ABSTRACT

ANALYSIS OF CIM PERFORMANCE
USING
DIFFERENT LAN STRUCTURES

Kirk Rawle

This research illustrates a systematic procedure for modeling and performance analysis of the integration effect of communication network to the physical system. The concept is to model different layouts of Computer Integration Manufacturing(CIM) using different Local Area Network(LAN) structures. The steps to accomplish this concepts are, a) To determine the performance measures for physical layouts and the communication network, in order to obtain a performance analysis. b) Modeling the physical layout using Promodel simulation package. c) Extracting results from the outcome of the simulation of the physical layout and using this as input to the communication network simulation. d) Modeling the communication network using LNET simulation package. e) Comparing the output of each simulation run and determine which is most acceptable.

Having different performance measures for both physical layout and networks, the proposed research objective is to illustrate the effectiveness of network structures on physical systems performance. Throughput, utilization, and delay are used as measures for both the physical layouts and network structures. Using these measures the optimum layout and network is selected.

ANALYSIS OF CIM PERFORMANCE
USING
DIFFERENT LAN STRUCTURES
A SIMULATION APPROACH

by
Kirk Rawle

APPROVAL PAGE

ANALYSIS OF CIM PERFORMANCE
USING
DIFFERENT LAN STRUCTURES
A SIMULATION APPROACH

Kirk Rawle

DR/George Abdou, Thesis Advisor / Date
Associate Professor and Acting Chairperson of Industrial
and Manufacturing Engineering, NJIT

DR Samir Billatos, Committee Member Date
Visiting Professor of Industrial and Manufacturing Engineering, NJIT

DR L. Malek, Committee Member / Date
Professor of Industrial and Manufacturing Engineering, NJIT

BIOGRAPHICAL SKETCH

Author: Kirk Rawle

Degree: Master of Science in Manufacturing Engineering

Date: October 1995

Undergraduate and Graduate Education:

- Master of Science in Manufacturing Engineering,
  New Jersey Institute of Technology,
  Newark, New Jersey, 1995

- Bachelor of Science in Computer Science,
  William Paterson University,
  Wayne, New Jersey, 1988

Major: Manufacturing Engineering

ACKNOWLEDGEMENT

This thesis is dedicated to
the Rawle family.

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

Chapter   **Page**

LIST OF FIGURES

Figure   **Page**

LIST OF FIGURES
(continued)

Figure	**Page**

LIST OF TABLES

CHAPTER 1

INTRODUCTION

Computer Integrated Manufacturing (CIM) systems are basically the evolution of manufacturing systems with information technology integrated into them. The integration of information technology into manufacturing systems leads not only to immediate cost benefits but also better decision support, risk limitation, better cash flow, better inventory management, enhanced customer service and improved quality of working life in the long term. Also this gives improved efficiencies with increased scope of product line.

Communication through Local Area Networks has played a key role in the design of fully automated CIM systems for many reasons. Among them are; reduced machine set up times, reduced tooling, simplification of planning and control, reduced in process inventory, near constant load time and system modularity.

Different functions such as part design, process planning, production control, etc., are integrated in order to carry out the manufacturing task efficiently. Integration is possible when the computer systems in all functions are able to communicate.

In an automated manufacturing system, there are three types of interactions:
1. The interaction between cells based on the type and frequency of information flow, and the direction of information (unidirectional, bi-directional or multidirectional).
2. The interaction between the cell components, i.e., the machines, robots, AGV's, sensors, loading shuttles, tools, jigs and fixtures. For each component there is a controller, and these are interfaced through a network system. The resulting output from one component forms the basis for input to another component in its specific format.

1

Therefore, networking between the controllers must be precise since the products are manufactured in time as a result of the desired specifications.

3. The interaction between management/technical information and real-time information is important for an efficient network system to control the interaction between the CAD and CAM.

Conventional manufacturing systems do not take into consideration the integration of information exchange or facility layout as factors in their system designs. Therefore, the focus of this research is to analyze the performance of the communication networks and the facility layout of a manufacturing environment.

1.1 Computer Integrated Manufacturing Systems

Computer integrated manufacturing is a conceptual technology which provides an automated flexible manufacturing system through the integration of computerized machines. Every machine must be intelligent enough to communicate with others in the system, as most manufacturing requires multiple machines. Therefore, communication is important in providing the coordination needed to match the sequence of activities. This is facilitated using protocol translating programs which have been developed to run the workstations. The manufacturing system can be divided into several levels according to their functions and information flow. A model summarizing the interactions is outlined in Figure 1.

Level	Function	Network

Facility — Information Management, Manufacturing Engineering, Products Management

Shop — Task Management, Resource Allocation

Cell — Task Analysis, Batch Management, Scheduling, Dispatching, Monitoring

Workstation — Setup, Equipment Tasking, Take down, Scheduling, Dispatching, Monitoring

Equipment

```
                              ┌────────────┐
                              │  Facility  │
                              └─────┬──────┘
                    ┌───────────────┴───────────────┐
              ┌───────────┐                   ┌───────────┐
              │  Machine  │                   │ Assembly  │
              │   Shop    │                   │   Shop    │
              └─────┬─────┘                   └─────┬─────┘
              ┌───────────┐                   ┌───────────┐
              │Virtual cell│                   │Virtual cell│
              │    #1     │                   │    #N     │
              └─────┬─────┘                   └─────┬─────┘
         ┌──────────┼──────────────────────────────┘
   ┌───────────┐ ┌───────────┐ ┌───────────┐
   │Workstation│ │Inspection │ │ Material  │
   │   with    │ │Workstation│ │ Handling  │
   │  NC/CNC   │ │           │ │Workstation│
   └─────┬─────┘ └─────┬─────┘ └─────┬─────┘
   ┌────────┐    ┌────────┐    ┌────────┐
   │ NC/CNC │    │Inspection│   │  AGV   │
   └────────┘    │ Machine │    └────────┘
  ┌─────┐┌─────┐ ┌─────┐┌─────┐ ┌─────┐┌────────┐
  │Robot││Part │ │Robot││Part │ │Robot││Conveyor│
  │     ││Buffer│ │     ││Buffer│ │     ││        │
  └─────┘└─────┘ └─────┘└─────┘ └─────┘└────────┘
```

Figure 1 Levels of a Manufacturing Systems

1.1.1 Information Flow in CIM systems

There are many instances where exchange of information is required between various equipment and facilities of CIM systems. The following are examples;

1. Processing information on a part is required; e.g. part program by a manufacturing/assembly/inspectionworkstation from CAD/CAM system.

2. The workstation requires some aid to process the given information; e.g. a machining center may require a tool or fixture from an Automatic Storage and Retrieval System (AS/RS) to process a particular part program to machine a part or it may require adaptive control data (finite element analysis results of vibrations, temperature, cutting forces involved in machining) from the CAD system.

3. Exchange of control data is required; e.g. two assembly robots coordinating through the network to make an assembly.

4. Dynamic distributed scheduling; e.g. Networkwide bidding scheme where schedules are made dynamically to allocate a part to a most suitable cell through extensive communication.

5. Status reporting and monitoring of workstations; e.g., regular status reporting by each workstation in the factory regarding its performance to a monitoring workstation.

6. Intracell communication; e.g., to achieve coordination between a robot and a machine center while loading/unloading a pallet or fixture, to get feedback from inspection station for subsequent corrective actions of machining center.

7. Intercell communication; e.g., manufacture of a common part and sharing of resources.

8. Traffic control of material handling systems; e.g., traffic control of automated guidance vehicle(AGVs) require information exchange between the cells, AS/RS and AGV controllers.

Although the highly automated machines and equipment in a CIM environment are highly reliable, still communication failure could occur because of problems related to information exchange as follows:

1. Information required by a particular machine did not reach it at all; i.e., information was lost during transmission between two stations because of poor transmission media.

2. Information which arrived carried noise (error), because of external interference.

3. Information required, arrives after a critical time period after which it loses its value.

This delay depends on the traffic load on the system and how much the system can handle.

1.2 Computer Communication Network

Computer networks are designed in a highly structured manner as a series of layers, each one built upon its predecessor. The purpose of each layer is to offer certain services to the higher layers. Layer 7 on one machine carries on a conversation with layer n on another machine. The rules and conventions used in this conversation are collectively known as the layer n protocol. The interface between each pair of adjacent layers defines which primitive operations and services the lower level offers to the upper level. The set of layers and protocol is called the network architecture, which is implemented by specific programs and hardware designed for each layer

International Standard Organization (ISO) has taken steps to standardize various protocols. Based on its proposals, OSI developed a model which deals with connecting systems that are open for communication with other systems. This seven layer model shows what each layer should do.

1.2.1 Local Area Networks

Computer networks are divided into two categories based on the physical distances that they cover. Local Area Networks (LAN), which cover few kilometers and Wide Area Networks (WAN) which cover thousands of kilometers.

Local Area Networks are most suitable for factory floors as their diameters are less than a kilometer. This research will focus on Local Area Networks for CIM environments.

1.2.2 Definition of LAN

A Local Area Network is a communication network that provides interconnections of a variety of data communicating devices within a small area. There are three significant elements in this definition. Firstly, a Local Network is a communication network not a computer network. Secondly, we broadly interpret the phase " data communication devices" to include devices that communicate over a transmission medium including;

Computers

Terminals

Peripheral Devices

Sensors (temperature, humidity, security alarm sensors)

Telephones

Television transmitters and receivers

Facsimile

However not all types of local networks are capable of handling all of these devices. Thirdly, the geographic scope of a local network is small, mostly commonly confined to a single building. Some of the key characteristics of local networks are, high data rates (0.1 - 100 MBPS), short distances (0.1 - 50 km), low error rate (10^{-8} - 10^{-11}).

1.2.3 Benefits and Disadvantages of LAN

Resource sharing is an important benefit of Local Area Networks. This includes not only expensive peripheral devices, but also data.

A Local Area Network is also more reliable, available to user and able to survive failures. The loss of any one system should have minimal impact, and key system can be made redundant so that other systems can quickly take up the load after a failure.

One of the more important potential benefits of a Local Network relates to the system evolution. In a non-network installation such as a time-sharing center, all data processing powers are in one or a few systems. In order to upgrade hardware, existing application

software must be converted to new hardware or reprogrammed with the risk of error in either case. Even adding new applications on the same hardware, or enhancing those that exist involve the risk of introducing errors and reducing performance of the entire system. With local networks it is possible to gradually replace applications or systems, avoiding the "all or nothing" approach.

Finally, a Local Network provides the potential to connect devices from multiple vendors, which would give the customer greater flexibility and bargaining power.

On the other hand, Local Networks present potential pitfalls as well. Firstly, there is a certain amount of loss of control in distributed system. It is difficult to manage this resource, to enhance standards for software and data and to control the information available through the network. The prime benefit of networking, distributed systems, also incorporates its prime pitfall.

It is likely that access of data will be possible from multiple sources. This raises the problem of integrity of data (e.g., two users trying to update a database at the same time), security of data and privacy.

1.2.4 Local Network Technology

The principles that determine the nature of a local network are its topology and transmission medium, which determines the type of data that may be transmitted, the speed and efficiency of communication.

1.2.5 Topologies

Local Networks are characterized in terms of their topologies, three of which are common (Figure 2), star, ring and bus.
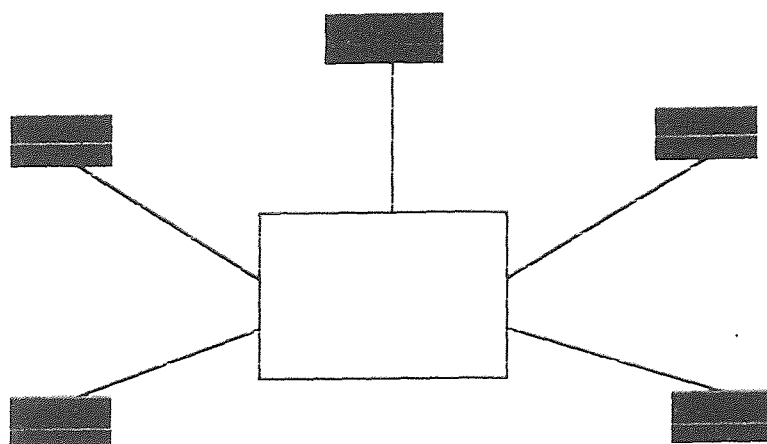
(a)
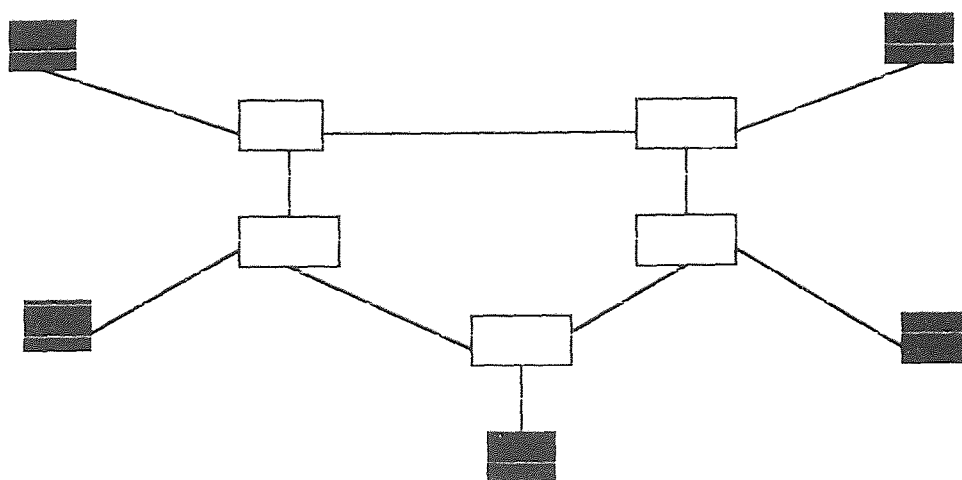
(b)
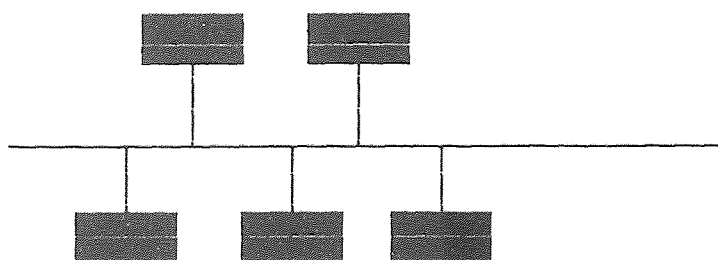
(c)

Figure #2
NETWORK TOPOLOGIES (a)STAR (b)RING(c)BUS

In the star topology, a central switching element is used to convert all the nodes in the network. A station wishing to transmit data sends a request to the central switch for a connection to some destination station and the central element uses circuit switching to establish a dedicated path between the two stations. Once the circuit is set up, data are exchanged between the two stations as if they were connected by a dedicated point-to-point link.

The ring topology consists of a closed loop, with each node attached to a repeating element. Data circulates around the ring on a series of point-to-point data links between repeaters. A station wishing to transmit waits for its next turn and then sends the data out unto the ring in the form of a packet which contains both the source and destination address fields as well as data. As the packet circulates, the destination node copies the data in a local buffer. The packet continues to circulate until it returns to the source node, providing a form of acknowledgment.

The bus topology is characterized by the use of a multiple-access broadcast medium. Since all devices share a common communication medium only one device can transmit, at a time, and as with the ring, transmission employs a packet containing source and destination address fields and data. Each station monitors the medium and complies packets address to itself.

1.2.6 Transmission Media

Twisted pair wiring is one of the most common communication transmission media and one that is certainly applicable to local networks. Although typically used for low speed transmission, data rates of up to a few megabits per second can be achieved. One weakness of twisted pair wiring is its susceptibility to interference and noise. Twisted pair wiring is relatively low in cost and is usually pre-installed in office buildings. It is the most cost effective choice for single building, low traffic requirements.

Coaxial cable can achieve higher throughput. It can also support a larger number of devices and can span greater distances than twisted pair wire. Two transmission methods, baseband and broadband can be employed on a coaxial cable.

Optical fiber has a higher potential capacity than coaxial cable and a number of advantages over both coaxial cable and twisted pair wire, including light weight, small diameter, low noise susceptibility and practically no emission.

1.2.7 Transmission Techniques

Two transmission techniques are used in LAN. They are Baseband and Broadband. Basebands use digital signaling and can be employed on twisted pair wire or coaxial cable. Broadband uses analog signaling in the radio frequency (RF) range and is employed only on coaxial cable. Some of the differences between baseband and broadband are as follows:-

Baseband is
1. Inexpensive and reliable
2. Good for data transmission only
3. Very fast transmission between processors
4. Entire bandwidth consumed by the signal
5. Inexpensive thin coaxial cable
6. Bi-directional
7. Can support multiple subnets and protocols easily
8. Distances up to a few kilometers

Broadband is
1. More expensive
2. Analog signaling (requires RF modem)
3. FDM possible - multiple data channels, video, audio
4. Unidirectional
5. Distances up to tens of kilometers

6. Coaxial cable (thick, expensive)

7. Cannot support multiple subnets and protocols

1.2.8 Medium Access Control Protocol

All Local Networks consist of a collection of devices that must share the network's transmission capacity. Some means of controlling access to the transmission medium is needed so that any of the devices can exchange data when required.

The IEEE has set up a series of standards for accessing local area networks. Included are IEEE standards 802.3 for a CSMA/CD bus, 802.4 for token bus and 802.5 for token ring. The various access methods of the IEEE 802 family of local area network standard are designed to conform to the OSI Reference Model.

IEEE 802.3 (CSMA/CD) Network Protocol is the most commonly used medium access protocol for bus topologies. The original baseband version is seen in Ethernet, and the original Broadband version is part of MITRENET. CSMA/CD protocol has the following features.

1. Listen for carrier

2. Transmit only when there is no energy on the medium

3. During transmission, listen for collision. If a collision is detected during transmission, immediately cease transmitting the packet and transmit a brief jamming signal to ensure that all stations know that there is a collision.

4. After transmitting the jamming signal, it waits for a random amount of time then attempts to transmit again using CSMA.

IEEE 802.4-TOKEN BUS (General Motor Corp. Manufacturing Automation Protocol), is a technique in which the stations in the bus form a logical ring. That is, the stations are assigned positions in an orderly sequence with the last number of the sequence followed by the first. Each station knows the identity of the station preceding it. A control packet known as the Token, regulates the right of access. When a station receives

the token, it is granted control of the medium for a specific time, during which it may transmit one or more packets and may poll stations and receive responses. When the station is done, or time has expired it passes the token on to the next station in logical sequence. See Figure 3.

IEEE 802.5-TOKEN RING (IBM Corp.) is probably the oldest control technique. This technique is based on the use of a small token packet that circulates around the ring. When all the stations are idle the token packet is labeled as a " free" token. A station wishing to transmit waits until it detects the token passing by, alters the bit pattern of the token from "free" token to "busy" token. The transmitting station will insert a new "free" token on the ring when the following two conditions are met;

1. The station has completed transmission of its packet

2. The "busy" token has returned to the station.

When a transmitting station releases a new "free" token, the next station downstream with data to send, will be able to seize the token and transmit. See Figure 4.

1.3   Problem Definition

Studying the physical system performance is not adequate, since the real time control for networks is not considered. For instance, a CNC machine in the physical system idle, awaiting the NC code to be transmitted from network. Having different performance measures for both physical layout and networks, the proposed research objective is to illustrate the effectiveness of network performance on physical system performance.
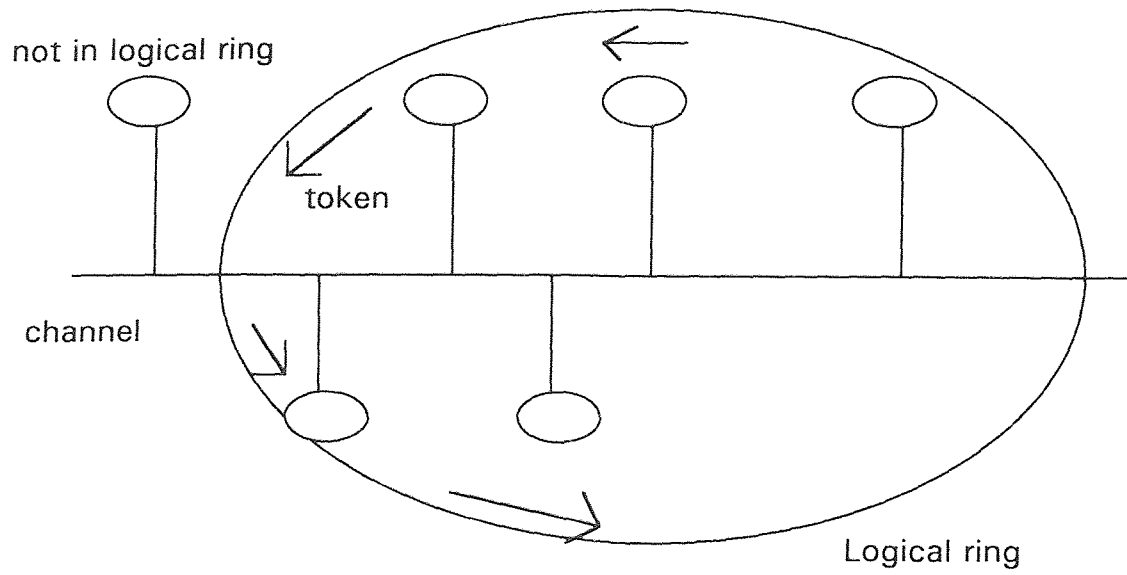
Figure 3 TOKEN BUS CONFIGURATION
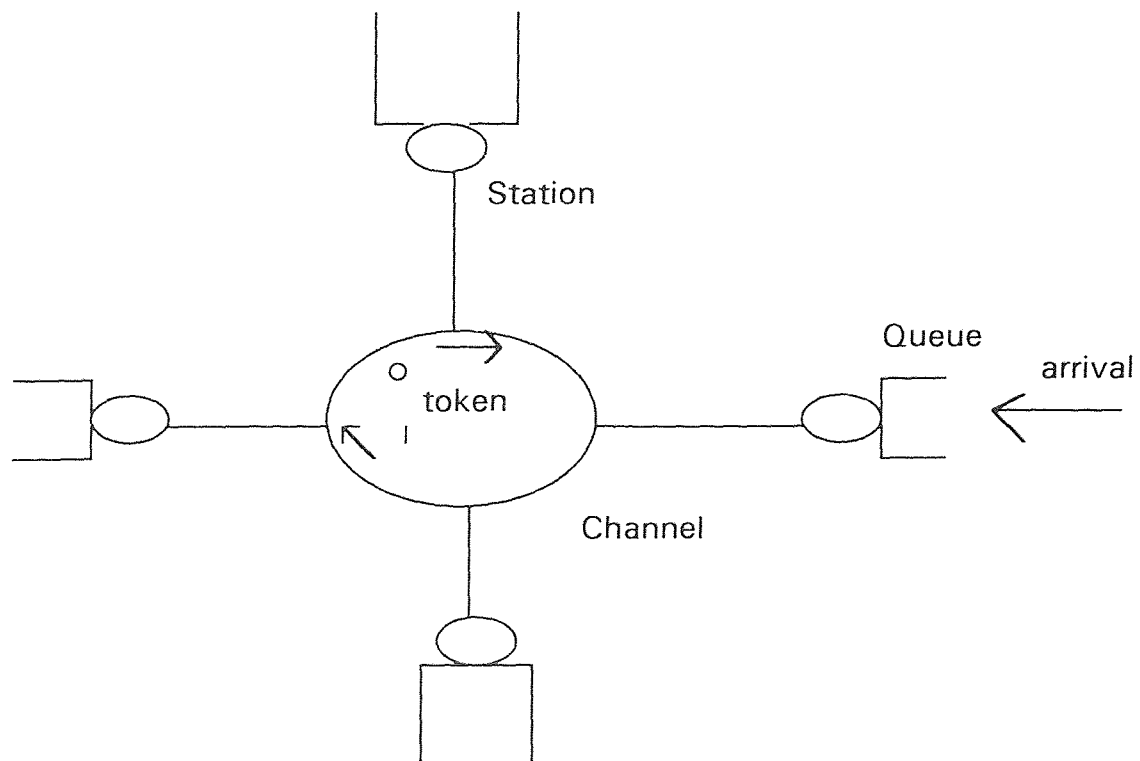
Figure 4 TOKEN RING CONFIGURATION

CHAPTER 2

LITERATURE REVIEW

Performance evaluation on Networks in a manufacturing environment and Facility Layout has been discussed by a number of researchers. Both analytical and simulation approaches have been attempted.

