of charge from university development labs. A representative sample of good packages from both categories are included below. The platforms on which they run, their list price, and a brief comment on their best distinguishing features are included.

#### 3.4.1 COMMERCIAL NEURAL NETWORK SOFTWARE

- NeuralWorks Predict  
DOS, Windows, Macintosh \$1995  
Automatic selection of best architecture  
Trained network is converted into C Fortran, or Visual Basic
- NeuralWorks Professional II/Plus  
PC/MAC \$3995 - SUN \$6995 - RISC 6000 \$7995  
SGI \$7995 - HP \$7995  
Very complete and powerful system with many network models  
C code generation

Both packages above are available from:

NeuralWare  
Penn Center West Bldg IV  
Pittsburgh, PA 15276-9910  
412-7878222

- IBM Neural Network Utility  
Windows, OS2 \$1500  
RS6000 \$4995  
AS400 \$550 to \$9075 depending on the number of users  
Graphical interface, many network models, access to databases  
C code generation

IBM  
800-3426672

- The Owl  
DOS, Windows \$295  
UNIX Workstations \$995  
Many network models

HyperLogic  
1855 E. Valley Parkway, Suite 210  
Escondido, CA 92027  
619-7462765

- NeuroWindows  
DOS, Windows \$369
- Neuroshell2  
DOS \$195 - Windows \$495  
Graphical interface and many network models

Both packages above are available from

Ward Systems Group, Inc  
Executive Park West  
5 Hillcrest Drive  
Frederick MD 21702  
301-6627950

- Brainmaker Pro  
DOS, Windows \$795

California Scientific Software  
10024 Newton Rd  
Nevada City, CA 95959  
800-2848112

### 3.4.2 FREE NEURAL NETWORK SOFTWARE

- PlanNet  
UNIX  
Nice graphical output, very good tutorial  
<ftp://boulder.colorado.edu/pub/generic-sources/>  
e-mail [miyata@sccs.chukyo-u.ac.jp](mailto:miyata@sccs.chukyo-u.ac.jp)
- SNS  
UNIX  
Graphical interface for creating and running network  
<ftp://ftp.informatic.uni-stuttgart.de/pub/SNNS/>
- Xerion and UTS  
UNIX  
Nice graphical output  
<ftp://ftp.cs.toronto.edu/pub/xeron/>  
e-mail [xerion@ai.toronto.edu](mailto:xerion@ai.toronto.edu)
- PDP  
UNIX and DOS (source code)  
Simple to run but primitive interface  
<ftp://nic.funet.fi/pub/sci/neural/sims/>

### 3.4.2 HARDWARE AVAILABLE

- Ni1000 digital chip  
~\$10000 for board and development software  
3.7 million transistors, 16.5 billion operations/sec  
256 inputs and 64 outputs  
Significant number of commercial applications

Nestor, Inc.  
One Richmond Square  
Providence, RI 02906  
401-3319640

## IV

## ASYNCHRONOUS DATA TRANSFER TECHNOLOGY

Asynchronous transfer mode (ATM) is the latest technique developed for communication in computer networks. It is being promoted as the most effective way to increase the bandwidth of existing computer networks. It is also promoted as the communication technology that will allow the simultaneous transmission of audio, video, and data within the same network.

There are several reasons given for the predicted success of ATM. ATM, in contrast to ethernet or token-ring, uses a switching scheme that connects two nodes for the time needed to transfer data and it uses fixed size data packets. It also has theoretical speed capabilities on the order of gigabits per second. This makes ATM capable of transmitting audio and video signals which require large bandwidth and are very sensitive to the time and the sequence in which the information arrives. ATM is also independent of upper layer communication protocols and can be used with existing network architectures such as ethernet, and token ring providing a reasonable migration path for existing networks requiring increase bandwidth.

The following specific questions regarding ATM technology are of special interest to NASA:

- Is ATM being offered by a significant number of reputable vendors ?
- Have ATM standards been agreed upon ?
- Does ATM implement multicasting ?
- Which fault tolerant features, if any, are offered by ATM ?
- What interfaces are available for ATM ?

These questions are addressed below.