As noted by Adiga and Gadre (1990), the analytical model represents the quantities and relationships as mathematical variables and expressions. These are then mathematically manipulated to obtain the desired performance. Simulation models take the same input data as the real system and transform them into output similar to that produced by the real system. The behavior of the complete system is described by defining in detail how its various components interact with each other. The more complex the system, the more inappropriate the theoretical equations become and the more appropriate the simulation becomes.

The computer revolution has contributed much for the advancement of manufacturing automation. As computer systems became more sophisticated the level and flexibility of manufacturing automation improved. With the advent of robots and AGVs (automated guidance vehicles) the flexible manufacturing systems were developed.

2.1   Physical System Modeling

Ghosh and Wysk (1989) modeled the performance of communication facilities at each station level with CNC and DNC approaches. They compared the application of queuing and simulation models in their paper and concluded that simulation models should be used when more accurate information is required, while queuing models can be used when seeking quick results on system performance.

Bilberg and Alting, has determined that during production, simulation as an integral part of the real-time production planning and control has some interesting potential for on-line decision making. Simulation is used in the first instance to analyze and plan the FMS layout and later to analyze system control. Many installation problems and shut-down periods are avoided because the performance and behavior of the control system can be analyzed and tested at an early stage.

Chan (1993) research was to develop and implement a Petri net model for performance evaluation of FMS in the early system design stage. A utilization estimate of each machine is essential for this stage of system design. The main purpose was to develop a methodology for obtaining utilization rate of stations in FMS. In addition, bottleneck station, throughput rate and time in system were also points of interest. Petri nets are used as basic tools to evaluate the performance of an FMS.

Ciardo (1993) presents a decomposition approach for the solution of large stochastic reward nets (SRNS) based on the concept of near-independence. The models presented consist of a set of submodels whose interactions are described by an import graph. Each node of the graph corresponds to parametric SRN submodel and an arc from submodel A to submodel B corresponds to a parameter value that B must receive from A. The quantities exchanged between submodels are based on only three primitives. Import graph normally contain cycles so the solution method is based on fixed point interaction. This technique is applied to analysis a flexible manufacturing system.

Prakash (1993) exhibit results of a simulation study of a FMS. The FMS considered for this research includes ten machining centers capable of performing a variety of tasks, and automated guided vehicle (AGV) base material handling system and an automated input-single storage and retrieval system connected to the manufacturing system by conveyors. The model for the present study accounts for uncertainties such as stochastic part arrival patterns, variable machining times and machine breakdowns. The performance of the system has been investigated under different AGV availability conditions, operation

time levels, scheduling rules, and layouts of the system using factorial design techniques. Statistical methods are used to analyze the effects of these parameters on the system performance.

The basis of Noto (1993) approach lies on an analysis of the production process aimed at singling out proper cost drivers for the use of the various employed manufacturing resources. Traditional techniques of product costing, cost control and performance evaluation in advanced manufacturing environment supplies poor result to operation management.

Stecke (1992) addresses the problem of determining the part mix ratios at which a set of part types should be produced over the next production period. Integer programming is used to solve his problem, with computations based on machine utilization. Several objectives are discussed, each applicable in different FMS situations. Three complimentary models are also presented as follows: (1) closed queuing network model, providing pessimistic, aggregated and steady-state performance evaluation results. (2) a deterministic, timed petri net model, and its associated algebraic representation, which provides optimistic results. (3) simulation, which provides the detail modeling capabilities necessary to evaluate the performance of the ratios for research purposes. Either of the first two models is adequate to evaluate the ratios in practice. The part mix ratios can help solve other planning and operating problems.

Barad (1992) investigates the relative impact of versatility as a selected physical characteristic of the resources, versus some operating strategies, on flexible manufacturing systems performance. Versatility measures at machine and system level are discussed. The extent of the machines' workload imbalance is presented as an off-line system performance indicator, expected to provide rough cut, useful information at the design stage.

A majority of part types manufactured by the system require machining in a single cell only. However, a few part types need processing in two or more cells. It is precisely the

intercell movement of the latter that leads to weak interaction among the otherwise independent cell. Ram(1992) displays how the structure can be exploited to achieve significant computational savings in the performance evaluation of the cellular flexible manufacturing systems by using product from closed queuing network models and generalized stochastic petri net models. He also presents a comparison of computational requirements of the analysis using decomposition approach and the exact analysis.

Fischer (1992) determines approximation of the first two moments of the per-class waiting time distribution, the probabilities of delay and the second moments of the per-class interdeparture time distribution in the σ-i$/$ GI$-i$//GI$-i$//1 system. The researcher analyze all arrival and service process are defined by the first few moments of the interarrival time and service time distribution.

Zhuang (1991) use closed queuing networks with a central server configuration and finite queuing are used to model an FMS with limited local buffers. The author assumes exponential service time distribution, an exact numerical algorithm is developed for the performance analysis of FMS.

As manufacturers continue to automate their factories, Son (1991) determines that the cost measures should be updated. He expands the cost concept to include quality and flexibility because they are critical factors for a performance evaluation and project justification of advance manufacturing system.

Dotan (1991) presents a flexible manufacturing system focusing on shop-floor control processes. His approach is based on concurrent logical programming, which uses the theoretical foundation of communicating sequential processes and guarded commands with nondeterminants.

Mishra (1989) researched the performance evaluation of batch job shop FMS. The experiments are being conducted for a system with six machines processing six different types of jobs, whereas the system performance has been evaluated on the basis of

maximum makespan and average machine utilization. Models for the system performance indicates indices have been developed by the use of multi regression analysis technique.

Stecke (1989) researched the appropriateness of unbalancing the workload per machine in certain types of FMS configured as polled machines of equal sizes. Simulation is used to compare unbalancing and balancing on realistic, detailed models.of flexible flow system. Experiments are constructed to evaluate the impact of operational factors such as blocking, transportation, buffer utilization, fixture requirements of various types and different workload distribution among the machine types.

Tempelmeier (1989) presents an analytical approximation for the performance of FMS with blocking of machines due to limited local buffers. These approximations are based on a detailed analysis of FMS configurations used in industry. The proposed method uses information generated by applying the classical closed queuing network model to the FMS. The approximation developed are tested against simulation models for a wide variety of FMS configurations.

2.2   Communication Network Modeling

Significant effort has been spent in recent years to standardize a communication networking architecture for CIM environment. This would allow the manufacturers of automation equipment to design their equipment to be compatible with the communication standards. Examples of these standards are MAP and TOP now being standardized by GM and Boeing respectively. Local Area Networks have emerged as powerful media for meeting communication requirements of the automated manufacturing environment. Ilic et al (1989) discusses the role of LAN as a primary communication tool in factory automation as well as the problem of real-time control segments.

Models developed by Agrawal (1992) are useful in determining the maximum and minimum transmission frame duration for the performance evaluation of binary tree type

LAN protocols and other reservation type LAN protocols which employ binary tree type probing algorithm.

Melamed (1992) considered modeling methodologies of variable bit rate video sources for performance evaluation of integrated networks. They considered an example in which compress video is transmitted over a Local Area Network carrying both video and data. A new modeling methodology called transform-expand-sample (TES) which is a method for generating autocorrelated varieties. TES is a non-parametric method which can accurately capture the histogram and approximate autocorrelation function of any data set.

Satoyoshi (1991) analyzes a system which consists of a token ring LAN as the main network to which some CSMA/CD LANs are connected with bridges. Such a system is called the "compound LAN system" in his research. The optimum condition of this system due to the performance evaluation of the compound LAN system is shown by comparison with the throughput of each LAN.

Lee (1991) studies the performance of a multi-local-area-network (LAN) environment composed of a ethernet and a token ring network with mixed voice/data traffic. In particular the effects of system parameters such as the number of cross-bridge voice calls and limited versus exhaustive service disciplines in transmission on performance are studied.

Pimentel(1990) has concluded that queuing theory does not lends itself to model systems that exhibits the following properties:

1 concurrency;

2 timeliness;

3 fault tolerance; and

4 degradable performance

The concurrency factor arises from the fact that the system performance must be assessed across various hierarchies or data link, which is very difficult, if not impossible to achieve through analytical modeling.

Blusseau (1989) addressed the problem of whether load brought about by the addition of connected workstations to local area network and by the use of high level service such as network file system (NFS) saturates the network. The methodology used relies on performance evaluation techniques based on modeling queuing networks.

Samcheko (1989) article deals with performance evaluation of LAN bridges. The analysis takes account of the time relationship required for direct execution of management commands and interaction of bridge modules via the internal bus. Attention is given to structural solutions that involve introduction of specialized hardware for reducing the time spent in generating the location table for stations in the networks, and for filtering of internetwork frames. The analysis yields a worst-case estimate for throughput of various types of structures, and provides a comparison of them.

Guardieiro et al (1989) uses analytical models for the voice traffic and for the data traffic are utilized for the performance of Local Area Network using a proposed access mechanism and network architecture. The performance of the modified Cambridge Ring Access Mechanism (mCRAM) was analyzed for the case of voice traffic only and data traffic only. For the voice traffic, a simple binomial model for the steady-state probability distribution of the number of active sources has been used. The analysis indicates that the efficiency of slot utilization can be improved with the negligible effects on speech quality. The adapted cyclic server model of H. Takagi (1986) was used for determining the message delay in mCRAM for data traffic. It is shown that mCRAM is able to perform well over a wide range of stations and transmission rates.

Schmickler (1989) applies the SRPT (shortest remaining process time first) principle to the ethernet LAN using the CSMA/CD (carrier sense multiple access with collision detection) access protocol. He presents a description of the new CSMA/CD/SRPT protocol and detailed simulation results are presented. The comparison with other strategies shows that the performance gain is considerable and that the new protocol is near optimal.

Ghosh (1989) presents a LAN protocol which is design to exploit the topological advantages of direct connection to the net without incurring the high cost associated with direct connection to one of the established IEEE standard design. The protocol, Flexinet,employs token passing for medium access control on a bus. Advantage is taken of the short data frames involved in terminal interaction to minimize the hardware and software costs of the access units.

Hassanein (1989) proposed a two-class prioritized collision-avoidance star local area network (CASLAN) protocol. The retry time of a node is used for priority assignment. A three dimensional Markovian chain is used to model the CASLAN which is represented by a polling system in which the central node chooses at random one of the idle or ready nodes. Numerical results from the analytical model are presented and these results are compared to results from a simulation model.

A composite local area network consisting of CSMA/CD (carrier-sense multiple-access/collision detection) LANs connected via an N-port bridge is considered. Xie (1989) evaluates the performance for bridge priority protocols, in which the bridge is persistent and does not back off. The stations access the channels according to the controlled nonpersistent protocol. The bridge inter connected system is compared to a system in which the bridge is replaced by a repeater and the performance advantages of the former system over the latter are quantified.

Alfonzetti (1989) presents a double token-ring LAN at the LLC (logical link control) layer. The throughput/delay characteristics of DAFNE (deterministic access fiber network), a double token-ring optical-fiber LAN is illustrated. A queuing model of a connection between two end users at remote stations is given.

A new deterministic protocol for the integration of voice and data on a LAN with bus topology is presented by Kamel (1989). This protocol implements the moveable boundary strategy and is modeled analytically according to this scheme.

Economou (1989) presented a modified token-ring local area network called Skipnet. It uses the ring channel for all the normal functions of the standard token-ring and an extra bus channel for controlled messages. In the model idle stations are bypassed, therefore the relevant delay produced in the standard token-ring is minimized.

Jayasumana and Jayasumana (1989) developed a simulation model, using the timer assignment scheme, to evaluate the performance of the IEEE 802.4 Token Bus. The model is based on several approximations which are only valid for homogeneous network of a large number of stations. The model considers only three types of messages and it does not distinguish the differences in the characteristics of each type.

Weaver and Summers(1989) research the performance of the IEEE802.4 Bus and reported the effects access delay and queuing delay on message delivery times,message size and number of active station. Nevertheless, the study did not include other mix of network hardware and protocols.

Faro et al (1986), carried out a performance evaluation of the Proway network through a simulation model. They concluded that a simulator is an important tool that can help the designer to choose the best compromise among various parameters, (i.e., network configuration, frame length, throughput, service time, data transmission rate, frame generation time), and might be used to obtain the parameter range which provides the expected performance. They also concluded that the simulator offers sufficient flexibility to study how system parameters and the use of new technological products influence performance. However, the simulation model is limited to the Proway network which includes a token ring and user's specified protocol.

2.3   Limitations of Existing Models

In reviewing the literature for the physical system, evaluation is focused on different performance measures based on:

1. Shut down periods

2. Utilization rates of stations

3. Operating time levels

4. Scheduling rules

5. Layout of system

6. Part mix ratios

7. Intercell movements of parts

8. Shop floor control

The communication network literature also focuses on different performance measures such as;

1. Performance evaluation of protocols

2. Transmission of data

3. Throughput comparison when using token ring LAN and CSMA/CD LAN.

4. Throughput for different topology and access mechanism

It is critical to observe the effect of communication network performance such as block throughput, packet delay, or station utilization on the physical system performance such as throughput, work in progress or resource utilization. Therefore the main focus of this research is to illustrate the integration effect of communication network to the physical system.

2.4 Objectives of the Research

The main objective of this research work is to provide methodology for modeling and performance analysis of the integration effect of communication network to the physical system. The concept is to model different layouts of CIM using different LAN structures. The steps to accomplish this concept are as follows;

1. To determine the performance measures for physical layouts and the communication network, in order to attain a performance analysis.

2. Modeling the physical layout using a simulation package.

3. Extracting results from the outcome of the simulation of the physical layout and using this as input to the communication network simulation.

4. Modeling the communication network using a simulation package.

5. Comparing the output of each simulation run of the communication network and determine which is most acceptable.

CHAPTER 3

PERFORMANCE MEASURES

3.1   Performance Measures for Facility Layouts

As mentioned in the previous chapter, the main aim of this research is to provide a methodology for modeling and performance analysis. There are three performance measures which will aid us in obtaining the optimal performance of the four Facility Layouts. These are as follows;

1. THROUGHPUT -   is the total number of parts that entered a particular resource during the course of the simulation.

2. WORK IN PROGRESS - this is the time parts spend in a resource. Parts are delayed due to many reasons. This delay may affect total cycle time and hence the productivity of the manufacturing system as the machines may remain idle waiting for parts. For example, consider a machining center which has requested a part program from the CAM system. If there is a delay in the arrival of this information, productive machine hours are wasted. If this is a critical part of this operation, the completion time is affected. Therefore the work in progress is an important performance measure of the system.

3. RESOURCE UTILIZATION -   this is expressed as the percentage of time the resource was being used or was occupied by parts (which may include time that parts were simply idle).

   UTIL = 100 * (total part time in resource)/(resource capacity * simulation time). Transport utilization is calculated from the time a part is picked up (excluding pick up time) to the time the part is deposited (including deposit time).

3.2   Performance Measures for Networks

The performance measures which is used to measure the Local Area Network, are ;

1. THROUGHPUT - is the average transmission rate of data bits through the system. This gives a measure of utilization of the networking system as it represents the fraction of time the network is used to transmit data packets. .

2. PACKET DELAY - is the time from the start of the message transmission to the arrival of the message at the destination.   The packets are delayed in the system before they reach their destination due to many reasons depending on the states of the system they have to go through. This delay may affect the total cycle time of the product and therefore the productivity of the manufacturing system, as the machines may remain idle waiting for information.

3 STATION UTILIZATION - refers to the percentage of time during the process in which the station was busy. This includes the time the station spent waiting for a resource as well as the time it spent executing activities.

CHAPTER 4

PROPOSED METHODOLOGY

Simulation is defined as the technique of imitating the behavior of some systems by means of an analogous situation , to gain information about the system. When a model is constructed, the ability to analyze the behavior of a system under a variety of operation conditions is required. Simulation using models offers a number of advantages. The system can be monitored when still in the development phase, and existing systems can be optimized without risking disruption to production or to the control system.

There are other analytical methods, such as mathematical programming and queuing networks, which are alternatives. However, mathematical programming does not consider the dynamic behavior of a system, whereas, simulation and queuing do. The difference in applying queuing networks and simulation is that complex systems can be modeled in more detail by simulation, whereas queuing networks are easier to use.

As mentioned in the section, OBJECTIVE OF THE RESEARCH, there are specific steps involved in attaining the objective. These steps are depicted in Figure 5.
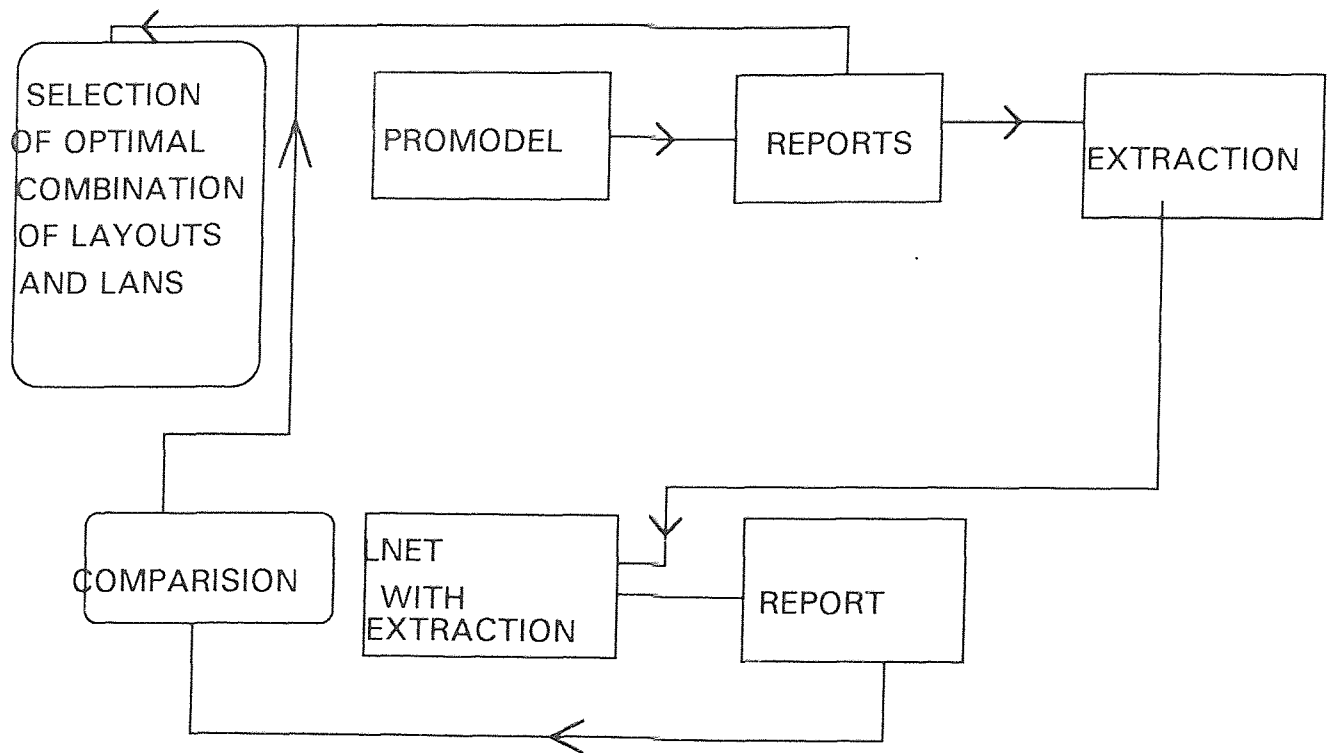
Figure 5 : Flow chart of objectives

4.1 Simulation of Physical Layout Using Promodel

This is a simulation language used for simulating production systems. The gradual evolution of ProModel began in 1983 (with Charles Harrell, Technical University of Denmark), and the goal of the program has been to combine modeling flexibility and ease of use.

ProModel permits the simulation application for manufacturing, material handling, warehousing, distribution, job shops, group technology cells and just-in-time manufacturing.

Once the model is constructed, ProModel allows one to view the operation in actual motion to verify accuracy. In the course of animated simulation, changes are easily made to schedules, resources, speed and other performance factors. During simulation, a report generator keeps records of manufacturing plans with the resource utilization, part activity, WIP reports, snap shot reports or hourly production reports. The information is also available as pie charts and bar graphs.

4.1.1 Model Description

Model definition is the essence of simulation. It establishes the relationship between the parts to be processed and the network of operations and activities that execute the processing task.

The model building includes five modules as follows;

1. ROUTING - This is a series of statements which describes a part name, its location, what operation is to be performed and where the resultant output is to be sent next.

2. PART SCHEDULING - This defines when and where parts are to be introduced into the system. It does not specify when parts are to be moved from one location to another. Movement from location to location is controlled in the part routing and is based on routing conditions and the available capacity of each receiving location. In the part

scheduling model, one may specify any number of arrivals for any number of part types for any location in the module. In addition to scheduling parts, attribute values for each part may also be assigned in this module.

The description of the part scheduling module is as follows;

(a)Part - This is the arriving part name. In addition to a part name, entities may also be assigned a priority (1 to 9) in the schedule model to determine preference for subsequent routings. The higher the number, the higher the priority.

(b)Location - This is the name of the routing location where the part is to arrive. Any location except those aboard transporters and conveyors may be specified as point of arrival.

(c)Quantity per arrival - This is the quantity of parts, expressed as an integer constant (1 to 9999) or distribution, that enters the designated location with each arrival (i.e. batch size). If parts arrive individually or if a batch is processed as a single unit, the value should be 1. If the quantity specified exceeds the available capacity of the arrival location, excess parts will be discarded and a notice that parts were lost will be generated at the end of the simulation.

(d)   Number of arrivals - This is the number of arrivals (1 to 9999) which are scheduled to arrive. If parts are to arrive throughout the simulation, a high value such as 9999 may be entered.

(e)Start minutes - This is the time, expressed in minutes, into the simulation when the first arrival is to occur. If several different parts are specified to arrive at the same location at the same time, they will arrive in the same order in which they are listed here.

(f) Arrival frequency - This is any constant, expressed in minutes, or distribution which defines the inter-arrival time of each batch. For cases in which the number of arrival is 1, a due time value expressed in hours may be entered here.

3. DOWN TIME - The module schedules the time when resources are to become unavailable due to, set up time, equipment failure, shift changes, rest breaks, etc. Not all

types of downtime follow the same logic or have the same parameters, field headings will change as different types of downtimes are selected. The following is an example set up based downtimes.

(a)Resource - This is the name of a single capacity routing location to which the downtime is to be applied.

(b)Basis - Set up

(c)Parts for which setup occurs - This is the name of the base part entering the location for which the set up will occur.

(d) Duration - This is the amount of time expressed in minutes that the resource is down (i.e. time to set up). Time may be expressed as a constant or distribution.

(e)Preceding part - This is the name of the part which immediately precedes the part for which set up occurs. If the set up time is the same for any or all remaining part types which the base part follows, then the reserve word ALL should be entered and no addition part entries are required.

(f) Quantity - This is automatically entered as 1.

(g) Maintenance resource - Since cycle based downtime pertains to single capacity Routing location resources only, any general resource may be named as the maintenance resource.

4. CAPACITY - This module stores information concerning capacity of location, general resources, transporters and transporter points to include which resources require extended output statistics. Standard file titles and accompanying entries for the capacity module are as follows;

(a)Resource - This is the name of the resource, routing location, transporter or transporter point to which the capacity is being assigned. The names of all resource except transporter points are automatically assigned by ProModelPC based on previous input.

(b)Quantity - For routing location and transporter points, this is the number of parts or transporters that may enter and occupy the resource location. For transporters, this is the number of transporters or general resources available for movement or work. Conveyor resources do not appear here since their capacity is implicitly derived from their speed, load length and part spacing. The capacity given to a routing location on a conveyor is for the purpose of controlling the maximum number of parts that can be in route to a location. No more than one part at a time can ever occupy a routing location situated on a conveyor.

5. SIMULATION PARAMETERS - This contains elements which establish limits and general routing requirements of the simulation per se including the simulation run time, special report requirements and the selection of random number speeds for different run streams and distributions.

Standard field titles and accompanying entries for simulation parameter models are as follows;

(a)Run (hrs) - This is the number of hours the simulation is to be run. If a 0 is entered, the simulation will continue only until there are no more part related events scheduled to occur. Otherwise the simulation will run until either the specified time has elapsed or all parts have exited the system and no more events are scheduled to occur.

(b)Start up (hrs) - This is the length of time in hours that the simulation is to be run before the collection of statistics is begun. When some time value "t" (where t is a positive value greater than 0) is entered, activity which occur from time 0 to t will not be reflected in the final statistical summary. The modular is cautioned concerning the scheduling of critical events during start up periods.

(c)Report Code - The report code determines what information will be gathered and reported in the simulation results file. The following reporting options are available;

    1. Resource Utilization only

    2. Resource Utilization and part activity

3. Resource Utilization and hourly output

4. Resource Utilization, part activity and hourly output

5. Everything including CONTENT AND DURATION files.

(d)   Resource to track - This entry is optional and is the name of any resource (except conveyor sections) for which an hourly utilization report is to be generated.

(e) Speed - This is the initial value code (0 to 9) of the speed for each random stream. If for example you are using four streams in your model, you would enter a four digit number wherein each digit represents an initial speed value for each stream

4.1.2 Output Reports

Promodel generates a comprehensive output report that summarizes resource utilization, part activity, and hourly production. Simulation output is very informative and can be useful in making decisions which lead to system improvements. The output results are only useful, however, if they are properly understood and analyzed. An important report that is generated, as stated above, is the Resource Utilization Summary. It provides information concerning the usage of each location and resource described as follows;

RESOURCE - This is the name of the resource for which the column information is provided.

CAPACITY - This is the capacity originally assigned to the resource. Conveyor locations, which never allow more than one part to enter at time, always show a capacity of 1 regardless of the capacity specified in the model.

% UTILIZATION - This is the resource utilization expressed as a percentage of time the resource was being used or was occupied by parts (which may include time that parts were simply idle). Resource utilization is calculated as follows:

UTIL = 100 X (total part time in resource)/(resource capacity x simulation time)

TOTAL ENTRY - This is the total number of parts that entered (but not necessarily exited) this resource during the course of the simulation.

AVG. MIN/ENTRY - This is the average time, expressed in minutes, that parts spend in this resource and is calculated by ;

$$\text{Avg. min/entry} = \text{(total part time in resource)/(total entries)}$$

AVG. CONTENTS - This is the average number of parts using the resource at any given time and is calculated by;

$$\text{Avg. contents} = \text{(total part time)/(total simulation time)}$$

MAX CONTENTS - This is the maximum number of parts that used or occupied the resource at any one time.

FINAL CONTENTS - This is the number of parts that were used in the resource at the time the simulation ended.

% DOWN - This is the percentage of the simulation time that the resource was down for reasons other than setup time.

4.2   Extracting Average Min/Entry

The Average Min/entry is the average time that a part spends in a particular resource. This time is expressed in minutes. The purpose of extracting it is, to use it as input to the simulation of the communication network as delay time at the control unit of the network node. A conversion from minutes to seconds is necessary.

The Average Min/entry includes processing time, material handling delay time and machine busy time. The value of the average min/entry depends on scheduling and routing. Therefore this entry can be considered to be the cycle time of a part in a specified resource.

4.3   Simulation of Local Area Network using LNET

LNET is a local area network design and analysis tool which can be used to evaluate the technology, topology, and loading in both proposed and existing network. Discrete event simulation is combined with interactive model description, captured network traffic, and

graphical results in a powerful, comprehensive, easy to use package. The LAN modeling
process may be broken down into three phases: Network Description, Network
Simulation and Simulation Results Analysis. LNET was created for people whose work
functions may include LAN design, LAN maintenance, and evaluation of LAN technology.

4.3.1 Creating LAN model

The steps involved in LAN description are as follows;

   1. Defining the network topology.

Each LAN in the network model has the following attributes, illustrated in Figure 6;

      (a)LAN name - identifies a LAN within a model.

      (b)Comment - an optional text comment which describes the LAN in further detail.

      (c)LAN type - specifies the basic protocol used by the LAN. Three LAN types are
         available in LNET; Collision, Token Ring and Token Bus.

      (d)LAN implementation - several predefined LAN implementations are available. If
         necessary the user may define a special implementation within the LAN type
         referred to as user defined.

      (e)Connection List - list of stations and gateways connected to LAN. For Token
LAN's the connection list determines the order in which the token is passed.

   2. Defining network operations.

Stations are the producers and consumers of all LAN traffic. A station may send
messages over a LAN, read/write the station disc, and process data. All of these functions
are programmed through the station activity and actions. Activity schedules a station's
workload while actions perform the functions which carry out a station's workload.
Illustrated in Figure 7 is the station form. The parameters which describe a station are
listed ;
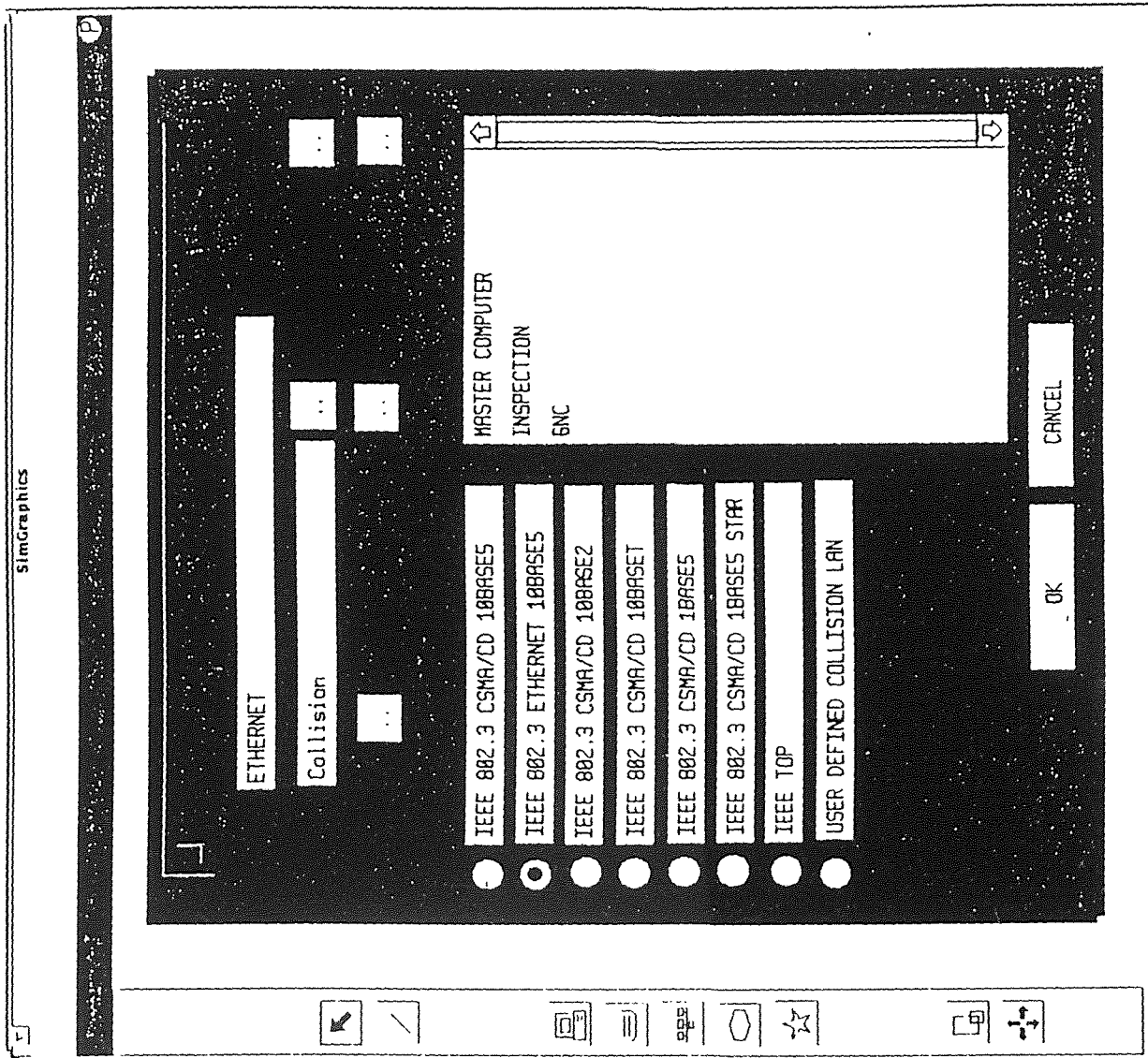
FIGURE 6 : THE COLLISION LAN FORM
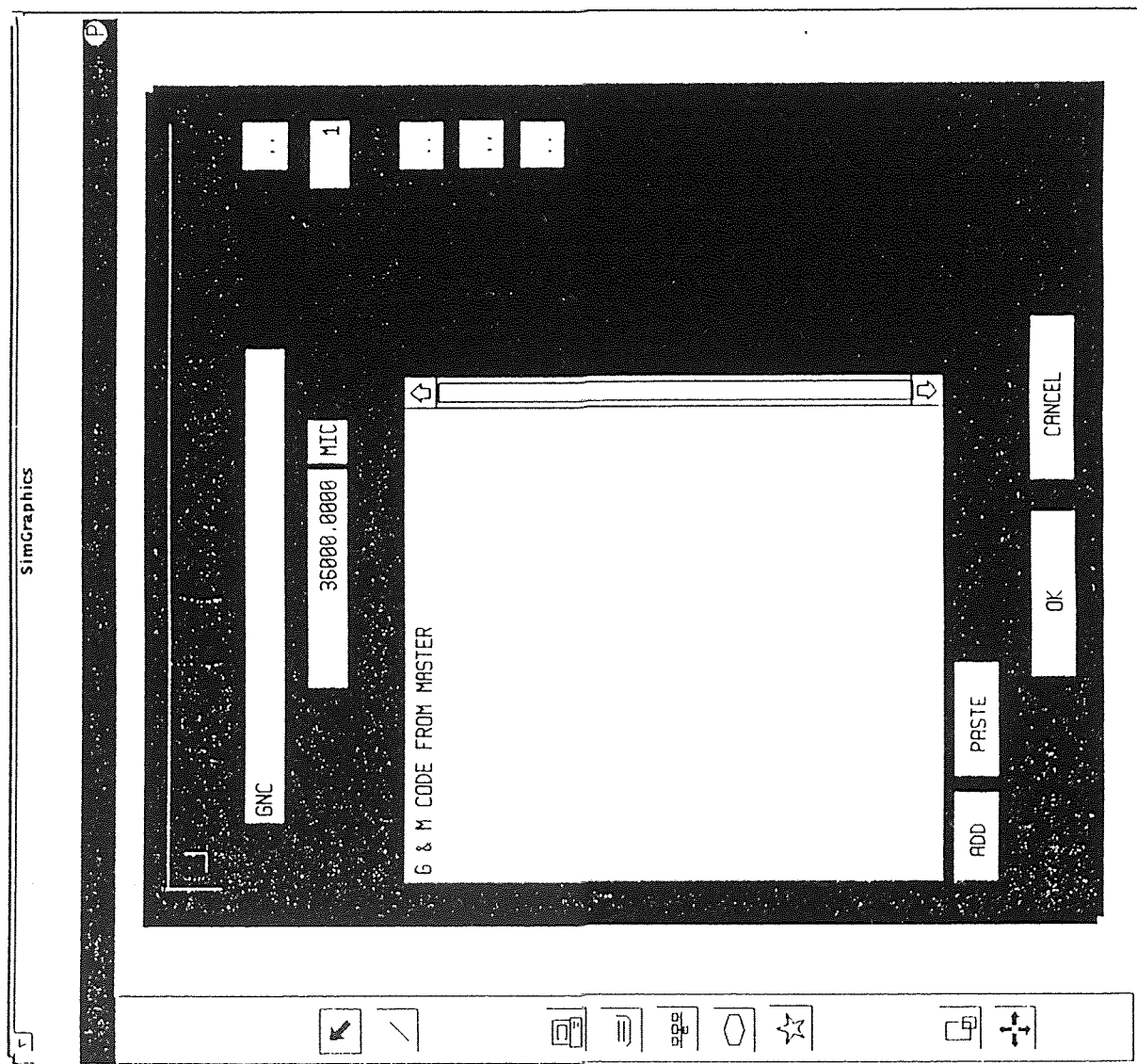
FIGURE 7 : THE STATION FORM

(a)STATION NAME - identifies the station within a model.

(b)COMMENT - optional text comment which describes the stations in further detail.

(c)QUANTITY - represents the number of identical copies of the station which will be created in the simulation.

(d)PROCESSING TIME/CYCLE - is the basic time unit of processing actions performed by the station. All action times are given as a multiple of this value. The processing multiplier is an indication of a station's speed. A station with a 0 processing multiplier, the default value, is infinitely fast and completes all processing actions in 0 time units.

(e)ACTIVITY LIST - is the list of activities which will be scheduled by the station during simulation. Activity schedule and aggregate a series of action which generate LAN traffic, processing data, and access the station disc. Each station must have one or more activities in order for the station to do anything. The Activity form is illustrated in Figure 8, and this form contains the following parameters;

    (i)   NAME - used to identify an activity within a model.

    (ii)   SCHEDULING METHODS - based either on a function of time or on the message which the station has received during simulation. Two methods are provided for scheduling activity as a function of time. These are Delay Time Scheduling and Iteration Scheduling. When a delay time activity scheduling method is used, a delay equal to a specified amount elapses between the completion of one occurrence of an activity and the next occurrence of that activity. If iteration period scheduling is chosen, the activity will be scheduled cyclically with an interval equal to specified iteration time.

When the activity scheduling method is based on received message, the activity will not be scheduled until the station has received all the messages in the activities received message list.

(iii)   START TIME , STOP TIME - describes the period over which an activity is eligible to be scheduled for execution.

SimGraphics

Activity 6 & M CODE FROM MASTER

Start Time 0.   MIC

Stop Time NR   MIC

Time Units

Scheduling Method

◯ Received Message

◉ Delay Time 50000.0   MIC

◯ Iteration Time

Action List

1.0	READ CODE
2.0	PROCESS CODE
3.0	WRITE CODE

ADD   OK   CANCEL

FIGURE 8 : ACTIVITY FORM

(iv) ACTION LIST - is a series of instructions which the station will execute when the activity is scheduled. Activities may contain four types of actions; processing, message, read and write. See Action form illustrated in Figure 9.

3. Defining simulation control parameters.

LNET is the graphics based simulation engine. Before running an LNET simulation the simulation parameters have to be filled in. Illustrated in Figure 10 is the Simulation Setup Form. The parameters for the setup form ensues;

(a) PERIODIC REPORTS - generated if requested during the simulation run and details the current status of selected items in the report list.

(b) TRACE - generated if requested during the simulation run. A narrative trace report of the LAN traffic flow will be generated for each LAN in the trace item list.

(c) LAN ANALYZER FILE - specifies the name of an external traffic file.

(d) LAN UTILIZATION GRAPH - may be plotted during the simulation run by specifying a LAN name in a graph field.

(e) RUN LENGTH - tells the LNET how long to run the simulation.

(f) RESET TIME - allow the "warm up" of a simulation whose start up activity may be different from its steady state activity.

(g) CLOCK TICK - controls how often LNET updates the simulation progress clock and the run time utilization graph.

4.3.2 Output Report

The report contains the simulation statistics for the LANs, Stations, Gateways, Activities, and messages in the network description. The report includes the following reports.

(1) LAN Utilization Statistics(collision or Token LAN)

Collision LAN Utilization Report (illustrated in Figure 11)

FIGURE 9 : ACTION FORM

conle.lan loaded.

☐ Input Listing

☐ Periodic Reports

☑ Warnings   ☐ Screen   ☑ File

☐ Trace   Screen   File

☑ Plot Data File

LAN Analyzer File

Graph 1 ETHERNET

Graph 2 BUS1

Graph 3

Run Length   28800.000 SEC

Clock Tick   576.000 SEC

Reset Time   0.000 SEC

From   To

From   0.000   To   28800.000 SEC

Periodic Report List

Traced Items

LNET

Release 4.01

Waste

FIGURE 10 : THE SIMULATION SETUP FORM

```
                    COLLISION LAN UTILIZATION STATISTICS

                      FROM   0.  TO    28800. SECONDS

                    (ALL TIMES REPORTED IN MICROSECONDS)


       LAN NAME                    ETHERNET


       COLLISION EPISODES            0

       COLLIDED TRANSFERS            0
       AVG TO RESOLVE                0.
       MAX TO RESOLVE                0

       DEFERRALS                     0
       AVG DEFERRAL DELAY            0.
       MAX DEFERRAL DELAY            0.
       STD DEV DEFERRAL DELAY        0.

       AVG DEFERRAL QUEUE            0.
       MAX QUEUE SIZE                0.
       STD DEV QUEUE SIZE            0.

       MULTIPLE COLLISIONS           0
       AVG MULT COLLISIONS           0.
       MAX MULT COLLISIONS           0

       SUCCESSFUL TRANSFERS         444
       AVG USAGE TIME          40610.364
       MAX USAGE TIME          50873.600
       STD DEV USAGE TIME      17670.317

       PER CENT OF TIME BUSY        .063
       ^L
       CACI LNET  RELEASE 4.01   05/18/1995    14:20:34          PAGE   2
```

FIGURE 11 :   COLLISION LAN UTILIZATION REPORT

```
                     TOKEN LAN UTILIZATION STATISTICS

                      FROM   0.  TO    28800. SECONDS

                    (ALL TIMES REPORTED IN MICROSECONDS)


       LAN NAME                    BUS1



       LAN REQUESTS GRANTED         166
       AVG REQUEST DELAY             0.
       MAX REQUEST DELAY             0.
       STD DEV REQUEST DELAY         0.

       COMPLETED TRANSFERS          166
       AVG USAGE TIME          1164.892
       MAX USAGE TIME          1192.000
       STD DEV USAGE TIME       139.987

       AVG QUEUE SIZE                0.
       MAX QUEUE SIZE            1.000
       STD DEV QUEUE SIZE            0.

       PER CENT OF TIME BUSY        .001
       ^L
       CACI LNET  RELEASE 4.01   05/18/1995    14:20:34          PAGE   3
```

FIGURE 12 :   TOKEN LAN UTILIZATION REPORT

The collision LAN utilization contains the following information:

(a) LAN name

(b) Collision Episodes - occurs when two or more potential LAN users attempt to use the LAN when it is in an unsettled state.

(c) Collided transfer - refers to LAN users attempting to use the LAN resulting in a collision.

(d) Average/maximum to resolve - is the statistics on the number of retries required to resolve the collision.

(e) LAN Deferrals - is the number of times LAN users had to wait to use the LAN because the LAN was in a busy state.

(f) Average/Maximum/Standard Deviation Deferral delay - is the time spent by LAN users waiting to use the LAN.

(g) Average/Maximum/Standard Deviation Deferral Queue size - is the number of LAN users in the LAN's deferral queue.

(h) Multiple Collision - the number of times that individual collision episodes included more than two LAN users.

(i) Average/Maximum Users per Multiple Collision - statistics on the number of LAN users involved in multiple collisions.

(j) Number of successful LAN transfers - the number of successful transfers completed by the LAN. This is also the total number of messages delivered by the LAN.

(k) Average/Maximum/Standard Deviation Usage Time - time spent by LAN users transferring data over the LAN.

(l) Percentage of Time Busy - time during the simulation that the LAN's status was either unsettled or busy.

For the Token Ring and Token Bus, the following information is provided by the LAN Utilization Report, illustrated in Figure 12.

(a) LAN name

(b) Number of LAN Requests Granted - request made by the LAN users to send a message that were satisfied by the LAN.

(c) Average/Maximum/Standard Deviation Request Delay - the delay between the time a LAN user requested access to the LAN and the time at which LAN access was granted.

(d) Number of Completed Transfers - the number of LAN transfers completed during the simulation.

(e) Average/Maximum/Standard LAN Usage Time- the length of time a user held the LAN from the time of acquisition to the time LAN was released. This does not include the Delay Time encountered waiting for the LAN.

(f) Average/Maximum/Standard Deviation LAN Queue Size - the number of user requests in the queue waiting to use the LAN. This includes any time periods during the simulation when the queue was empty.

(g) Number of Token Passes - the number of times the token is passed.

2. Station Utilization Report

The Station Utilization report contains the following information, (represented in Figure 13).

(a) Station Name

(b) Number of LAN Requests Granted - the number of times that the station was granted access to a LAN.

(c) Average/Maximum/Standard Deviation LAN Wait Time - the time a station spends waiting for a LAN.

```
                    STATION UTILIZATION STATISTICS

               FROM   0. ' TO    28800. SECONDS

              (ALL TIMES REPORTED IN MICROSECONDS)

STATION NAME               PNC           INSPECTION        LOAD



LAN REQUESTS GRANTED        0                0              0
AVERAGE WAIT TIME           0.               0.             0.
MAXIMUM WAIT TIME           0.               0.             0.
STD DEV WAIT TIME           0.               0.             0.

DISK REQUESTS GRANTED       84               5              25

AVERAGE BITS USED        325785.988      499998.500      325142.342
MAXIMUM BITS USED        1024000.        800000.         1024000.
STD DEV BITS USED        301859.363      299999.778      301461.087

STATION UTILIZATION      100.000         100.000         100.000



STATION NAME               GNC          MASTER COMPUTER



LAN REQUESTS GRANTED        0               610
AVERAGE WAIT TIME           0.              3.494
MAXIMUM WAIT TIME           0.              9.600
STD DEV WAIT TIME           0.              4.619

DISK REQUESTS GRANTED       1               305

AVERAGE BITS USED        500000.000      1201250.000
MAXIMUM BITS USED        500000.         1201250.
STD DEV BITS USED           0.              0.

STATION UTILIZATION      100.000          .093

^L
CACI LNET  RELEASE 4.01   05/18/1995   14:20:34              PAGE   6
```

FIGURE 13 :   STATION UTILIZATION REPORT

(d)Number of Station Disk Requests Granted

(e)Average/Maximum/Standard Deviation Bits Used - a catalog of the number of bits
stored in the station disk from the start of simulation to the time of this report.

(f) Station Utilization - the percentage of time during the simulation in which the
station was busy.

3. Gateway Utilization Report

The following information is contained in the Gateway Utilization Report, illustrated in
Figure 14.