## 4.1 VENDORS OF ATM TECHNOLOGY

There are significant numbers of reputable vendors of ATM products. The picture that emerges from the different brochures and white technical papers from these vendors is that ATM technology will dominate the computer network market as existing networks try to increase their bandwidth. The following vendors were contacted by phone or via the world wide web or both. Brochures and papers obtained from these vendors were placed in a binder and given to my NASA colleagues.

- 3Com Corp.  
407-6611999 Ben Johnson  
<http://www.3com.com>  
3Com Corp  
2250 Lucien Way

Suite 100  
Maitland, FL 32751

- AT&T  
201-6062978 Bill Price  
908-2212935 Christine Corliss  
301-6084596 Tim Russos  
<http://www.att.com>

- Cabletron Systems  
603-3329400  
<http://www.ctron.com>  
35 Industrial Way  
Rochester NH 03867

- Cisco Systems Inc.  
800-5536387  
<http://www.cisco.com>

- IBM  
800-4262255  
<http://www.ibm.com>

- Newbridge Networks Corp  
<http://www.newbridge.com>

- Whitetree Network Technologies  
415-8550855  
<http://www.whitetree.com>  
3200 Ash St.  
Palo Alto, CA 94306

In addition, the University of New Hampshire's Interoperability lab tests ATM products from many of these vendors and is a good source of information about ATM. Another good source of information is the ATM forum, to which many of these vendors belong. It is an organization started in 1991 dedicated to promoting ATM and disseminating information about ATM. At present it has over 500 members and includes network equipment vendors, service providers, carriers, semiconductor manufacturers, and users.

- Interoperability Lab  
University of New Hampshire  
603-8620204 Ron Pashby  
<http://www.iol.unh.edu>
- ATM Forum  
<http://www.atmforum.com>

#### 4.2 OTHER ATM ISSUES

It appears that 3 different sets of standards are being followed at the present time. The first one is RFC 1483 which includes bridging formats and routing protocols. The second one is RFC 1577 which includes IP over ATM. And the third one is LAN emulation. At this time it is not clear if any of these will eventually be accepted as the standard. The ability to multicast is provided by bridges and routers as well as by those products that provide IP over ATM. However ATM LAN emulators do not provide multicasting capabilities. The lack of clear standards makes it very unlikely that third party vendor hardware will be widely available.

It is possible today to purchase products which interface ethernet, token ring and FDDI networks to an ATM network. These products can process TCP/IP and IPX routing protocols and can convert shared media packets to ATM cells. There are also available products to connect workstations to an ATM network. These are interface cards which can convert the workstation data to an ATM cell.

It appears that at the present time most vendors are concentrating on offering ATM as a solution to the problem of limited bandwidth with today's ethernet and token ring based networks. It is rare to find an application which integrates audio, video, and data. Increasing data bandwidth seems to be the bulk of today's demand for ATM products.

However the cost of ATM products today is rather steep in comparison with other networking products. Network adapters cost between \$2000 to \$4000 and switches cost between \$5000 and \$10000. It is generally agreed that this high cost of ATM products as well as the lack of standards presents a serious obstacle to the rapid spread of ATM use.



V

## EXPERT SYSTEMS TECHNOLOGY

Expert systems technology has been successfully used since the 1970's for a wide range of problems. It is considered today by most people to be a proven technology. At Kennedy Space Center quite a few projects based on this technology have been undertaken. Below is a list of recent or current projects at KSC funded through the Technology Programs and Commercialization Office. This list was provided by Carrie Parrish from the KSC Technology Transfer Office.