(a)Gateway Name

(b)Number of LAN requests granted

(c)Average/Maximum/Standard Deviation LAN Wait Time - the time a gateway
spends waiting for a LAN.

(d)Average/Maximum/Standard Deviation Message Queue Size - the number of
messages in the gateway queue. Messages are queued at the gateway when the
gateway is busy processing other messages.

(e)Gateway Utilization - the percentage of time during the simulation when the
gateway is busy. It includes the time the gateway was waiting to use a LAN as well
as the time it spent processing messages.

4. Completed Activity Statistics

This report provides information on activities which have completed running the
simulation; and is outlined in Figure 15.

(a)Activity Name

(b)Host Station - the Station on which the Activity was executed

```
                GATEWAY  UTILIZATION STATISTICS
                  FROM    0.  TO      5. SECONDS
              (ALL TIMES REPORTED IN MICROSECONDS)


GATEWAY NAME                      G1/GATEWAY          G2/GATEWAY

LAN REQUESTS GRANTED                 248                 248
AVERAGE WAIT TIME                     0.                  0.
MAXIMUM WAIT TIME                     0.                  0.
STD DEV WAIT TIME                     0.                  0.


MAX MESSAGE QUEUE SIZE                 1                   1
AVG MESSAGE QUEUE SIZE                0.                  0.
STD DEV MESSAGE QUEUE                 0.                  0.


GATEWAY UTILIZATION                 1.135                .883
```

FIGURE 14: GATEWAY UTILIZATION REPORT

```
                    COMPLETED ACTIVITY STATISTICS

                    FROM   0.  TO    28800. SECONDS

                  (ALL TIMES REPORTED IN MICROSECONDS)


ACTIVITY NAME              GET WORK ORDER   INPUT CODE FROM    RECEIVE LOAD
                             FROM MC           MASTER            FILE


HOST STATION                  PNC            INSPECTION          LOAD


COMPLETED EXECUTIONS           20                 1          .    6

AVG EXECUTION TIME       4910496000.000  14400096000.000   4095096000.000
MAX EXECUTION TIME      18432096000.000  14400096000.000  18432096000.000
MIN EXECUTION TIME         72096000.000  14400096000.000     18096000.000
STD DEV EXECUTION TIME   6954529160.195             0.     6605221343.755



ACTIVITY NAME              G & M CODE FROM  SEND MESSAGE TO  SEND G & M CODE
                             MASTER            LOAD             TO GNC


HOST STATION                  GNC         MASTER COMPUTER   MASTER COMPUTER


COMPLETED EXECUTIONS           0                 3              166

AVG EXECUTION TIME            0.            28884.000        129756.800
MAX EXECUTION TIME            0.            28884.000        129756.800
MIN EXECUTION TIME            0.            28884.000        129756.800
STD DEV EXECUTION TIME        0.                0.               .008
^L
CACI LNET  RELEASE 4.01   05/18/1995    14:20:34            PAGE    4
```

FIGURE 15:   COMPLETED ACTIVITY STATISTIC REPORT

```
                    RECEIVED MESSAGE REPORT

                    FROM   0.  TO    28800. SECONDS

RECEIVER     COUNT       MESSAGE NAME

PNC
              160        WORK ORDER TO PNC

INSPECTION
              112        CODE TO INSPECTION

LOAD
               6         MESSAGE TO LOAD

GNC
              332        MESSAGE TO GNC
^L
CACI LNET  RELEASE 4.01   05/18/1995    14:20:34           PAGE    7
```

FIGURE 16:   RECEIVED MESSAGE REPORT

(c)Number of Completed Executions - the number of times an Activity successfully completed running on its host Station.

(d)Average/Maximum/Standard Deviation Execution Time - the activity's execution time. An activity is considered to be executing from the start of the first action to the completion of the last action. It is measured in microseconds and includes only activities which have completed executing.

5. Received Message Report

This report displays the number of times a specific message was received by a station. It is useful in determining if a message which will trigger an activity has been sent, or in determining if the simulation has fully exercised the network under consideration. The following information is contained in this report and is outlined in Figure 16.

(a)Receiver - this is the name of the Receiving Station

(b)Count - the number of times during the simulation that a Station received the message.

(c)Message - message name.

6. Message Delivery Report

This report displays the delivery times of messages from the source station to the destination station. The following information is presented in this report and is illustrated in Figure 17.

(a)Message Name

(b)Source Station

```
                        MESSAGE DELIVERY REPORT

                  FROM   0.  TO    28800. SECONDS

                 (ALL TIMES REPORTED IN MICROSECONDS)


MESSAGE NAME                 CODE TO        MESSAGE TO LOAD   MESSAGE TO GNC
                            INSPECTION


SOURCE STATION           MASTER COMPUTER   MASTER COMPUTER   MASTER COMPUTER


DESTINATION STATION        INSPECTION           LOAD              GNC


NUMBER SENT                   112                6                 332
AVG DELIVERY TIME          10192.000          442.000          50878.400
MAX DELIVERY TIME          10196.800          442.000          50883.199
MIN DELIVERY TIME          10187.200          442.000          50873.602
STD DEV DELIVERY TIME          4.800            0.                  4.800



MESSAGE NAME              WORK ORDER TO
                             PNC


SOURCE STATION           MASTER COMPUTER


DESTINATION STATION          PNC


NUMBER SENT                   160
AVG DELIVERY TIME          1192.000
MAX DELIVERY TIME          1192.000
MIN DELIVERY TIME          1192.000
STD DEV DELIVERY TIME          0.
```

FIGURE 17 :   MESSAGE DELIVERY REPORT

(c) Destination Station

(d) Number of messages sent - the number of completed message deliveries to the specified destination.

(e) Average/Maximum/Standard Deviation Delivery Time - a measurement of the time from the start of the message transmission to the arrival of the message at the destination. (Times measured in microseconds).

7. Snapshot Status Report

This report is always included in the Simulation Report File at the end of a LNET simulation. It lists the status of the model's elements at the end of the simulation and contains the same information as the Periodic Snapshot Report.

4.4 Comparison of Output Reports

In this section, the reports generated will be compared as follows;

1. Comparison of the Physical Performance of different layouts. This comparison will be based on the resource utilization report, part activity summary and overall part activity summary report.

2. Comparison of the three LNET topologies .

3. Comparison of the three LNET reports to PROMODEL which is based on

   (i) Completed Activity report vs. Throughput.

   (ii) Station Utilization report vs. Resource Utilization report

   (iii) Packet Delay report vs. WIP

4. Selection of the best Layout and Network, based on the Physical System Performance which are; Throughput, Resource Utilization and WIP.

CHAPTER 5

FMS ACQUISITION CASE STUDY OF PHYSICAL SYSTEM : GENERAL ELECTRIC.

A buyer may not likely understand the full task of specifying an FMS, however, a better understanding of the specification process can be beneficial. Knowledge of the steps involved and being able to carry out some of them, will payoff in acquisition and operation of an FMS.

General Electric Ordnance System Division(GEOS), Pittsfeild, Massachhusetts, has the responsibility to design and manufacture the Turret stabilization system for the Bradley Fighting Vehicle(BEV) and Cavalry Fighting Vehicle(CVF) programs. Figure 18 illustrates the major turret stabilization subsystems. These subsystems require the fabrication of eleven cast aluminum housings and cover. A set of parts for one vehicle is called a "ship set".

Early in the planning stage, a decision was made to have the parts manufactured by outside job shops. At the same time GEOS continue to consider eventual manufacture of parts in house. Emphases was placed upon FMS alternatives with configurations ranging from largely manual through fully automated systems. Some principle parameter categories used in differentiating the systems includes:

Manual versus Automated Material Handling.

Representative Material Handling techniques.

Bolted versus Palleted fixtures.

Representative Machine Assemblage.
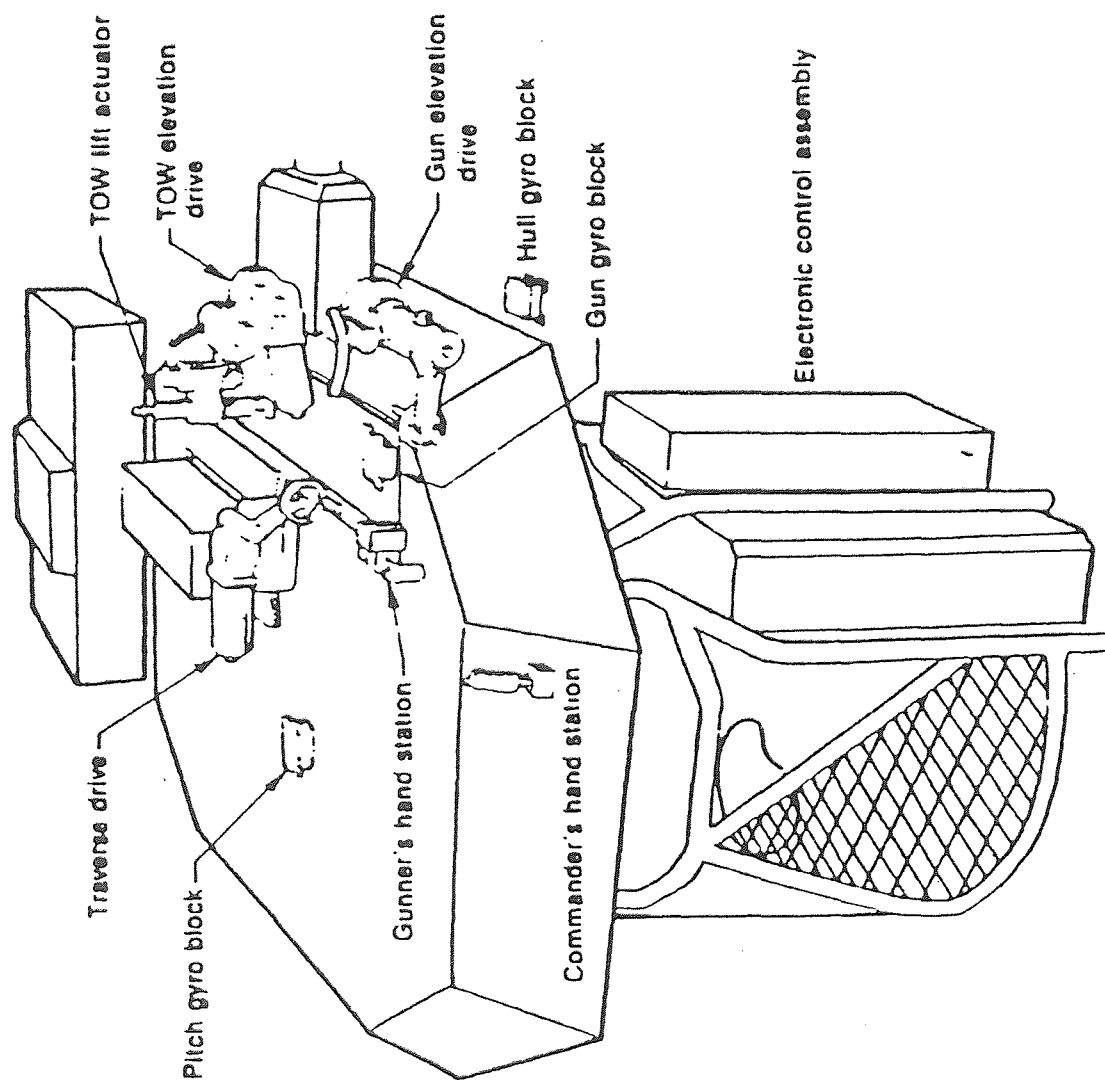
FIGURE 18 : TURRET STABILIZATION

5.1 Alternative Physical Layouts

Common to all configurations are, the parts attributes and their scheduling and the machine characteristics.

All parts arrive at the load station. After which the are moved according to part scheduling. The Turret stabilization systems require the fabrication of eleven cast aluminum housings and covers. A set of parts for one vehicle is called a "ship set". Each part has different characteristics. Table 1 specifies these differences.

PART NUMBER	PART NAME	Part Size high * wide * thick
	Traverse Drive	
1	Top (TRA/T)	8-1/2 * 10 * 10-1/2
2	Middle(TRA/M)	12-1/2 * 8 2-3/4
3	Lower(TRA/L)	16-1/4 * 6-1/4 * 6-1/4
	Tow Elevation	
4	Housing(TOW/H)	11 * 15 * 7-1/4
5	Cover(TOW/C)	12 * 10 * 2-1/4
	Gun Elevation	
6	Housing(GUN/H)	14 * 11 * 9-1/2
7	Cover(GUN/C)	8-1/2 * 10-1/2 * 1-1/4
	Tow Lift	
8	Housing(TL/H)	10-1/4 * 13 * 5-1/4
	Manual Drive	
9	Top(MAN/T)	10-1/2 * 13-1/4 * 3/8
10	Housing(MAN/H)	10-1/2 * 19-1/2 * 5
11	Lower(MAN/L)	3-1/2 * 9-1/8 * 3/8

Table #1. Turret Stabilization parts set.

Table #2 illustrates the machinability data (feed and speeds for assumed operation types).

	SURFACE FEET/ MIN	FEED/ TOOTH (0.001')	FEED/ REVOLUTION	FEED/ INCHES/ MIN
ROUGH MILL	600	4		
FINISH MILL	600	2		
CONTOUR MILL	250	3		
DRILL	150	1		
TAP			30	
FORM TOOL	600	4		
WOODRUFF KEY	600	16		
SEMIFINISH BORE	500	5		
FINISH BORE	500	2		

Table #2 Machinability data

5.2 Layout Alternatives

The four configurations(alternatives) will be discussed in the next section. In all of the four configuration illustrated there is an automatic inspection (INSPECT) machine allocated on the line.

5.2.1 Configuration 1 (Manual Layout)

This is based on a combination of several precision boring mills (PNC) and a general-purpose NC machine center(GNC). Four precision manual machines are used, with the potential advantage that through the use of manual in-process gauging and compensation, the resulting machine accuracy will be better than all but the most precise automated machines. Only one general-purpose machine center will be required to handle the standard accuracy machine production load. Another general-purpose machining center is shown in phantom because of the concern of possible catastrophic system down time, if reliance is placed solely upon a single machine. The extra capacity afforded by a

redundant machine is not needed for this level of production, but may be necessary to avoid a dangerously weak link in the production schedule. Production of additional part types could be used to make redundancy more economic. See Figure 19.

5.2.2 Configuration 2 (Conveyor)

A mixture of precision (PNC) and general-purpose (GNC) automated machine centers are used. Only one of each is required to satisfy the nominal production rate. This configuration incorporates an automated one way loop pallet transport system (CONVEYOR), and is illustrated in Figure 20.

5.2.3 Configuration 3 (Robot)

This based upon the use of two essentially identical precision machining centers (PNC). As a result, there is a reduction of the frequency of material handling movements by nearly half, since all the precision work and the "roughing" can be done on the same machine, thereby allowing the use of less expensive material handling. The material handling system assumed in this configuration is a transfer arm (ROBOT) which could readily serve these machines in a minimum of space. See Figure 21.

5.2.4 Configuration 4 (Cart)

This configuration is also based upon the use of duplicate precision machining centers (PNC). The difference from Configuration 3 is the incorporation of a linear cart-way which accesses a set of pallet load stations on one side and the machines on the other. Only one cart is required to easily service the scheduled pallet movements. See Figure 22.
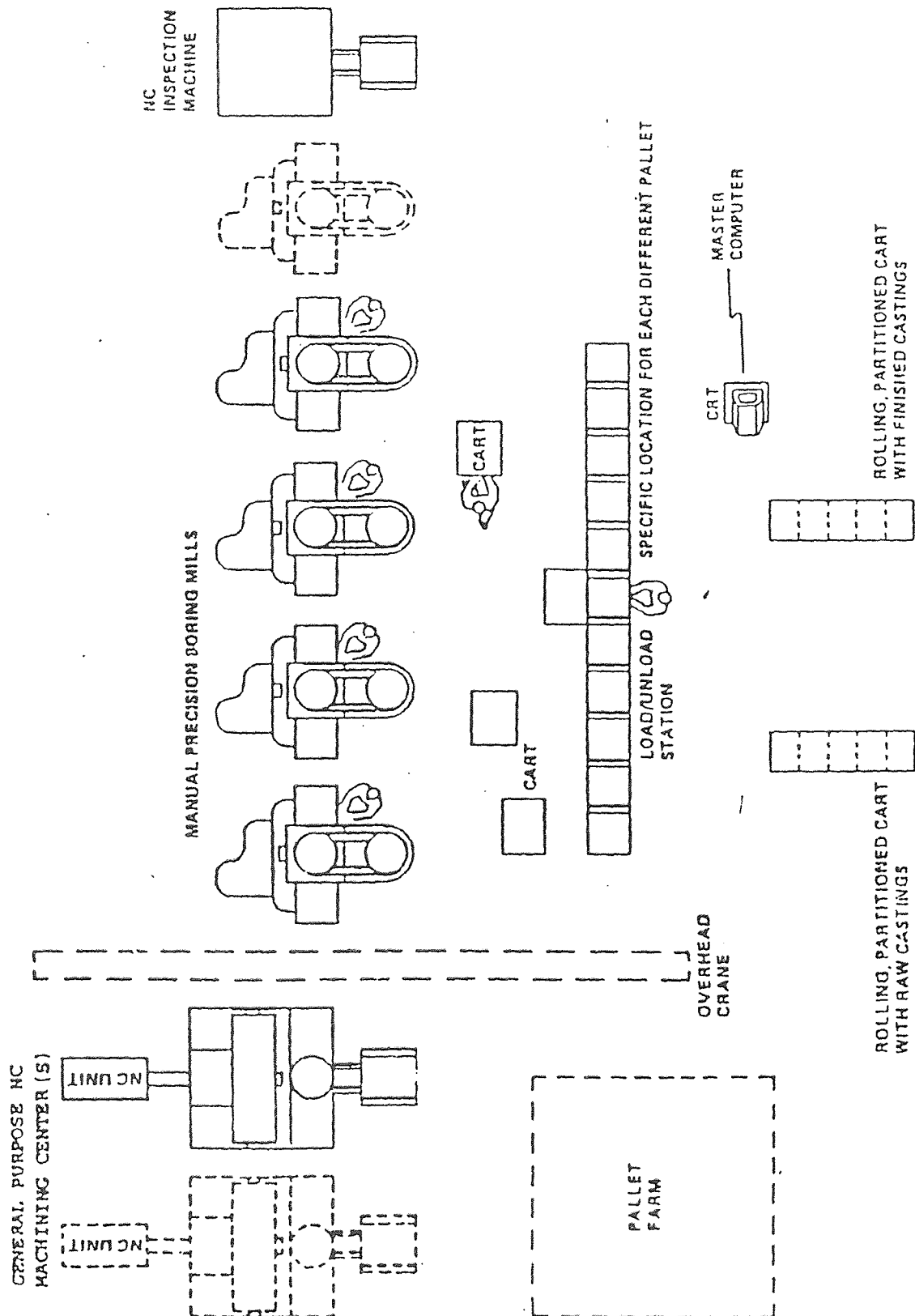
FIGURE 19 : MANUAL LAYOUT
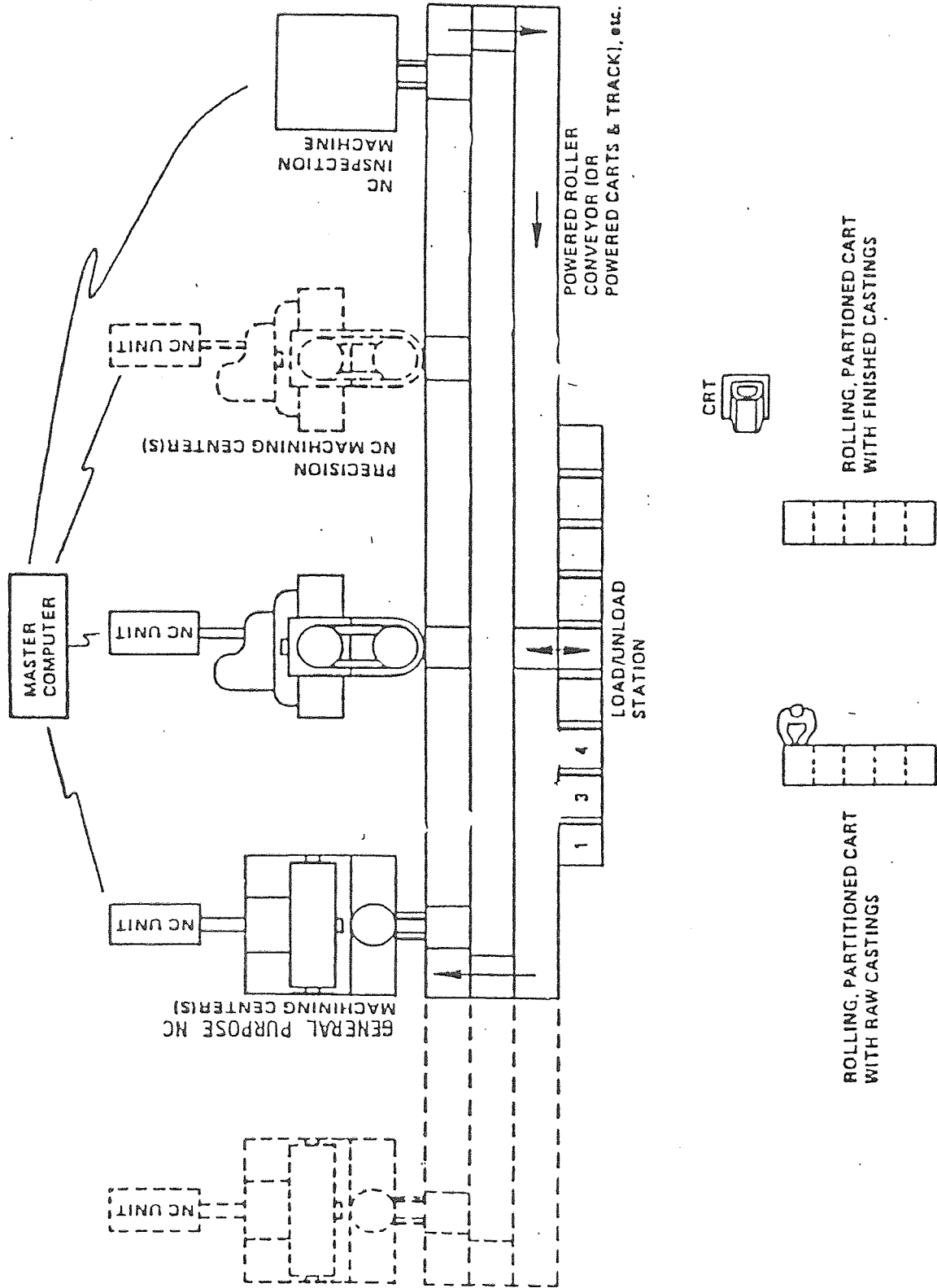
FIGURE 20 : CONVEYOR LAYOUT
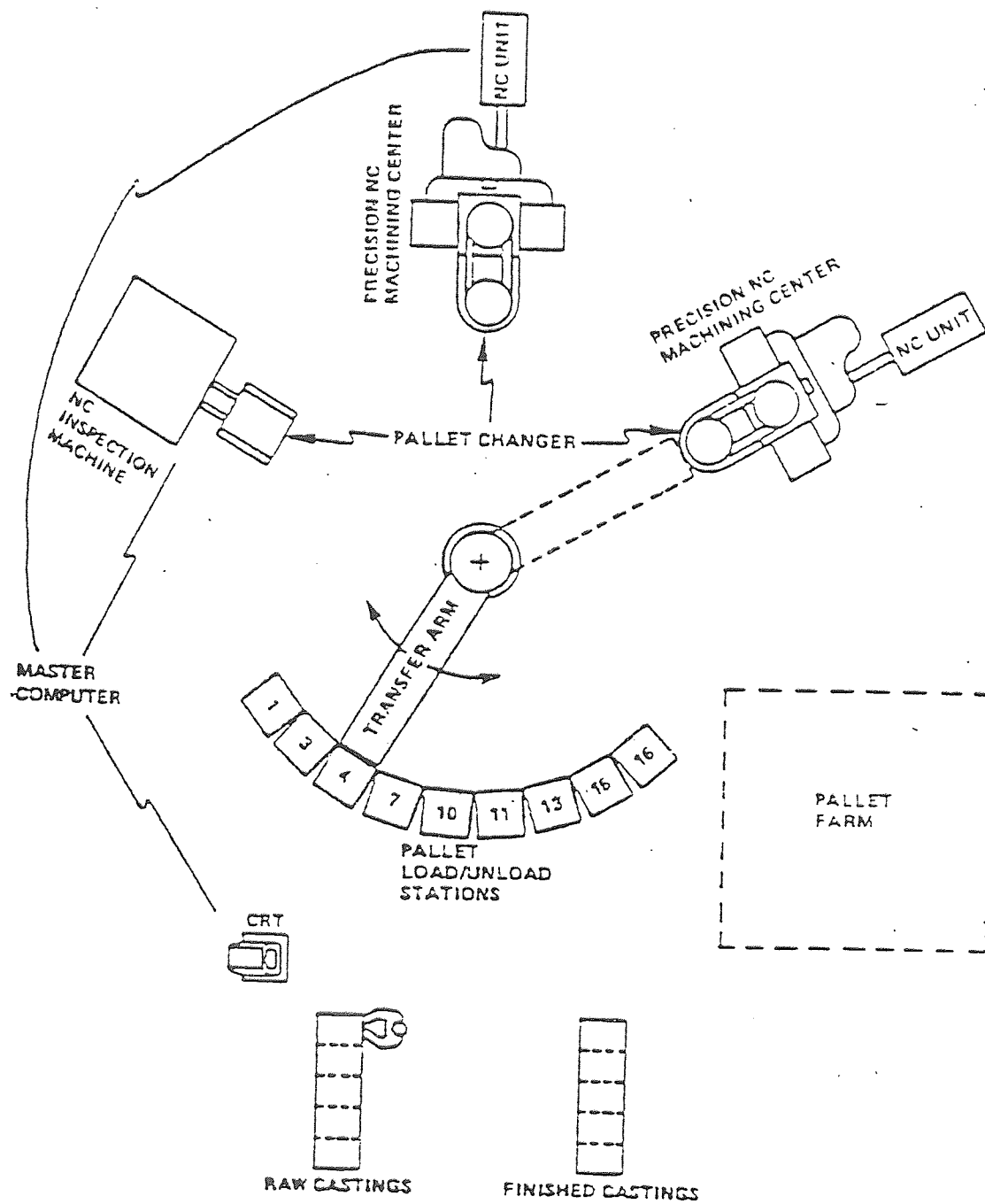
FIGURE 21 : ROBOT LAYOUT
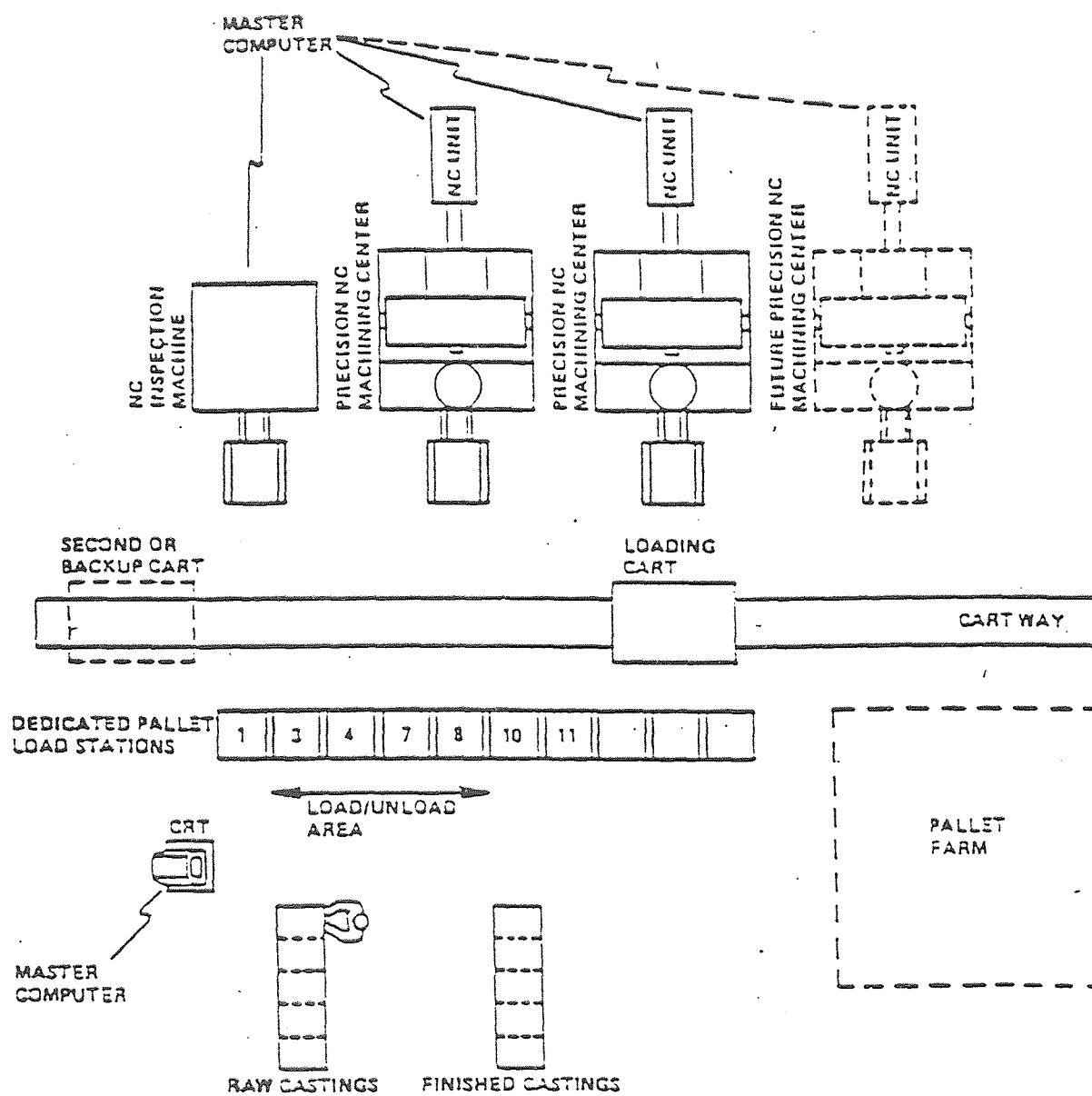
FIGURE 22 : CART WAY LAYOUT

5.3   Alternative Lan Networks

The topologies used to model the Local Area Network are ; IEEE 802.3 (ETHERNET),

IEEE 802.4 (TOKEN BUS), and IEEE 802.5 (TOKEN RING).

5.3.1 Network Configurations

Shown in Figures 23 a, b, & c, are four Network Configurations. In each configuration,

three topologies are used to model Local Area Network as mentioned above.

The attributes for each topology are described in Table 3.

IEEE 802.3	ETHERNET	10 BASE 5
Speed	10.0 Mb	
Retry Interval	IEEE	Sdf
Collision Window	4.33	Mic
Interface gap	9.6	Mic
Jam time	3.2	Mic
Bits per cycle	1	Bit
Cycles per work	8	Cycle
Data words per frame	1500	Word
Min data per frame	304	Bits
Word overhead	0	Bits
Frame overhead	208	Bits
Slot time	51.2	Mic
Retry limit	16	
Limit delay	51.2	Mic

IEEE 802.4	TOKEN BUS	1MB
Speed	1.00	Mb
Bits per cycle	1	Bit
Cycle per word	8	Cycle
Data words per frame	8170	Words
Min data per frame	0	Bits
Word overhead	0	Bit
Frame overhead	192	Bits
Token passing time	NR	Mic

Table #3:   Topologies and Attributes.

Table 3 (cont'd)

IEEE 802.5	TOKEN RING	4Mb
Speed	4.000	Mb
Bits per cycle	1	Bit
Cycle per word	8	Cycle
Data word per frame	4438	Word
Min data per frame	0	Bit
Word overhead	0	Bit
Frame overhead	200	Bits
Token passing time	NR	Mic

IEEE 802.4	TOKEN BUS(STAR)	5Mb
Speed	5.00	Mb
Bit per cycle	1	Bit
Cycle per word	8	Cycle
Data words per frame	8170	Word
Min data per frame	0	Bits
Word overhead	0	Bits
Frame overhead	200	Bit
Token passing time	NR	Mic

From the above specifications, three alternative networks have been generated. Table 4 specifies these alternatives.

ALTERNATIVE	HARDWARE	PROTOCOL
1	Ethernet	CSMA/CD
2	Token Bus	Token Packet
3	Token Ring	Token Packet

Table 4: Hardware and Protocol.
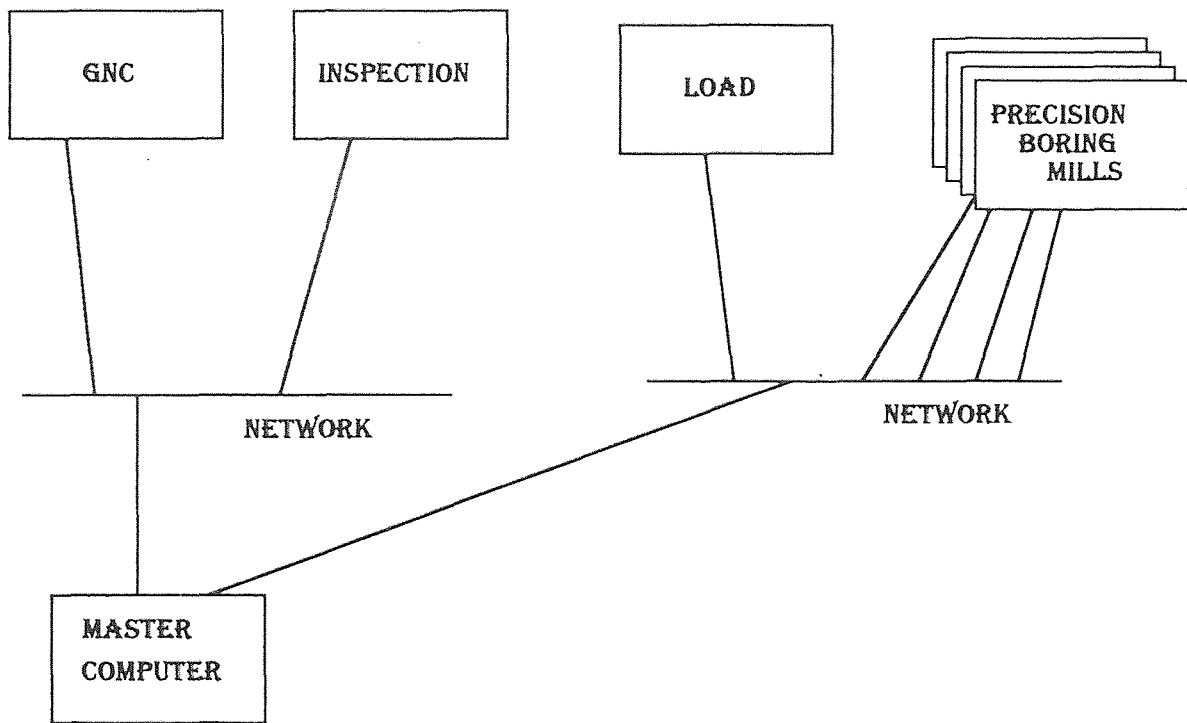
Figure #23a(configuration #1)
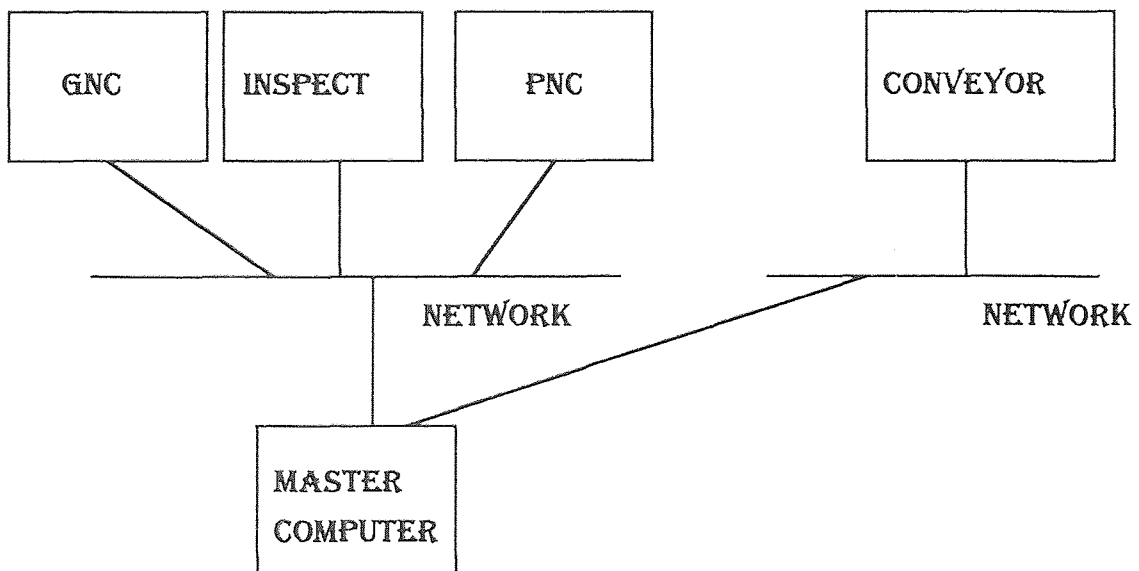
Figure 23b(configuration #2)
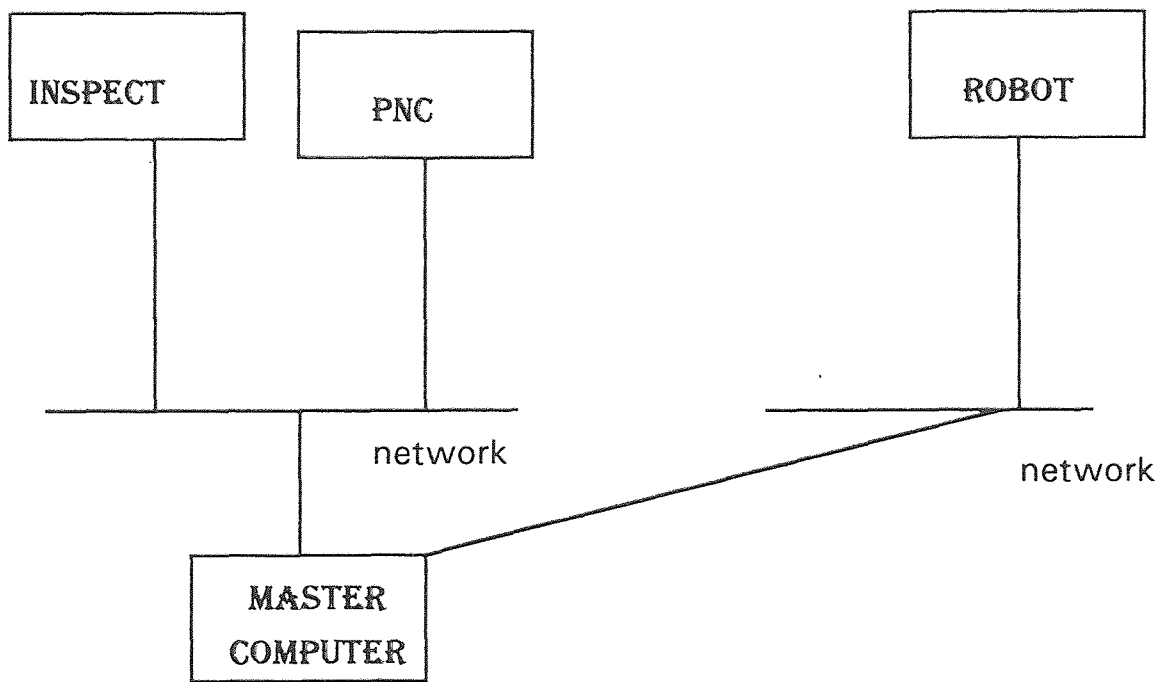
Figure #23c(configuration *3)*
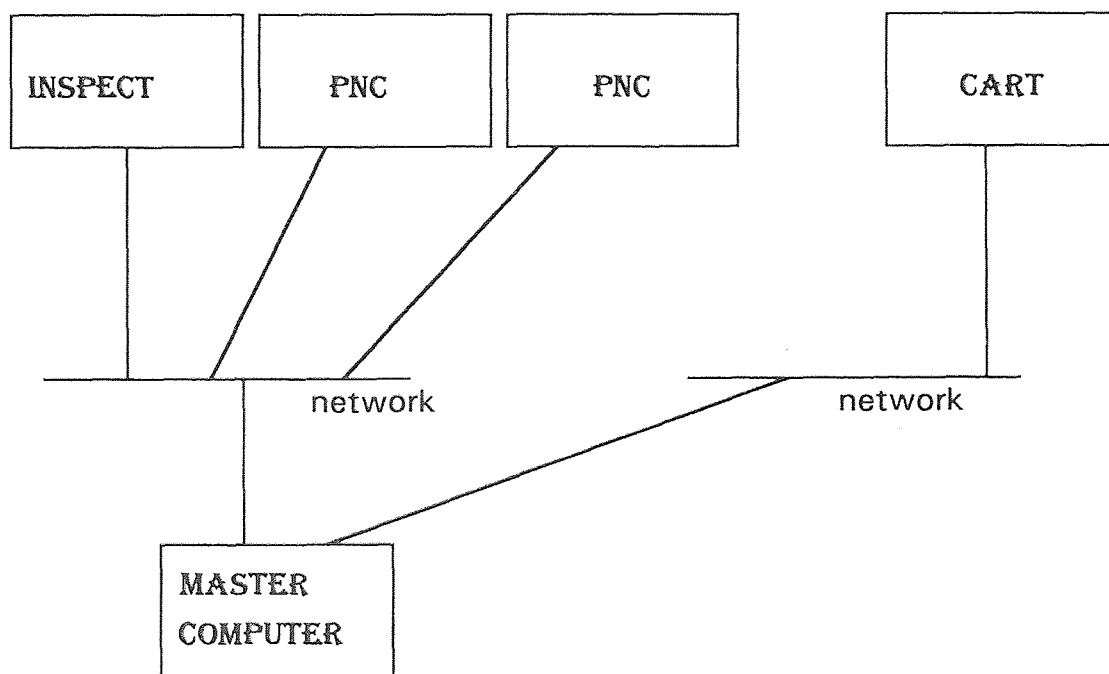
Figure #23d(configuration #*4)*

5.4   Heuristic Application

Each of the four configurations are built using the five modules i.e., Routing, Part scheduling, Downtime, Capacity and Simulation parameters. The models of the four configurations are included in Appendix A.

5.4.1. Promodel Applications

There are various output reports generated from each simulation run, however the resource utilization report is selected for comparison purposes.

CONFIGURATION 1. (Manual)

RESOURCE UTILIZATION   SUMMARY

RESOURCE	CAPA-CITY	% UTIL	TOTAL ENTRY	AVG MIN/ ENTRY	AVG CON-TENTS	MAX CON-TENTS	TENTS	
LOAD	50	99.38	139	171.6	49.7	50	50	
GNC	1	53.74	89	2.9	0.5	1	1	
PNC	4	14.64	89	3.16	0.6	1	1	
I`NSPECT	1	47.4	89	2.56	0.5	1		
MANU	3	25.28	267	1.36	0.8	1	2.22	0.66
EXIT	1	0	89	0	0	1	0	

CONFIGURATION 2 (Conveyor)

RESOURCE UTILIZATION   SUMMARY

RESOURCE	CAPA-CITY	% UTIL	TOTAL ENTRY	AVG MIN/ ENTRY	AVG CON-TENTS	MAX CON-TENTS	FINAL CON-TENTS	
LOAD	11	96.3	4	129	39.4	3	10.6	11 11
GNC	1	64.8	5	119	2.62	0.6	1	1
PNC	2	34.7	119	2.8	0.7	1	1	
INSPECT	1	59.29	119	2.39	0.6	1	1	
EXIT	1	0	118	0	0	1	1	

CONFIGURATION 3 (Robot)

RESOURCE UTILIZATION   SUMMARY

RESOURCE	CAPA-CITY	% UTIL	AVG TOTAL ENTRY	AVG MIN/ ENTRY	MAX CON-TENTS	FINAL CON-TENTS	CON-TENTS
LOAD	50	99.66	105	227.78	49.8	50	50
PNC1	2	76.54	57	12.89	1.5	2	1
INSPECT	1	48.37	56	4.15	0.5	1	0
UNLOAD	50	0.12	56	0.5	0. 1	1	0
ROBOT	1	58.79	167	1.69	0.6	35.8	1.03
EXIT	1	0	56	0	0	1	0

CONFIGURATION 4 (Cart)

RESOURCE UTILIZATION   SUMMARY

RESOURCE	CAPA-CITY	% UTIL	AVG TOTAL ENTRY	AVG MIN/ ENTRY	MAX CON-TENTS	FINAL CON-TENTS	CON-TENTS
LOAD	50	99.08	189	125.82	49.5	50	49
PNC1	2	88.92	142	6.01	1.8	2	2
INSPECT	1	77.83	141	2.65	0.8	1	1
UNLOAD	50	0.29	140	0.5	0.1	1	0
CART	1	18.37	420	0.21	0.2	25.96	0.3
EXIT	1	0	140	0	0	1	0

5.4.2 Extracting Data

A special input to the communication network simulation is obtained from the

RESOURCE UTILIZATION SUMMARY. This is the Average Min/Entry. The time at

each resource are in minutes . A conversion is necessary before inputting the information

to LNET. The conversion is as follows in table #5

	RESOURCE		AVG MIN / ENTRY	SECONDS
CONFIG1	GNC		2.9	174
	PNC		3.16	189
	INSPEC		2.56	154
CONFIG2	GNC		2.62	157
	PNC		2.8	168
	INSPECT		2.39	143
CONFIG3	PNC		12.89	773
	INSPECT		4.15	249
CONFIG4	PNC		6.01	361
	INSPECT		2.65	159

Table 5: Data Extraction Conversion.

5.4.3. LNET Applications and Output Reports

For each configuration three different topologies were modeled; i.e. BUS (ethernet), RING and STAR . The output reports and models for the twelve LAN are included in APPENDIX B.

5.6 Comparisons

Different simulation models have been developed and applied to the General Electric case study. The results were reported in APPENDICES. The comparison is described in the next chapter.

CHAPTER 6

ANALYSIS AND RESULTS

Having finalized the models it is important to compare and analyze the behavior of the system through the models. In this chapter the important performance measures for both the physical layout and network are identified and compared. The first comparison is the physical layout performance. This is based on the Resource Utilization report .The second comparison will be the LNET report without the delay extracted from the Promodel report. The third comparison is the LNET report with the extraction from the Promodel report.

Traditional analyses performed with output data from simulation models are mean value analysis and variance analysis. Although there are several ways to approach the analyses, presented here is a conceptual approach which involves visually identifying the factors which are significant. (Performance measures).