### 5.4.1 EXPERT SYSTEMS PROJECTS AT KSC

- Expert Systems for Operations Distributed Users (EXODUS)  
Contact: Jody Fluhr / TV-GDS-5 / 861-3788  
A platform of common utilities and services to facilitate the development, maintenance, and standardization of advanced software systems at KSC, including: data acquisition, recording and retrieval services; electronic documentation and measurement database services; and heterogeneous network communication services.
- Knowledge-based Autonomous Test Engineer (KATE)  
Contact: Peter Engrand / DM-ASD / 867-3770  
A generic, model-based reasoning shell for monitoring, fault detection and diagnosis of launch processing systems. The model-based system compares predicted performance with actual performance to determine system integrity.
- Vehicle Health Maintenance System (VHMS)  
Contact: Warren Lackie / TV-PEO-2 / 861-3968  
An expert system to monitor day-to-day vehicle operations (major power-on systems only) that will provide rapid detection and analysis of anomalies. KATE was used as the underlying model-based reasoning technology.
- Propulsion Advisory Tool (PAT)  
Contact: Bob Beil / TV-FSD-3 / 861-3944  
A Shuttle Main Propulsion System (MPS) advisory system that provides enhanced displays and plotting techniques, anomaly prediction, detection, warning and corrective action, trend analysis, and system diagnostics for use by the MPS console operators.
- Reasoning Based on Intelligent Computers and Networking (RUBICON)  
Contact: Scott Wilson / TV-GDS-4 / 861-3846  
A generic shell for KSC expert systems' technologies that provide telemetry data, database access, common utility functions, and a design standard for future expert systems.
- Test Management Plan Automation  
Contact: Rudy Tench / LSO-217 / 861-7435  
A system that applies available project management tools and automation techniques to the process of producing a control sequence which is a textual interpretation of a detailed

- schedule for all of the work instructions that support Shuttle processing.
- **Advanced Shuttle Scheduling Technology, Ground Processing Scheduling System (GPSS)**  
 Contact: Nicole Passonno / TV-PED-2 / 861-5434  
 An interactive, intelligent scheduling tool for Shuttle ground processing based on vehicle configuration, constraints, and resources.
  - **Advanced Data Management System (ADMS), Structured Surveillance System**  
 Contact: Randy Tilley / RM-INT / 867-2020  
 A system to be used for the collection, manipulation, and dissemination of information collected by NASA Quality Inspectors for the Structure Surveillance program.
  - **SR&QA Portable Data Collection (PDC)**  
 Contact: Randy Tilley / RM-INT / 867-2020  
 A data collection system that provides accurate, near-real-time status of work in progress, as well as work completed. The technology may involve the use of pen-based computers, electronic stamps, and the Wireless Information Network (WIN).
  - **Smart O&M Manual Development Project**  
 Contact: Carolyn McCrary / DL-ICD-1 / 867-4449  
 A system that used CD-ROM storage, search and retrieval capabilities for system engineer's documentation, such as Operations and Maintenance (O&M) manuals, to enable a decrease in storage requirements and access time to information.
  - **Mapping, Analysis and Planning System (MAPS)**  
 Contact: Burton Summerfield / MD-MED / 867-4287  
 A centralized information database system that provides KSC operational elements with environmental compliance, management and impact assessment information through the use of a knowledge-based decision support system.
  - **Automated Database Design from Natural Language Input**  
 Contact: Carl Delaune / CG-ISO-1 / 867-3526  
 The implementation of natural language understanding, knowledge acquisition, knowledge representation, and problem solving methodologies as an interface for the design and development of databases through natural language input.
  - **Electronic Performance Support System (EPSS) Research and Applications**  
 Contact: Dick Davis / DE-TPO / 867-2780  
 An intelligent, interactive multimedia database system that provides quick assistance and information without the need for user training. EPSS may incorporate all forms of multimedia delivery, as well as artificial intelligence techniques such as expert systems and natural language recognition.
  - **Worksite Thunderstorm Prediction System**  
 Contact: Frank Merceret / TM-LLP-3 / 867-2666  
 A mesoscale modeling system designed to provide accurate forecasts of specific thunderstorm-related phenomena such as precipitation and high winds thereby reducing

downtime due to false weather advisories and alerts, hazardous weather events occurring without warning, and unnecessary restrictive weather-based flights rules for manned and unmanned missions.

#### 5.4.2 COMMERCIAL EXPERT SYSTEMS DEVELOPMENT SOFTWARE

A number of reliable software vendors were identified and their brochures provided to my NASA colleagues. As with neural network software, hooks to databases are also available with expert system development software on a variety of operating systems and platforms making integration within an advanced launch processing center very feasible.