The analysis of the simulation output for the physical layout performance, as shown in Table 6 (Comparison #1) was done and it was concluded that configuration 4 would be the optimum choice. This choice was made because Configuration 4 carries the highest throughput (TOTAL ENTRY), and the highest utilization of the workstations.

In the analysis of the network performance Table 7 (comparison #2), Configuration 2 generates the highest throughput (Received Message), and stations utilization are at 100%.

In comparing the network performance vs. the physical layout performance Table 8 (comparison # 3), the performance measures used were completed activity of LNET and throughput of PROMODEL. The effectiveness ratio was determined by completed activity/message sent for the network, and for the physical layout, throughput/total entry.

71

The most effective configuration for the network is Configuration 3 which has a 62.14%

effectiveness.

On the other hand, Configuration 4 (Table 8) of the Physical layout has the highest

percentage effectiveness of 91.47%.

		capacity	UTILIZATION	TOTAL ENTRY	AVG MIN/ENTRY
	MANUAL	3	25.28	267	1.36
CONFIG1	GNC	1	53.74	89	2.9
Manual	PNC	4	14.64	89	3.16
	INSPECT	1	47.4	89	2.56
	LOAD	50	96.34	129	39.43
CONFIG2	GNC	1	64.85	119	2.62
CONVEYOR	PNC	1	34.7	119	2.8
	INSPECT	1	59.29	119	2.39
CONFIG3	ROBOT	1	58.79	167	1.69
ROBOT	PNC	2	76.54	57	12.89
	INSPECT	1	48.37	56	4.15
CONFIG4	CART	1	18.37	420	0.21
CART	PNC	2	88.92	142	6.01
	INSPECT	1	77.83	141	2.65

Table # 6: comparison #1(Physical layout performance.)

Configuration #1(manual.)

MANUAL		RECEIVED MESSAGE	STATION UTILIZATION	MAXI WAIT TIME MICROSEC
	LOAD	6	100	
	GNC	332	100	
CON1(ETHERNET)	PBM	160	100	
	INSPECT	112	100	
	MC		0.093	9.6
	LOAD	6	100	
	GNC	332	100	
CON1(TOKEN RING)	PNC	160	100	
	INSPECT	112	100	
	MC		0.185	
	LOAD	6	100	
	GNC	332	100	
CON1(STAR)	PNC	160	100	
	INSPECT	112	100	
	MC		0.154	

Configuration #2(conveyor.)

CONVEYOR		RECEIVED MESSAGE	STATION UTILIZATION	MAXI WAIT TIME
	CONVEYOR	26	100	
	GNC	368	100	
CON2(ETHERNET)	PNC	178	100	
	INSPECT	124	100	
	MC		0.103	9.6
	CONVEYOR	26	100	
	GNC	368	100	
CON2(TOKEN RING)	PNC	178	100	
	INSPECT	124	100	
	MC		0.206	
	CONVEYOR	26	100	
	GNC	368	100	
CON2(STAR)	PNC	178	100	
	INSPECT	124	100	
	MC		0.171	

Table #7: comparison #2 (Network performance.)

Table 7 cont'd

Configuration #3(robot.)

ROBOT		RECEIVE MESSAGE	STATION UTILIZATION	MAXI WAIT TIME
CON3(ETHERNET)	ROBOT	6	100	
	PNC	76	100	
	INSPECT	58	100	
	MC		0.009	9.6
CON3(TOKEN RING)	ROBOT	6	100	
	PNC	76	100	
	INSPECT	58	99.97	
	MC		0.012	
CON3(STAR)	ROBOT	6	100	
	PNC	76	100	
	INSPECT	58	100	
	MC		0.011	

Configuration #4(cart.)

CART		RECEIVE MESSAGE	STATION UTILIZATION	MAXI WAIT TIME
CON4(ETHERNET)	CART	4	100	
	PNC	160	100	
	INSPECT	112	100	
	MC		0.18	9.6
CON4(TOKEN RING)	CART	8	100	
	PNC	160	100	
	INSPECT	112	100	
	MC		0.024	
CON4(STAR)	CART	8	100	
	PNC	160	100	
	INSPECT	112	100	
	MC		0.021	

	NETWORK	COMPLETE ACTIVITY LNET	THROUGHPUT PROMODEL	EFFECTI- VENESS CA	TP
CONFIGURATION 1	ETHERNET TOKEN RING TOKEN BUS(STAR)	332 332 332	89	54.43	64.0$
CONFIGURATION 2	ETHERNET TOKEN RING TOKEN BUS(STAR)	360 360 360	118	59.31	91.4$\overline{\imath}$
CONFIGURATION 3	ETHERNET TOKEN RING TOKEN BUS(STAR)	87 87 87	56	62.14	33.5$
CONFIGURATION 4	ETHERNET TOKEN RING TOKEN BUS(STAR)	157 157 157	140	56.07	74.0$\overline{\imath}$

Table #8: Comparison #3(Network Vs Physical system performance.)

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

In this research a methodology for modeling and performance analysis of the integration effect of communication network to the physical system was accomplished. The performance measures for the physical layout and the network were determined in order to attain performance analysis.

The next step was to model the physical layout using a simulation package. Extracting the results from the outcome of this simulation and using this as input to the communication network. After this was done, the communication network was modeled using a simulation package. The output of each simulation run was compared.

From the results of the analyses, the following observations can be made. Firstly, an optimum selection for the physical layout is achieved.(Table 6: Configuration 4) This layout carries the highest throughput and utilization at each work station. Secondly, the analysis of the network performance reveals that Configuration 2(Table 7) generates the highest throughput and station utilization. Finally, in comparing both network performance and physical layout performance, the most effective configuration for the network is Configuration 3.(Table 8) This has a 62.14% effectiveness. While Configuration 2(Table 8) of the physical layout has the highest percentage effectiveness of 91.47%.

The inspection workstation is the final station and the throughput at this point for both the physical system and the network can also be compared (Table 9).It is noted, in all cases the throughput at each configuration is greater in the network. Similar delays were used, which was extracted from the physical system(Promodel), therefore this indicates the effectiveness of network performance on the physical.

	RECEIVED MESSAGES (NETWORK)		TOTAL ENTRY PHYSICAL
CONFIGURATION 1	112		89
CONFIGURATION 2	124		119
CONFIGURATION 3	58		56
CONFIGURATION 4	112		104

Table #9 Throughput comparison

Simulation through software modeling is an important activity in planning the production capacities, schedules and choosing the best compromise among various parameters.

APPENDIX A

PROMODEL PROGRAM

CONFIGURATION #1
MANUAL LAYOUT

ProModel model: KIRK
*Several boring and NC machining

ROUTING

Part	Location	Operation (min)	Output part	Next location	Condi- tion	Qty	Move time (min)
TRA/T	LOAD	.5	TRA/T	GNC	0	1	MANU
TRA/T	GNC	2.00	TRA/T	PNC	0	1	MANU
TRA/T	PNC	2.10	TRA/T	INSPECT	0	1	MANU
TRA/T	INSPECT	2.00	TRA/T	EXIT	0	1	0
TRA/M	LOAD	.5	TRA/M	GNC	0	1	MANU
TRA/M	GNC	1.54	TRA/M	PNC	0	1	MANU
TRA/M	PNC	2.31	TRA/M	INSPECT	0	1	MANU
TRA/M	INSPECT	2.00	TRA/M	EXIT	0	1	0
TRA/L	LOAD	.5	TRA/L	GNC	0	1	MANU
TRA/L	GNC	2.45	TRA/L	PNC	0	1	MANU
TRA/L	PNC	2.60	TRA/L	INSPECT	0	1	MANU
TRA/L	INSPECT	2.00	TRA/L	EXIT	0	1	0
TOW/H	LOAD	.5	TOW/H	GNC	0	1	MANU
TOW/H	GNC	2.44	TOW/H	PNC	0	1	MANU
TOW/H	PNC	1.31	TOW/H	INSPECT	0	1	MANU
TOW/H	INSPECT	1.50	TOW/H	EXIT	0	1	0
TOW/C	LOAD	.5	TOW/C	GNC	0	1	MANU
TOW/C	GNC	1.54	TOW/C	PNC	0	1	MANU
TOW/C	PNC	2.00	TOW/C	INSPECT	0	1	MANU
TOW/C	INSPECT	2.00	TOW/C	EXIT	0	1	0
GUN/H	LOAD	.5	GUN/H	GNC	0	1	MANU
GUN/H	GNC	2.41	GUN/H	PNC	0	1	MANU
GUN/H	PNC	2.41	GUN/H	INSPECT	0	1	MANU
GUN/H	INSPECT	2.50	GUN/H	EXIT	0	1	0
GUN/C	LOAD	.5	GUN/C	GNC	0	1	MANU
GUN/C	GNC	2.50	GUN/C	PNC	0	1	MANU
GUN/C	PNC	2.42	GUN/C	INSPECT	0	1	MANU
GUN/C	INSPECT	2.43	GUN/C	EXIT	0	1	0
TL/H	LOAD	.5	TL/H	GNC	0	1	MANU
TL/H	GNC	2.44	TL/H	PNC	0	1	MANU
TL/H	PNC	3.00	TL/H	INSPECT	0	1	MANU
TL/H	INSPECT	3.97	TL/H	EXIT	0	1	0
MAN/T	LOAD	.5	MAN/T	GNC	0	1	MANU
MAN/T	GNC	3.38	MAN/T	PNC	0	1	MANU
MAN/T	PNC	3.00	MAN/T	INSPECT	0	1	MANU
MAN/T	INSPECT	3.00	MAN/T	EXIT	0	1	0
MAN/H	LOAD	.5	MAN/H	GNC	0	1	MANU
MAN/H	GNC	2.77	MAN/H	PNC	0	1	MANU
MAN/H	PNC	2.34	MAN/H	INSPECT	0	1	MANU
MAN/H	INSPECT	2.38	MAN/H	EXIT	0	1	0
MAN/L	LOAD	.5	MAN/L	GNC	0	1	MANU
MAN/L	GNC	2.21	MAN/L	PNC	0	1	MANU
MAN/L	PNC	3.00	MAN/L	INSPECT	0	1	MANU
MAN/L	INSPECT	2.30	MAN/L	EXIT	0	1	0

PART SCHEDULING

Part	Location	Qty per arrival	No. of arrivals	Start (min)	Arrival frequency (min)

```
-----        --------      --------  ---------   -----     ----------------
TRA/T    LOAD            1         999         0         12
TRA/M    LOAD            1         999         0         12
TRA/L    LOAD            1         999         0         12
TOW/H    LOAD            1         999         0         16
TOW/C    LOAD            1         999         0         16
GUN/H    LOAD            1         999         0         5
GUN/C    LOAD            1         999         0         5
TL/H     LOAD            1         999         0    ·    5
MAN/T    LOAD            1         999         0         7
MAN/H    LOAD            1         999         0         7
MAN/L    LOAD            1         999         0         7
```

TRANSPORTER SPECIFICATIONS FOR MANU

Speed ft(m)/min	Pickup (sec)	Deposit (sec)	Start position	Search rule	Accel (fpss)	Decel (fpss)
40	20	10	1	OLDEST	2	2

PATH LOGIC FOR MANU

From	To	Block	Speed ft(m)/min	Distance ft(m) or Time(min)
1	2	0	0	40
2	3	0	0	20
3	4	0	0	20
4	1	0	0	40

LOCATION INTERFACES FOR MANU

Location	Point	Location	Point	Location	Point	Location	Point
PNC	3	GNC	2	LOAD	1	INSPECT	4

CAPACITIES

Resource	Qty	Resource	Qty	Resource	Qty	Resource	Qty	Resource	Qt
PNC	4	MANU	3	GNC	1	INSPECT	1	LOAD	50

SIMULATION PARAMETERS   GRAPHIC OPTIONS

Run (hrs)	Startup (hrs)	Rept code	Resource to track	Seed	Graph mode	Max row	Max col	Scr clr	Fig clr	Icon file
8	1	5	PNC	0	2	133	240	D	W	PM.LIB

STATIC SYMBOLS

ID	Sym	Clr	Row	Col	ID	Sym	Clr	Row	Col	ID	Sym	Clr	Ro
LOAD	4	O	14	18	EXIT	3	W	14	33	GNC	2	G	
PNC	6	G	6	18	INSPECT	3	R	7	33				

DYNAMIC SYMBOLS

ProModel Results for A:KIRK
*Several boring and NC machining
Date: 1/10/1995
Simulation Time: 8.00 hours
Startup Period: 1.00 hours

RESOURCE UTILIZATION SUMMARY

Resource	Capa-city	% Util	Total entry	Avg. min/ entry	Avg. con-tents	Max con-tents	Final con-tents	Times down	Tc m: dc
LOAD	50	99.38	139	171.60	49.7	50	50	0	(
GNC	1	53.74	89	2.90	0.5	1	1	0	(
PNC	4	14.64	89	3.16	0.6	1	1	0	(
INSPECT	1	47.40	89	2.56	0.5	1	0	0	(
MANU	3	25.28	267	1.36	0.8	12.22*	0.66**	0	(
EXIT	1	0.00	89	0.00	0.0	1	0	0	(

       * Percentage of time traveling to and picking up parts.
      ** Average minutes to travel to and pick up each part.

PART ACTIVITY SUMMARY BY LOCATION

Part	Location	Total entry	Avg move time	Avg wait opn	Avg opn time	Avg wait output	Avg wait loc	Avg wait mover
TRA/T	LOAD	16	0.00	0.00	0.41	183.26	4.29	1.33
TRA/T	GNC	10	1.17	0.00	1.88	0.00	0.00	0.33
TRA/T	PNC	9	0.67	0.00	2.10	0.00	0.82	0.33
TRA/T	INSPECT	9	2.18	0.00	2.00	0.00	0.00	0.00
TRA/T	EXIT	9	0.00	0.00	0.00	0.00	0.00	0.00
TRA/M	LOAD	2	0.00	0.00	0.00	88.92	3.50	1.33
TRA/M	GNC	2	1.17	0.00	1.54	0.00	0.00	0.33
TRA/M	PNC	2	0.97	0.00	2.31	0.00	0.00	0.33
TRA/M	INSPECT	2	2.34	0.00	2.00	0.00	0.00	0.00
TRA/M	EXIT	2	0.00	0.00	0.00	0.00	0.00	0.00
TRA/L	LOAD	2	0.00	0.00	0.00	93.75	3.04	1.33
TRA/L	GNC	2	1.17	0.00	2.45	0.00	0.00	0.33
TRA/L	PNC	2	0.68	0.00	2.60	0.00	0.00	0.33
TRA/L	INSPECT	2	2.79	0.00	2.00	0.00	0.00	0.00
TRA/L	EXIT	2	0.00	0.00	0.00	0.00	0.00	0.00
TOW/H	LOAD	11	0.00	0.00	0.41	186.28	4.18	1.33
TOW/H	GNC	6	1.17	0.00	2.44	0.00	0.00	0.33
TOW/H	PNC	6	0.67	0.00	1.31	0.00	1.76	0.33
TOW/H	INSPECT	6	2.16	0.00	1.50	0.00	0.00	0.00
TOW/H	EXIT	6	0.00	0.00	0.00	0.00	0.00	0.00
TOW/C	LOAD	2	0.00	0.00	0.00	144.01	3.94	1.33
TOW/C	GNC	2	1.17	0.00	1.54	0.00	0.00	0.33
TOW/C	PNC	2	1.26	0.00	2.00	0.00	0.00	0.33
TOW/C	INSPECT	2	2.80	0.00	2.00	0.00	0.00	0.00
TOW/C	EXIT	2	0.00	0.00	0.00	0.00	0.00	0.00
GUN/H	LOAD	43	0.00	0.00	0.40	178.59	3.91	1.33
GUN/H	GNC	21	1.17	0.00	2.41	0.00	0.00	0.33

GUN/H	PNC	22	0.65	0.00	2.41	0.00	0.16	0.3:
GUN/H	INSPECT	22	2.55	0.00	2.50	0.00	0.00	0.0(
GUN/H	EXIT	22	0.00	0.00	0.00	0.00	0.00	0.0(
GUN/C	LOAD	7	0.00	0.00	0.00	108.14	3.35	1.2:
GUN/C	GNC	7	1.17	0.00	2.50	0.00	0.00	0.3:
GUN/C	PNC	7	0.67	0.00	2.42	0.00	0.08	0.3:
GUN/C	INSPECT	7	2.44	0.00	2.43	0.00	0.00	0.0(
GUN/C	EXIT	7	0.00	0.00	0.00	0.00	0.00	0.0(
TL/H	LOAD	7	0.00	0.00	0.00	112.76	4.00	1.3:
TL/H	GNC	7	1.17	0.00	2.44	0.00	0.00	0.3:
TL/H	PNC	7	0.67	0.00	3.00	0.00	0.00	0.3:
TL/H	INSPECT	7	2.21	0.00	3.97	0.00	0.00	0.0(
TL/H	EXIT	7	0.00	0.00	0.00	0.00	0.00	0.0(
MAN/T	LOAD	39	0.00	0.00	0.42	187.73	4.09	1.3:
MAN/T	GNC	22	1.17	0.00	3.38	0.00	0.00	0.3:
MAN/T	PNC	22	0.67	0.00	2.98	0.00	0.14	0.3:
MAN/T	INSPECT	21	2.08	0.00	3.00	0.00	0.00	0.0(
MAN/T	EXIT	21	0.00	0.00	0.00	0.00	0.00	0.0(
MAN/H	LOAD	5	0.00	0.00	0.00	111.45	4.88	1.3:
MAN/H	GNC	5	1.17	0.00	2.77	0.00	0.00	0.3:
MAN/H	PNC	5	0.67	0.00	2.34	0.00	0.66	0.3:
MAN/H	INSPECT	5	1.71	0.00	2.38	0.00	0.00	0.0(
MAN/H	EXIT	5	0.00	0.00	0.00	0.00	0.00	0.0(
MAN/L	LOAD	5	0.00	0.00	0.00	117.66	4.27	1.3:
MAN/L	GNC	5	1.17	0.00	2.21	0.00	0.00	0.3:
MAN/L	PNC	5	0.67	0.00	3.00	0.00	0.00	0.3:
MAN/L	INSPECT	6	1.56	0.00	2.30	0.00	0.00	0.0(
MAN/L	EXIT	6	0.00	0.00	0.00	0.00	0.00	0.0(

OVERALL PART ACTIVITY SUMMARY

Part	% move time	% wait opn	% opn time	% outQ time	% wait loc	% wait mover	Cum part minutes in system
-----	----	----	----	----	----	-----	---------
TRA/T	1	0	2	95	2	1	3094
TRA/M	3	0	5	87	3	1	204
TRA/L	4	0	6	87	3	1	216
TOW/H	1	0	2	95	2	0	2150
TOW/C	3	0	3	91	2	1	317
GUN/H	1	0	2	95	1	0	8077
GUN/C	3	0	6	87	3	1	870
TL/H	3	0	7	86	3	1	922
MAN/T	1	0	3	94	1	1	7754
MAN/H	2	0	5	87	4	1	643
MAN/L	3	0	6	87	3	1	673

OVERALL LOCATION ACTIVITY SUMMARY

% down or no	% wait part	% wait before	% in actual	% wait output	% wait	% wait

ID	Sym	Clr	ID	Sym	Clr	ID	Sym	Clr	ID	Sym	Clr
MANU	A	O	GUN/C	.	W	GUN/H	,	W	MAN/H	/	G
MAN/L	<	R	MAN/T	>	R	TL/H	;	M	TOW/C	/	G

2

ID	Sym	Clr	ID	Sym	Clr	ID	Sym	Clr	ID	Sym	Clr
TOW/H	,	W	TRA/L	>	B	TRA/M	,	C	TRA/T	/	G

TRANSPORTER POINTS

Point	Row	Col	Point	Row	Col	Point	Row	Col	Point	Row	Col
1	14	17	2	8	8	3	8	17	4	8	31

TRANSPORTER PATH LAYOUT

From	To	Layout
1	2	L9 U6
2	3	R9
3	4	R14
4	1	D7 L14 U1

FIGURES AND LABELS

Type	Clr	Row	Col	Figure
HORZ	D8	18	12	LOADING
VERT	2O	2	38	INSPECTION
HORZ	D8	20	13	AREA
HORZ	DW	2	15	BORING
VERT	2W	5	2	GNC
LINE	0	16	1	R9
LINE	0	16	1	U15 R39 D15 L18

END

CONFIGURATION #2
CONVEYOR

ProModel model: CONFIG2
*A mixture of precision and general purpose automated machining centers

ROUTING

Part	Location	Operation (min)	Output part	Next location	Condition	Qty	Move time (min)
TRA/T	LOAD	.5	TRA/T	GNC	0	1	CONVEYOR
TRA/T	GNC	2.00	TRA/T	PNC	0	1	CONVEYOR
TRA/T	PNC	2.10	TRA/T	INSPECT	0	1	CONVEYOR
TRA/T	INSPECT	2.00	TRA/T	EXIT	0	1	0
TRA/M	LOAD	.5	TRA/M	GNC	0	1	CONVEYOR
TRA/M	GNC	1.54	TRA/M	PNC	0	1	CONVEYOR
TRA/M	PNC	2.31	TRA/M	INSPECT	0	1	CONVEYOR
TRA/M	INSPECT	2.00	TRA/M	EXIT	0	1	0
TRA/L	LOAD	.5	TRA/L	GNC	0	1	CONVEYOR
TRA/L	GNC	2.45	TRA/L	PNC	0	1	CONVEYOR
TRA/L	PNC	2.60	TRA/L	INSPECT	0	1	CONVEYOR
TRA/L	INSPECT	2.00	TRA/L	EXIT	0	1	0
TOW/H	LOAD	.5	TOW/H	GNC	0	1	CONVEYOR
TOW/H	GNC	2.44	TOW/H	PNC	0	1	CONVEYOR
TOW/H	PNC	1.31	TOW/H	INSPECT	0	1	CONVEYOR
TOW/H	INSPECT	1.50	TOW/H	EXIT	0	1	0
TOW/C	LOAD	.5	TOW/C	GNC	0	1	CONVEYOR
TOW/C	GNC	1.54	TOW/C	PNC	0	1	CONVEYOR
TOW/C	PNC	2.00	TOW/C	INSPECT	0	1	CONVEYOR
TOW/C	INSPECT	2.00	TOW/C	EXIT	0	1	0
GUN/H	LOAD	.5	GUN/H	GNC	0	1	CONVEYOR
GUN/H	GNC	2.41	GUN/H	PNC	0	1	CONVEYOR
GUN/H	PNC	2.41	GUN/H	INSPECT	0	1	CONVEYOR
GUN/H	INSPECT	2.50	GUN/H	EXIT	0	1	0
GUN/C	LOAD	.5	GUN/C	GNC	0	1	CONVEYOR
GUN/C	GNC	2.50	GUN/C	PNC	0	1	CONVEYOR
GUN/C	PNC	2.42	GUN/C	INSPECT	0	1	CONVEYOR
GUN/C	INSPECT	2.43	GUN/C	EXIT	0	1	0
TL/H	LOAD	.5	TL/H	GNC	0	1	CONVEYOR
TL/H	GNC	2.44	TL/H	PNC	0	1	CONVEYOR
TL/H	PNC	3.00	TL/H	INSPECT	0	1	CONVEYOR
TL/H	INSPECT	1.50	TL/H	EXIT	0	1	0
MAN/T	LOAD	.5	MAN/T	GNC	0	1	CONVEYOR
MAN/T	GNC	3.38	MAN/T	PNC	0	1	CONVEYOR
MAN/T	PNC	3.00	MAN/T	INSPECT	0	1	CONVEYOR
MAN/T	INSPECT	3.00	MAN/T	EXIT	0	1	0
MAN/H	LOAD	.5	MAN/H	GNC	0	1	CONVEYOR
MAN/H	GNC	2.77	MAN/H	PNC	0	1	CONVEYOR
MAN/H	PNC	2.34	MAN/H	INSPECT	0	1	CONVEYOR
MAN/H	INSPECT	2.38	MAN/H	EXIT	0	1	0
MAN/L	LOAD	.5	MAN/L	GNC	0	1	CONVEYOR
MAN/L	GNC	2.21	MAN/L	PNC	0	1	CONVEYOR
MAN/L	PNC	3.00	MAN/L	INSPECT	0	1	CONVEYOR
MAN/L	INSPECT	2.30	MAN/L	EXIT	0	1	0

PART SCHEDULING

Part	Location	Qty per arrival	No. of arrivals	Start (min)	Arrival frequency (min)

```
  -----    ---------       -------    ---------    -----     -----------------
  TRA/T   ·LOAD            1          999          0          12
  TRA/M    LOAD            1          999          0          12
  TRA/L    LOAD            1          999          0          12
  TOW/H    LOAD            1          999          0          16
  TOW/C    LOAD            1          999          0          16
  GUN/H    LOAD            1          999          0          5
  GUN/C    LOAD            1          999          0          5
  TL/H     LOAD            1          999          0   ·       5
  MAN/T    LOAD            1          999          0          7
  MAN/H    LOAD            1          999          0          7
  MAN/L    LOAD            1          999          0          7
```

CONVEYOR SPECIFICATIONS

Section	Type	Speed ft(m)/min	Length of load ft(m)	Spacing ft(m)
CON1	TRANS	10	1	.1
CON2	TRANS	10	1	.1
CON3	TRANS	10	1	.1
CON4	TRANS	10	1	.1

CONVEYOR INTERFACE LOCATIONS

Location	Conv	Ft(m)	Sec	Location	Conv	Ft(m)	Sec	Location	Conv	Ft(m)
GNC	CON2	5	3	INSPECT	CON4	5	3	LOAD	CON1	1
PNC	CON3	5	3							

CONVEYOR TRANSFER LOGIC

From sect	Distance ft(m)	To sect	Distance ft(m)	Time (sec)
CON1	10	CON2	1	2
CON2	10	CON3	1	2
CON3	10	CON4	1	2
CON4	10	CON1	1	2

CAPACITIES

Resource	Qty	Resource	Qty	Resource	Qty	Resource	Qty
GNC	*1	INSPECT	*1	LOAD	*11	PNC	*2

SIMULATION PARAMETERS   GRAPHIC OPTIONS

Run (hrs)	Startup (hrs)	Rept code	Resource to track	Seed	Graph mode	Max row	Max col	Scr clr	Fig clr	Icon file
8	1	5	GNC	0	2	133	200	R	W	PM.LIB

STATIC SYMBOLS

ID	Sym	Clr	Row	Col	ID	Sym	Clr	Row	Col	ID	Sym	Clr	Row

ProModel Results for A:CONFIG2
*A mixture of precision and general purpose automated machining centers
Date: 1/10/1995
Simulation Time: 8.00 hours
Startup Period: 1.00 hours

RESOURCE UTILIZATION SUMMARY

Resource	Capacity	% Util	Total entry	Avg. min/ entry	Avg. contents	Max contents	Final contents	Times down	T(m d(
LOAD	11	96.34	129	39.43	10.6	11	11	0	
GNC	1	64.85	119	2.62	0.6	1	1	0	
PNC	2	34.70	119	2.80	0..7	1	1	0	
INSPECT	1	59.29	119	2.39	0.6	1	1	0	
EXIT	1	0.00	118	0.00	0.0	1	0	0	

VARIANCE SUMMARY

Resource	Avg. Contents	Std. dev.	Avg. min/ exit	Std. dev. (min)	Min time (min)	Max time (min)	Zero time count	Total Count
LOAD	10.60	27.66	43.15	1.68	39.16	46.86	0	118
GNC	0.65	0.48	2.64	0.51	2.00	3.38	0	118
PNC	0.69	0.46	2.82	0.38	2.01	3.60	0	118
INSPECT	0.59	0.49	2.41	0.51	1.50	3.00	0	118

PART ACTIVITY SUMMARY BY LOCATION

Part	Location	Total entry	Avg move time	Avg wait opn	Avg opn time	Avg wait output	Avg wait loc	Avg wait move:
TRA/T	LOAD	22	0.00	0.00	0.48	37.11	4.19	0.0(
TRA/T	GNC	21	1.43	0.00	2.00	0.00	0.00	0.0(
TRA/T	PNC	22	0.98	0.00	2.01	0.00	0.82	0.0(
TRA/T	INSPECT	21	1.03	0.00	2.00	0.00	0.00	0.0(
TRA/T	EXIT	21	0.00	0.00	0.00	0.00	0.00	0.0(
TRA/M	LOAD	0	0.00	0.00	0.00	0.00	0.00	0.0(
TRA/M	GNC	0	0.00	0.00	0.00	0.00	0.00	0.0(
TRA/M	PNC	0	0.00	0.00	0.00	0.00	0.00	0.0(
TRA/M	INSPECT	0	0.00	0.00	0.00	0.00	0.00	0.0(
TRA/M	EXIT	0	0.00	0.00	0.00	0.00	0.00	0.0(
TRA/L	LOAD	0	0.00	0.00	0.00	0.00	0.00	0.0(
TRA/L	GNC	0	0.00	0.00	0.00	0.00	0.00	0.0(
TRA/L	PNC	0	0.00	0.00	0.00	0.00	0.00	0.0(
TRA/L	INSPECT	0	0.00	0.00	0.00	0.00	0.00	0.0(
TRA/L	EXIT	0	0.00	0.00	0.00	0.00	0.00	0.0(
TOW/H	LOAD	18	0.00	0.00	0.47	36.62	4.17	0.0(
TOW/H	GNC	17	1.43	0.00	2.44	0.00	0.00	0.0(
TOW/H	PNC	17	1.03	0.00	1.31	0.00	1.45	0.0C
TOW/H	INSPECT	17	1.03	0.00	1.50	0.00	0.00	0.0C
TOW/H	EXIT	17	0.00	0.00	0.00	0.00	0.00	0.0C

TOW/C	LOAD	0	0.00	0.00	0.00	0.00	0.00	0.00
TOW/C	GNC	0	0.00	0.00	0.00	0.00	0.00	0.00
TOW/C	PNC	0	0.00	0.00	0.00	0.00	0.00	0.00
TOW/C	INSPECT	0	0.00	0.00	0.00	0.00	0.00	0.00
TOW/C	EXIT	0	0.00	0.00	0.00	0.00	0.00	0.00
GUN/H	LOAD	46	0.00	0.00	0.45	33.92	3.92	0.00
GUN/H	GNC	41	1.40	0.00	2.35	0.00	0.00	0.00
GUN/H	PNC	40	1.03	0.00	2.41	0.00	0.26	0.00
GUN/H	INSPECT	40	1.03	0.00	2.50	0.00	0.00	0.00
GUN/H	EXIT	40	0.00	0.00	0.00	0.00	0.00	0.00
GUN/C	LOAD	3	0.00	0.00	0.50	40.06	3.84	0.00
GUN/C	GNC	3	1.43	0.00	2.50	0.00	0.00	0.00
GUN/C	PNC	3	1.03	0.00	2.42	0.00	0.12	0.00
GUN/C	INSPECT	3	1.03	0.00	2.43	0.00	0.00	0.00
GUN/C	EXIT	3	0.00	0.00	0.00	0.00	0.00	0.00
TL/H	LOAD	0	0.00	0.00	0.00	0.00	0.00	0.00
TL/H	GNC	0	0.00	0.00	0.00	0.00	0.00	0.00
TL/H	PNC	0	0.00	0.00	0.00	0.00	0.00	0.00
TL/H	INSPECT	0	0.00	0.00	0.00	0.00	0.00	0.00
TL/H	EXIT	0	0.00	0.00	0.00	0.00	0.00	0.00
MAN/T	LOAD	38	0.00	0.00	0.46	34.50	3.98	0.00
MAN/T	GNC	35	1.43	0.00	3.38	0.00	0.00	0.00
MAN/T	PNC	35	1.03	0.00	3.00	0.00	0.00	0.00
MAN/T	INSPECT	36	1.00	0.00	2.92	0.00	0.00	0.00
MAN/T	EXIT	35	0.00	0.00	0.00	0.00	0.00	0.00
MAN/H	LOAD	2	0.00	0.00	0.50	40.01	4.81	0.00
MAN/H	GNC	2	1.43	0.00	2.77	0.00	0.00	0.00
MAN/H	PNC	2	1.03	0.00	2.34	0.00	0.49	0.00
MAN/H	INSPECT	2	1.03	0.00	2.38	0.00	0.00	0.00
MAN/H	EXIT	2	0.00	0.00	0.00	0.00	0.00	0.00
MAN/L	LOAD	0	0.00	0.00	0.00	0.00	0.00	0.00
MAN/L	GNC	0	0.00	0.00	0.00	0.00	0.00	0.00
MAN/L	PNC	0	0.00	0.00	0.00	0.00	0.00	0.00
MAN/L	INSPECT	0	0.00	0.00	0.00	0.00	0.00	0.00
MAN/L	EXIT	0	0.00	0.00	0.00	0.00	0.00	0.00

OVERALL PART ACTIVITY SUMMARY

Part	% move time	% wait opn	% opn time	% outQ time	% wait loc	% wait mover	Cum part minutes in system
TRA/T	6	0	12	72	9	0	1130
TRA/M	0	0	0	0	0	0	1
TRA/L	0	0	0	0	0	0	1
TOW/H	6	0	11	73	10	0	907
TOW/C	0	0	0	0	0	0	1
GUN/H	6	0	14	72	8	0	2181
GUN/C	6	0	13	74	7	0	163
TL/H	0	0	0	0	0	0	1
MAN/T	6	0	18	68	7	0	1917

```
MAN/H      6      0     13     73      8      0          109
MAN/L      0      0      0      0      0      0            1
```

2

OVERALL LOCATION ACTIVITY SUMMARY

Location	% down or no parts	% wait part arrival	% wait before opn	% in actual opn	% wait output queue	% wait loc	% wait mover
LOAD	4	0	0	1	86	9	0
GNC	1	35	0	64	0	0	0
PNC	53	13	0	29	0	5	0
INSPECT	16	25	0	59	0	0	0
EXIT	100	0	0	0	0	0	0

CONVEYOR ACTIVITY SUMMARY

Section	Entries	Blocked attempts	Final conts	Section	Entries	Blocked attempts	Fin con
CON1	118	0	0	CON2	236	0	
CON3	236	0	0	CON4	118	0	

HOURLY PART EXIT SUMMARY

Part	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 8	Hour 9	Hour 10
TRA/T	3	3	3	3	3	2	1	3		
TRA/M	0	0	0	0	0	0	0	0		
TRA/L	0	0	0	0	0	0	0	0		
TOW/H	1	3	3	2	0	2	2	4		
TOW/C	0	0	0	0	0	0	0	0		
GUN/H	6	5	3	4	5	5	8	4		
GUN/C	0	0	0	0	1	0	1	1		
TL/H	0	0	0	0	0	0	0	0		
MAN/T	5	3	4	6	5	6	3	3		
MAN/H	0	1	1	0	0	0	0	0		
MAN/L	0	0	0	0	0	0	0	0		

```
LOAD       1   B    20  16   GNC       2   G    10   8   PNC       4   O    1
INSPECT    3   C    10  29
```

DYNAMIC SYMBOLS

2

ID	Sym	Clr	ID	Sym	Clr	ID	Sym	Clr	ID	Sym	Clr
GUN/C	.	B	GUN/H	,	W	MAN/H	/	W	MAN/L	<	W
MAN/T	>	R	TL/H	0	W	TOW/C	;	G	TOW/H	,	C
TRA/L	.	O	TRA/M	/	R	TRA/T	>	3			

CONVEYOR LAYOUT

Sect	Sym	Clr	Row	Col	Layout
CON1	1	B	19	16	L9 U5
CON2	1	B	13	8	R11
CON3	1	G	13	19	R11
CON4	1	C	13	30	D7 L13

CONVEYOR TRANSFERS

From	To	Row	Col	Dir	From	To	Row	Col	Dir	From	To	Row	Col	Dir
CON1	CON2	14	8	U	CON2	CON3	13	17	R	CON3	CON4	13	28	R
CON4	CON1	19	18	L										

END

CONFIGURATION #3
ROBOT

ProModel model: A:ROBOT
*two precision machining centers and a transfer arm use for material ha

ROUTING

Part	Location	Operation (min)	Output part	Next location	Condition	Qty	Move time (min)
TRA/T	LOAD	.5	TRA/T	PNC1	0	1	ROBOT
TRA/T	PNC1	2.10	TRA/T	INSPEC	0	1	ROBOT
TRA/T	INSPEC	2.00	TRA/T	UNLOAD	0	1	ROBOT
TRA/T	UNLOAD	.5	TRA/T	EXIT	0	1	0
TRA/M	LOAD	.5	TRA/M	PNC1	0	1	ROBOT
TRA/M	PNC1	2.32	TRA/M	INSPEC	0	1	ROBOT
TRA/M	INSPEC	2.00	TRA/M	UNLOAD	0	1	ROBOT
TRA/M	UNLOAD	.5	TRA/M	EXIT	0	1	0
TRA/L	LOAD	.5	TRA/L	PNC1	0	1	ROBOT
TRA/L	PNC1	2.60	TRA/L	INSPEC	0	1	ROBOT
TRA/L	INSPEC	2.00	TRA/L	UNLOAD	0	1	ROBOT
TRA/L	UNLOAD	.5	TRA/L	EXIT	0	1	0
TOW/H	LOAD	.5	TOW/H	PNC1	0	1	ROBOT
TOW/H	PNC1	1.31	TOW/H	INSPEC	0	1	ROBOT
TOW/H	INSPEC	1.50	TOW/H	UNLOAD	0	1	ROBOT
TOW/H	UNLOAD	.5	TOW/H	EXIT	0	1	0
TOW/C	LOAD	.5	TOW/C	PNC1	0	1	ROBOT
TOW/C	PNC1	2.00	TOW/C	INSPEC	0	1	ROBOT
TOW/C	INSPEC	2.00	TOW/C	UNLOAD	0	1	ROBOT
TOW/C	UNLOAD	.5	TOW/C	EXIT	0	1	0
GUN/H	LOAD	.5	GUN/H	PNC1	0	1	ROBOT
GUN/H	PNC1	2.41	GUN/H	INSPEC	0	1	ROBOT
GUN/H	INSPEC	2.50	GUN/H	UNLOAD	0	1	ROBOT
GUN/H	UNLOAD	.5	GUN/H	EXIT	0	1	0
GUN/C	LOAD	.5	GUN/C	PNC1	0	1	ROBOT
GUN/C	PNC1	2.41	GUN/C	INSPEC	0	1	ROBOT
GUN/C	INSPEC	2.43	GUN/C	UNLOAD	0	1	ROBOT
GUN/C	UNLOAD	.5	GUN/C	EXIT	0	1	0
TL/H	LOAD	.5	TL/H	PNC1	0	1	ROBOT
TL/H	PNC1	3.00	TL/H	INSPEC	0	1	ROBOT
TL/H	INSPEC	3.97	TL/H	UNLOAD	0	1	ROBOT
TL/H	UNLOAD	.5	TL/H	EXIT	0	1	0
MAN/T	LOAD	.5	MAN/T	PNC1	0	1	ROBOT
MAN/T	PNC1	30.83	MAN/T	INSPEC	0	1	ROBOT
MAN/T	INSPEC	3.00	MAN/T	UNLOAD	0	1	ROBOT
MAN/T	UNLOAD	.5	MAN/T	EXIT	0	1	0
MAN/H	LOAD	.5	MAN/H	PNC1	0	1	ROBOT
MAN/H	PNC1	2.34	MAN/H	INSPEC	0	1	ROBOT
MAN/H	INSPEC	2.38	MAN/H	UNLOAD	0	1	ROBOT
MAN/H	UNLOAD	.5	MAN/H	EXIT	0	1	0
MAN/L	LOAD	.5	MAN/L	PNC1	0	1	ROBOT
MAN/L	PNC1	3.00	MAN/L	INSPEC	0	1	ROBOT
MAN/L	INSPEC	2.30	MAN/L	UNLOAD	0	1	ROBOT
MAN/L	UNLOAD	.5	MAN/L	EXIT	0	1	0

PART SCHEDULING

Part	Location	Qty per arrival	No. of arrivals	Start (min)	Arrival frequency (min)

TRA/T	LOAD	1	999	0	12
TRA/M	LOAD	1	999	0	12
TRA/L	LOAD	1	999	0	12
TOW/H	LOAD	1	999	0	16
TOW/C	LOAD	1	999	0	16
GUN/H	LOAD	1	999	0	5
GUN/C	LOAD	1	999	0	5
TL/H	LOAD	1	999	0	5
MAN/T	LOAD	1	999	0	7
MAN/H	LOAD	1	999	0	7
MAN/L	LOAD	1	999	0	7

TRANSPORTER SPECIFICATIONS FOR ROBOT

Speed ft(m)/min	Pickup (sec)	Deposit (sec)	Start position	Search rule	Accel (fpss)	Decel (fpss)
10	2	2	R1	OLDEST	0	0

PATH LOGIC FOR ROBOT

From	To	Block	Speed ft(m)/min	Distance ft(m) or Time(min)
R1	R2	0	0	B10
R2	R3	0	0	B10
R3	R5	0	0	B10

LOCATION INTERFACES FOR ROBOT

Location	Point	Location	Point	Location	Point	Location	Point
INSPEC	R2	LOAD	R1	PNC1	R3	UNLOAD	R5

CAPACITIES

Resource	Qty	Resource	Qty	Resource	Qty	Resource	Qty	Resource	Qty
INSPEC	*1	LOAD	*50	PNC1	*2	ROBOT	*1	UNLOAD	*50

SIMULATION PARAMETERS

Run (hrs)	Startup (hrs)	Rept code	Resource to track	Seed	Graph mode	Max row	Max col	Scr clr	Fig clr	Icon file
8	1	5	0	0	2	100	200	D	W	PM.LIB

GRAPHIC OPTIONS

STATIC SYMBOLS

ID	Sym	Clr	Row	Col	ID	Sym	Clr	Row	Col	ID	Sym	Clr	Row
LOAD	1	R	20	18	PNC1	2	B	6	18	INSPEC	3	G	13
UNLOAD	5	M	20	24									

DYNAMIC SYMBOLS

ID	Sym	Clr	ID	Sym	Clr	ID	Sym	Clr	ID	Sym	Clr

```
--------- --- ---    --------- --- ---    --------- --- ---    --------- --- ---
GUN/C      .   W      GUN/H     .   B      MAN/H     ,   W      MAN/L     ,   G
MAN/T      ,   M      ROBOT     A2  C      TL/H      /   W      TOW/C     >   W      95
TOW/H      >   G      TRA/L     <   W      TRA/M     <   B      TRA/T     <   O
```

TRANSPORTER POINTS

```
Point Row Col   Point Row Col   Point Row Col   Point Row Col
----- --- ---   ----- --- ---   ----- --- ---   ----- --- ---
R1     19  18   R2     13   7    R3      7  19    R5     19  24
```

TRANSPORTER PATH LAYOUT

```
From To    Layout
---- ----  ------
R1   R2    BL7 U4 L1 U2 L3
R2   R3    BR2 U1 R1 U1 R1 U1 R1 U1 R1 U1 R6 U1
R3   R5    BR2 D9 R3 D3
```

FIGURES AND LABELS

```
Type Clr Row Col Figure
---- --- --- --- ------
HORZ W    23  15 LOAD / UNLOAD
HORZ B    16   2 INSPECT
HORZ B     9  16 PNC1
```

END

ProModel Results for A:ROBOT
*two precision machining centers and a transfer arm use for material har
Date: 1/10/1995
Simulation Time: 8.00 hours
Startup Period: 1.00 hours

RESOURCE UTILIZATION SUMMARY

Resource	Capa-city	% Util	Total entry	Avg. min/ entry	Avg. con-tents	Max con-tents	Final con-tents	Times down	Tc mi dc
LOAD	50	99.66	105	227.78	49.8	50	50	0	0
PNC1	2	76.54	57	12.89	1.5	2	1	0	0
INSPEC	1	48.37	56	4.15	0.5	1	0	0	0
UNLOAD	50	0.12	56	0.50	0.1	1	0	0	0
ROBOT	1	58.79	167	1.69	0.6	35.80*	1.03**	0	0
EXIT	1	0.00	56	0.00	0.0	1	0	0	0

    * Percentage of time traveling to and picking up parts.
    ** Average minutes to travel to and pick up each part.