- ART  
Windows, UNIX  
  
Brightware Inc.  
415-8999070  
101 Rowland Way, Suite 310  
Novato, CA 94945
- G2  
Windows, Windows NT, UNIX, VMS  
  
Gensym Corp.  
617-5472500  
125 CambridgePark Drive  
Cambridge, Massachusetts 02140
- Kappa  
Windows, UNIX \$9995  
  
Intellicorp  
415-9655500  
1975 El Camino Real West, Suite 101  
Mountain View, CA 94040-2216
- M.4  
Windows, \$995  
  
Teknowledge  
415-424-0500  
1810 Embarcadero Rd.  
Palo Alto, CA 94303
- Nexpert Object  
Windows, Windows NT, OS/2, Macintosh, UNIX

Neuron Data  
415-3214488  
156 University Avenue  
Palo Alto, CA 94301

- RTworks  
UNIX, VMS

Talarian Corp.  
415-9658050  
444 Castro St. Suite 140  
Mountain View, CA 94041

## VI

## CONCLUSIONS

Advanced technology available today can significantly improve the design of a new shuttle launch processing center. The following conclusions can be made regarding the technologies that were reviewed within the 10 week time period assigned to this project.

The latest high capacity data storage technology today, as reported by a group of reputable vendors, consists of disk arrays and magneto optical disks. Each is capable of storing more than the 1.3 Terabytes of data that it is estimated constitute today NASA's requirements for launch related data. Disk arrays are more expensive than magneto optical disks but they provide faster access to data. A 180 Gigabyte disk array would cost \$80,000 today not including the server, while an optical jukebox of similar capacity would cost \$50,000. Disk seek times of 10 milliseconds and latency times of 5 milliseconds are typical while magneto optical disk seek times of 24 milliseconds and latency times of 12 milliseconds are the norm - although it is expected that the access speed for optical disks will decrease within a year or two. In addition, disk arrays make all of the data available online, while a jukebox of magneto optical disks may provide only about 4 gigabytes of online data. Furthermore, it takes 8 seconds to load an optical disk within the jukebox for data not found online. It is quite possible that a storage system that combines both of these technologies, i.e. disk arrays for critical data that must be accessed quickly and optical disks for the rest, will provide a good solution for storing data in a new launch processing center.

Neural networks software has been successfully used for a variety of problems. A number of software vendors can provide reliable and effective development packages for neural network solutions which can execute on DOS, Windows, Mac, or Unix environments. Reasonable hooks from these products to databases are provided so that integration with a data storage system should be feasible. A commercially available hardware implementation of neural networks that could be used for speed critical applications also exists.

It is important that the selection of launch related problems for the application of neural network technology be done carefully. The person or team involved should be thoroughly familiar with the problem domain and with neural networks. The problem should be one where the relationships between cause and effect have not been explicitly identified but where there is sufficient historical data from which to learn these relationships. Neural networks can be retrained quickly to learn new relationships and therefore can also be effective for problems that frequently change.

Asynchronous transfer mode (ATM) is the latest technique developed for communication in computer networks and is expected to become the dominant networking technology in the future. Its main advantages are a transmission speed on the order of gigabits per second and a dedicated switched connection between sender and receiver nodes. These can allow the simultaneous transmission of audio, video, and data within the same network. Presently the main disadvantages of ATM are the lack of standards and the high cost of ATM products.

There are significant numbers of reputable vendors of ATM products. Brochures and papers

obtained from these vendors were placed in a binder and given to my NASA colleagues. It is possible today to purchase products which interface ethernet, token ring and FDDI networks to an ATM network as well as to purchase interface cards that connect workstations to ATM networks. It appears that at the present time most vendors are concentrating on offering ATM as a solution to the problem of limited bandwidth with existing networks. It is rare to find an application which integrates audio, video, and data. Increasing data bandwidth seems to be the bulk of today's ATM applications.

Expert systems technology has been successfully used since the 1970's for a wide range of problems. It is considered today by most people to be a proven technology. At Kennedy Space Center quite a few projects based on this technology have been undertaken. A number of reliable software vendors was identified and their brochures provided to my NASA colleagues. As with neural network software, hooks to databases are also available with expert system development software. They run on a variety of operating systems and platforms making integration within an advanced launch processing center very feasible.