VARIANCE SUMMARY

Resource	Avg. Con-tents	Std. dev.	Avg. min/ exit	Std. dev. (min)	Min time (min)	Max time (min)	Zero time count	Total Count
LOAD	49.83	103.05	264.93	115.87	65.97	433.65	0	55
PNC1	1.53	1.54	13.20	10.85	4.09	37.72	0	56
INSPEC	0.48	0.50	4.20	0.30	4.09	5.00	0	56
UNLOAD	0.06	0.23	0.50	0.00	0.50	0.50	0	56
ROBOT	0.59	0.49	1.70	0.47	1.03	2.03	0	166

PART ACTIVITY SUMMARY BY LOCATION

Part	Location	Total entry	Avg move time	Avg wait opn	Avg opn time	Avg wait output	Avg wait loc	Avg wait mover

-----	--------	-----	-----	-----	-----	------	-----
TRA/T	LOAD	9	0.00	0.00	0.39	291.65	9.39	1.6
TRA/T	PNC1	4	2.03	0.00	2.10	0.50	1.51	2.2
TRA/T	INSPEC	4	1.03	0.00	2.00	0.00	0.00	2.0
TRA/T	UNLOAD	4	2.03	0.00	0.50	0.00	0.00	2.0
TRA/T	EXIT	4	0.00	0.00	0.00	0.00	0.00	0.0
TRA/M	LOAD	2	0.00	0.00	0.00	168.66	6.12	2.0
TRA/M	PNC1	2	2.03	0.00	2.32	2.22	5.12	3.0
TRA/M	INSPEC	2	1.03	0.00	2.00	0.00	0.00	2.0
TRA/M	UNLOAD	2	2.03	0.00	0.50	0.00	0.00	0.0
TRA/M	EXIT	2	0.00	0.00	0.00	0.00	0.00	0.0
TRA/L	LOAD	2	0.00	0.00	0.00	176.84	6.57	2.0
TRA/L	PNC1	2	2.03	0.00	2.60	1.49	5.12	3.0
TRA/L	INSPEC	2	1.03	0.00	2.00	0.00	0.00	2.0
TRA/L	UNLOAD	2	2.03	0.00	0.50	0.00	0.00	0.0
TRA/L	EXIT	2	0.00	0.00	0.00	0.00	0.00	0.0
TOW/H	LOAD	12	0.00	0.00	0.42	249.46	6.12	2.0€
TOW/H	PNC1	2	2.03	0.00	1.31	2.78	6.03	3.0€
TOW/H	INSPEC	2	1.03	0.00	1.50	0.00	0.00	2.5ϛ
TOW/H	UNLOAD	2	2.03	0.00	0.50	0.00	0.00	0.0(
TOW/H	EXIT	2	0.00	0.00	0.00	0.00	0.00	0.0(
TOW/C	LOAD	2	0.00	0.00	0.00	255.47	6.12	2.0€
TOW/C	PNC1	2	2.03	0.00	2.00	3.00	5.12	3.0€
TOW/C	INSPEC	2	1.03	0.00	2.00	0.00	0.00	2.0ϛ
TOW/C	UNLOAD	2	2.03	0.00	0.50	0.00	0.00	0.00
TOW/C	EXIT	2	0.00	0.00	0.00	0.00	0.00	0.0C
GUN/H	LOAD	29	0.00	0.00	0.36	225.80	6.21	2.0€
GUN/H	PNC1	10	2.03	0.00	2.41	0.67	1.56	2.14
GUN/H	INSPEC	8	0.94	0.00	2.50	0.00	0.00	1.59
GUN/H	UNLOAD	8	2.03	0.00	0.50	0.00	0.00	0.00
GUN/H	EXIT	8	0.00	0.00	0.00	0.00	0.00	0.00
GUN/C	LOAD	7	0.00	0.00	0.00	198.92	6.12	2.06
GUN/C	PNC1	7	2.03	0.00	2.41	1.68	5.12	3.06
GUN/C	INSPEC	8	0.90	0.00	2.13	0.00	0.00	1.56
GUN/C	UNLOAD	8	2.03	0.00	0.50	0.00	0.00	0.00
GUN/C	EXIT	8	0.00	0.00	0.00	0.00	0.00	0.00
TL/H	LOAD	6	0.00	0.00	0.00	176.84	6.12	2.06
TL/H	PNC1	7	1.74	0.00	2.57	0.93	4.51	3.06
TL/H	INSPEC	7	1.03	0.00	3.97	0.00	0.00	1.03
TL/H	UNLOAD	7	2.03	0.00	0.50	0.00	0.00	0.00
TL/H	EXIT	7	0.00	0.00	0.00	0.00	0.00	0.00
MAN/T	LOAD	24	0.00	0.00	0.38	228.37	6.64	2.06
MAN/T	PNC1	9	1.80	0.00	30.81	0.00	2.68	2.61
MAN/T	INSPEC	9	1.03	0.00	3.00	0.00	0.00	1.09
MAN/T	UNLOAD	9	2.03	0.00	0.50	0.00	0.00	0.00
MAN/T	EXIT	9	0.00	0.00	0.00	0.00	0.00	0.00
MAN/H	LOAD	6	0.00	0.00	0.00	171.61	5.75	2.06
MAN/H	PNC1	6	2.03	0.00	2.34	0.00	0.00	2.36
MAN/H	INSPEC	6	1.03	0.00	2.38	0.00	0.00	1.71

MAN/H UNLOAD	6	2.03	0.00	0.50	0.00	0.00	
MAN/H EXIT	6	0.00	0.00	0.50	0.00	0.00	98
MAN/L LOAD	6	0.00	0.00	0.00	179.42	6.73	
MAN/L PNC1	6	2.03	0.00	3.00	0.00	0.00	
MAN/L INSPEC	6	1.03	0.00	2.30	0.00	0.00	1.7
MAN/L UNLOAD	6	2.03	0.00	0.50	0.00	0.00	0.0
MAN/L EXIT	6	0.00	0.00	0.00	0.00	0.00	0.0

OVERALL PART ACTIVITY SUMMARY

Part	% move time	% wait opn	% opn time	% outQ time	% wait loc	% wait mover	Cum part minutes in system
TRA/T	1	0	1	96	2	1	2743
TRA/M	3	0	2	86	6	4	396
TRA/L	2	0	2	86	6	3	412
TOW/H	0	0	0	98	1	0	3058
TOW/C	2	0	2	90	4	2	571
GUN/H	1	0	1	97	1	1	6784
GUN/C	2	0	2	88	5	3	1601
TL/H	3	0	4	85	5	3	1255

2

MAN/T	1	0	5	92	1	1	5965
MAN/H	3	0	3	89	3	3	1160
MAN/L	2	0	3	89	3	2	1208

OVERALL LOCATION ACTIVITY SUMMARY

Location	% down or no parts	% wait part arrival	% wait before opn	% in actual opn	% wait output queue	% wait loc	% wait mover
LOAD	0	0	0	0	98	2	0
PNC1	14	11	0	41	4	16	14
INSPEC	42	11	0	29	0	0	18
UNLOAD	100	0	0	0	0	0	0
EXIT	100	0	0	0	0	0	0

TRANSPORTER PATH POINT SUMMARY

Pt	Entries	Blocked attempts	Pt	Entries	Blocked attempts	Pt	Entries	Blocked Attempts
R1	55	0	R2	166	0	R3	167	0
R5	56	0						

HOURLY PART EXIT SUMMARY

Part	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 8	Hour 9	Hour 10

TRA/T	0	0	1	0	1	0	0	2
TRA/M	0	0	1	0	1	0	0	0
TRA/L	0	0	1	0	1	0	0	0
TOW/H	0	0	0	1	0	0	1	0
TOW/C	0	0	0	1	0	0	1	0
GUN/H	1	1	1	1	1	1	2	0
GUN/C	2	1	1	1	1	1	1	0
TL/H	1	2	0	2	0	2	0	0
MAN/T	1	1	1	0	1	1	1	3
MAN/H	1	1	1	1	0	1	1	0
MAN/L	1	1	1	0	1	1	1	0

CONFIGURATION #4
CART

ROUTING

Part	Location	Operation (min)	Output part	Next location	Condi-tion	Qty	Move time (min
TRA/T	LOAD	.5	TRA/T	PNC1	0	1	CART
TRA/T	PNC1	2.00	TRA/T	INSPEC	0	1	CART
TRA/T	INSPEC	2.10	TRA/T	UNLOAD	0	1	CART
TRA/T	UNLOAD	.5	TRA/T	EXIT	0	1	0
TRA/M	LOAD	.5	TRA/M	PNC1	0	1	CART
TRA/M	PNC1	2.31	TRA/M	INSPEC.	0	1	CART
TRA/M	INSPEC	2.00	TRA/M	UNLOAD	0	1	CART
TRA/M	UNLOAD	.5	TRA/M	EXIT	0	1	0
TRA/L	LOAD	.5	TRA/L	PNC1	0	1	CART
TRA/L	PNC1	2.60	TRA/L	INSPEC	0	1	CART
TRA/L	INSPEC	2.00	TRA/L	UNLOAD	0	1	CART
TRA/L	UNLOAD	.5	TRA/L	EXIT	0	1	0
TOW/H	LOAD	.5	TOW/H	PNC1	0	1	CART
TOW/H	PNC1	1.31	TOW/H	INSPEC	0	1	CART
TOW/H	INSPEC	1.50	TOW/H	UNLOAD	0	1	CART
TOW/H	UNLOAD	.5	TOW/H	EXIT	0	1	0
TOW/C	LOAD	.5	TOW/C	PNC1	0	1	CART
TOW/C	PNC1	2.00	TOW/C	INSPEC	0	1	CART
TOW/C	INSPEC	2.00	TOW/C	UNLOAD	0	1	CART
TOW/C	UNLOAD	.5	TOW/C	EXIT	0	1	0
GUN/H	LOAD	.5	GUN/H	PNC1	0	1	CART
GUN/H	PNC1	2.41	GUN/H	INSPEC	0	1	CART
GUN/H	INSPEC	2.50	GUN/H	UNLOAD	0	1	CART
GUN/H	UNLOAD	.5	GUN/H	EXIT	0	1	0
GUN/C	LOAD	.5	GUN/C	PNC1	0	1	CART
GUN/C	PNC1	2.42	GUN/C	INSPEC	0	1	CART
GUN/C	INSPEC	2.43	GUN/C	UNLOAD	0	1	CART
GUN/C	UNLOAD	.5	GUN/C	EXIT	0	1	0
TL/H	LOAD	.5	TL/H	PNC1	0	1	CART
TL/H	PNC1	3.00	TL/H	INSPEC	0	1	CART
TL/H	INSPEC	3.97	TL/H	UNLOAD	0	1	CART
TL/H	UNLOAD	.5	TL/H	EXIT	0	1	0
MAN/T	LOAD	.5	MAN/T	PNC1	0	1	CART
MAN/T	PNC1	3.00	MAN/T	INSPEC	0	1	CART
MAN/T	INSPEC	3.00	MAN/T	UNLOAD	0	1	CART
MAN/T	UNLOAD	.5	MAN/T	EXIT	0	1	0
MAN/H	LOAD	.5	MAN/H	PNC1	0	1	CART
MAN/H	PNC1	2.34	MAN/H	INSPEC	0	1	CART
MAN/H	INSPEC	2.38	MAN/H	UNLOAD	0	1	CART
MAN/H	UNLOAD	.5	MAN/H	EXIT	0	1	0
MAN/L	LOAD	.5	MAN/L	PNC1	0	1	CART
MAN/L	PNC1	3.00	MAN/L	INSPEC	0	1	CART
MAN/L	INSPEC	2.30	MAN/L	UNLOAD	0	1	CART
MAN/L	UNLOAD	.5	MAN/L	EXIT	0	1	0

PART SCHEDULING

Part	Location	Qty per arrival	No. of arrivals	Start (min)	Arrival frequency (min)

```
-----        ---------       --------      ---------      -----        -----------------
TRA/T    .LOAD          1          999          0          12
TRA/M     LOAD          1          999          0          12
TRA/L     LOAD          1          999          0          12
TOW/H     LOAD          1          999          0          16
TOW/C     LOAD          1          999          0          16
GUN/H     LOAD          1          999          0          5
GUN/C     LOAD          1          999          0       .   5
TL/H      LOAD          1          999          0          5
MAN/T     LOAD          1          999          0          7
MAN/H     LOAD          1          999          0          7
MAN/L     LOAD          1          999          0          7
```

TRANSPORTER SPECIFICATIONS FOR CART

Speed ft(m)/min	Pickup (sec)	Deposit (sec)	Start position	Search rule	Accel (fpss)	Decel (fpss)
40	5	5	1	CLOSEST	2	2

PATH LOGIC FOR CART

From	To	Block	Speed ft(m)/min	Distance ft(m) or Time(min)
1	3	0	0	B5
3	2	0	0	B5
2	5	0	0	B5

LOCATION INTERFACES FOR CART

Location	Point	Location	Point	Location	Point	Location	Point
INSPEC	2	LOAD	1	PNC1	3	UNLOAD	5

CAPACITIES

Resource	Qty	Resource	Qty	Resource	Qty	Resource	Qty	Resource	Qty
CART	1	INSPEC	*1	LOAD	*50	PNC1	*2	UNLOAD	*50

SIMULATION PARAMETERS   GRAPHIC OPTIONS

Run (hrs)	Startup (hrs)	Rept code	Resource to track	Seed	Graph mode	Max row	Max col	Scr clr	Fig clr	Icon file
8	1	5	0	7	2	100	200	R	W	PM.LIB

STATIC SYMBOLS

ID	Sym	Clr	Row	Col	ID	Sym	Clr	Row	Col	ID	Sym	Clr	Row
LOAD	1	R	20	18	PNC1	2	B	13	18	INSPEC	3	G	13
UNLOAD	5	M	20	24									

DYNAMIC SYMBOLS

ID	Sym	Clr	ID	Sym	Clr	ID	Sym	Clr	ID	Sym	Clr

```
 -------- --- ---   -------- --- ---   -------- --- ---   -------- ---
CART       A   W    GUN/C    .   W     GUN/H    .   B     MAN/H    ,   W
MAN/L      ,   G    MAN/T    ,   M     TL/H     /   W     TOW/C    >   W     103
TOW/H      >   G    TRA/L    <   W     TRA/M    <   B     TRA/T    <   O
```

TRANSPORTER POINTS

Point	Row	Col	Point	Row	Col	Point	Row	Col	Point	Row	Col
1	18	18	2	14	6	3	14	18	5	19	24

TRANSPORTER PATH LAYOUT

From	To	Layout
1	3	BU4
3	2	BD2 L12 U2
2	5	BD3 R18 D2

FIGURES AND LABELS

Type	Clr	Row	Col	Figure
HORZ	W	23	14	LOAD / UNLOAD
HORZ	B	10	2	INSPECT
HORZ	B	9	16	PNC1

END

ProModel Results for A:TEST4
*
Date: 1/10/1995
Simulation Time: 8.00 hours
Startup Period: 1.00 hours

RESOURCE UTILIZATION SUMMARY

Resource	Capa-city	% Util	Total entry	Avg. min/ entry	Avg. con-tents	Max con-tents	Final con-tents	Times down	Tc mi dc
LOAD	50	99.08	189	125.82	49.5	50	49	0	C
PNC1	2	88.92	142	6.01	1.8	2	2	0	0
INSPEC	1	77.83	141	2.65	0.8	1	1	0	0
UNLOAD	50	0.29	140	0.50	0.1	1	0	0	0
CART	1	18.37	420	0.21	0.2	25.96*	0.30**	0	0
EXIT	1	0.00	140·	0.00	0.0	1	0	0	0

* Percentage of time traveling to and picking up parts.
** Average minutes to travel to and pick up each part.

VARIANCE SUMMARY

Resource	Avg. Con-tents	Std. dev.	Avg. min/ exit	Std. dev. (min)	Min time (min)	Max time (min)	Zero time count	Total Count
LOAD	49.54	0.00	151.51	33.05	52.67	177.61	0	140
PNC1	1.78	1.81	6.10	0.75	4.68	8.15	0	140
INSPEC	0.78	0.41	2.67	0.55	1.71	4.18	0	140
UNLOAD	0.15	0.35	0.50	0.00	0.50	0.50	0	140

PART ACTIVITY SUMMARY BY LOCATION

Part	Location	Total entry	Avg move time	Avg wait opn	Avg opn time	Avg wait output	Avg wait loc	Avg wait mover

TRA/T LOAD	20	0.00	0.00	0.43	130.45	2.98	0.5
TRA/T PNC1	16	0.21	0.00	2.00	0.65	2.94	0.5
TRA/T INSPEC	16	0.21	0.00	2.10	0.00	0.00	0.2
TRA/T UNLOAD	16	0.21	0.00	0.50	0.00	0.00	0.0
TRA/T EXIT	16	0.00	0.00	0.00	0.00	0.00	0.0
TRA/M LOAD	7	0.00	0.00	0.29	126.04	2.81	0.5
TRA/M PNC1	7	0.21	0.00	2.31	0.79	2.43	0.5
TRA/M INSPEC	7	0.21	0.00	2.00	0.00	0.00	0.2
TRA/M UNLOAD	7	0.21	0.00	0.50	0.00	0.00	0.0
TRA/M EXIT	7	0.00	0.00	0.00	0.00	0.00	0.0
TRA/L LOAD	3	0.00	0.00	0.00	73.28	3.83	0.5
TRA/L PNC1	3	0.21	0.00	2.60	0.00	2.13	0.5
TRA/L INSPEC	3	0.21	0.00	2.00	0.00	0.00	0.2
TRA/L UNLOAD	3	0.21	0.00	0.50	0.00	0.00	0.0
TRA/L EXIT	3	0.00	0.00	0.00	0.00	0.00	0.0
TOW/H LOAD	24	0.00	0.00	0.44	134.24	3.11	0.5

TOW/H PNC1	16	0.21	0.00	1.31	1.46	3.01	0.55
TOW/H INSPEC	15	0.21	0.00	1.50	0.00	0.00	0.21
TOW/H UNLOAD	15	0.21	0.00	0.50	0.00	0.00	0.00
TOW/H EXIT	15	0.00	0.00	0.00	0.00	0.00	0.00
TOW/C LOAD	4	0.00	0.00	0.25	90.29	2.85	0.55
TOW/C PNC1	2	0.21	0.00	2.00	2.18	1.92	0.55
TOW/C INSPEC	2	0.21	0.00	2.00	0.00	0.00	0.21
TOW/C UNLOAD	2	0.21	0.00	0.50	0.00	0.00	0.00
TOW/C EXIT	2	0.00	0.00	0.00	0.00	0.00	0.00
GUN/H LOAD	57	0.00	0.00	0.43	128.12	2.80	0.55
GUN/H PNC1	39	0.20	0.00	2.35	0.27	2.67	0.55
GUN/H INSPEC	39	0.21	0.00	2.50	0.00	0.00	0.21
GUN/H UNLOAD	39	0.21	0.00	0.50	0.00	0.00	0.00
GUN/H EXIT	39	0.00	0.00	0.00	0.00	0.00	0.00
GUN/C LOAD	12	0.00	0.00	0.25	116.21	2.58	0.55
GUN/C PNC1	11	0.19	0.00	2.38	0.16	2.80	0.55
GUN/C INSPEC	11	0.21	0.00	2.43	0.00	0.00	0.21
GUN/C UNLOAD	11	0.21	0.00	0.50	0.00	0.00	0.00
GUN/C EXIT	11	0.00	0.00	0.00	0.00	0.00	0.00
TL/H LOAD	7	0.00	0.00	0.00	77.34	2.51	0.55
TL/H PNC1	7	0.21	0.00	3.00	0.00	2.56	0.55
TL/H INSPEC	7	0.21	0.00	3.97	0.00	0.00	0.21
TL/H UNLOAD	7	0.21	0.00	0.50	0.00	0.00	0.00
TL/H EXIT	7	0.00	0.00	0.00	0.00	0.00	0.00
MAN/T LOAD	42	0.00	0.00	0.44	131.67	2.83	0.55
MAN/T PNC1	30	0.21	0.00	2.91	0.06	2.36	0.55
MAN/T INSPEC	29	0.21	0.00	2.93	0.00	0.00	0.21
MAN/T UNLOAD	28	0.21	0.00	0.50	0.00	0.00	0.00
MAN/T EXIT	28	0.00	0.00	0.00	0.00	0.00	0.00
MAN/H LOAD	9	0.00	0.00	0.28	97.57	2.56	0.55
MAN/H PNC1	7	0.21	0.00	2.34	0.70	3.29	0.55
MAN/H INSPEC	7	0.21	0.00	2.38	0.00	0.00	0.21
MAN/H UNLOAD	7	0.21	0.00	0.50	0.00	0.00	0.00

```
      MAN/H EXIT              7    0.00    0.00    0.00      0.00    0.00   0.(
      MAN/L LOAD              4    0.00    0.00    0.00     71.94    3.40   0.5
      MAN/L PNC1              4    0.21    0.00    3.00      0.21    2.80   0.5   106
      MAN/L INSPEC           5    0.17    0.00    2.11      0.00    0.00   0.2
      MAN/L UNLOAD           5    0.21    0.00    0.50      0.00    0.00   0.(
      MAN/L EXIT              5    0.00    0.00    0.00      0.00    0.00   0.(
```

OVERALL PART ACTIVITY SUMMARY

Part	% move time	% wait opn	% opn time	% outQ time	% wait loc	% wait mover	Cum part minutes in system
TRA/T	0	0	3	93	3	1	2821
TRA/M	0	0	4	92	4	1	968
TRA/L	0	0	6	87	7	1	252
TOW/H	0	0	2	95	3	1	3428
TOW/C	0	0	3	95	2	1	385
GUN/H	0	0	3	93	3	1	7828
GUN/C	0	0	4	91	4	1	1529
TL/H	0	0	8	85	5	1	636
MAN/T	0	0	3	93	3	1	5939

2

MAN/H	0	0	4	91	4	1	969
MAN/L	0	0	7	84	7	1	341

OVERALL LOCATION ACTIVITY SUMMARY

Location	% down or no parts	% wait part arrival	% wait before opn	% in actual opn	% wait output queue	% wait loc	% wait mover
LOAD	1	0	0	0	97	2	0
PNC1	10	3	0	35	6	39	7
INSPEC	19	5	0	71	0	0	5
UNLOAD	100	0	0	0	0	0	0
EXIT	100	0	0	0	0	0	0

TRANSPORTER PATH POINT SUMMARY

Pt	Entries	Blocked attempts	Pt	Entries	Blocked attempts	Pt	Entries	Blocked Attempts
1	140	0	3	420	0	2	420	0
5	140	0						

HOURLY PART EXIT SUMMARY

Part	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 8	Hour 9	Hour 10

TRA/T	1	1	1	3	3	1	3	3
TRA/M	1	1	1	2	1	0	1	0
TRA/L	1	1	1	0	0	0	0	0
TOW/H	1	1	1	2	3	3	3	1
TOW/C	1	0	1	0	0	0	0	0
GUN/H	3	2	4	5	6	9	5	5
GUN/C	3	2	2	0	0	2	1	1
TL/H	2	3	2	0	0	0	0	0
MAN/T	1	2	2	5	4	3	4	7
MAN/H	1	2	1	1	1	0	1	0
MAN/L	2	2	1	0	0	0	0	0

APPENDIX B
LNET PROGRAM

CONFIGURATION #1
ETHERNET
IEEE 802.3

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

LAN NAME   ETHERNET

COLLISION EPISODES   0   .

COLLIDED TRANSFERS   0
AVG TO RESOLVE   0.
MAX TO RESOLVE   0

DEFERRALS   0
AVG DEFERRAL DELAY   0.
MAX DEFERRAL DELAY   0.
STD DEV DEFERRAL DELAY   0.

AVG DEFERRAL QUEUE   0.
MAX QUEUE SIZE   0.
STD DEV QUEUE SIZE   0.

MULTIPLE COLLISIONS   0
AVG MULT COLLISIONS   0.
MAX MULT COLLISIONS   0

SUCCESSFUL TRANSFERS   444
AVG USAGE TIME   40610.364
MAX USAGE TIME   50873.600
STD DEV USAGE TIME   17670.317

PER CENT OF TIME BUSY   .063

LAN NAME   BUS1

LAN REQUESTS GRANTED   166
AVG REQUEST DELAY   0.
MAX REQUEST DELAY   0.
STD DEV REQUEST DELAY   0.

COMPLETED TRANSFERS   166
AVG USAGE TIME   1164.892
MAX USAGE TIME   1192.000
STD DEV USAGE TIME   139.987

AVG QUEUE SIZE   0.
MAX QUEUE SIZE   1.000
STD DEV QUEUE SIZE   0.

PER CENT OF TIME BUSY   .001

COMPLETED ACTIVITY STATISTICS

FROM   0.   TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

ACTIVITY NAME	GET WORK ORDER FROM MC	INPUT CODE FROM MASTER	RECEIVE LOAD FILE
HOST STATION	PNC	INSPECTION	LOAD
COMPLETED EXECUTIONS	20	1	6
AVG EXECUTION TIME	4910496000.000	14400096000.000	4095096000.000
MAX EXECUTION TIME	18432096000.000	14400096000.000	18432096000.000
MIN EXECUTION TIME	72096000.000	14400096000.000	18096000.000
STD DEV EXECUTION TIME	6954529160.195	0.	6605221343.755

ACTIVITY NAME	G & M CODE FROM MASTER	SEND MESSAGE TO LOAD	SEND G & M CODE TO GNC
HOST STATION	GNC	MASTER COMPUTER	MASTER COMPUTER
COMPLETED EXECUTIONS	0	3	166
AVG EXECUTION TIME	0.	28884.000	129756.800
MAX EXECUTION TIME	0.	28884.000	129756.800
MIN EXECUTION TIME	0.	28884.000	129756.800
STD DEV EXECUTION TIME	0.	0.	.008

COMPLETED ACTIVITY STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

ACTIVITY NAME	SEND WORK ORDER	SEND CODE TO INSPECTION
HOST STATION	MASTER COMPUTER	MASTER COMPUTER
COMPLETED EXECUTIONS	80	56
AVG EXECUTION TIME	30384.000	48384.000
MAX EXECUTION TIME	30384.000	48384.000
MIN EXECUTION TIME	30384.000	48384.000
STD DEV EXECUTION TIME	0.	0.

STATION UTILIZATION STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

STATION NAME	PNC	INSPECTION	LOAD
LAN REQUESTS GRANTED	0	0	0
AVERAGE WAIT TIME	0.	0.	0.
MAXIMUM WAIT TIME	0.	0.	0.
STD DEV WAIT TIME	0.	0.	0.
DISK REQUESTS GRANTED	84	5	25
AVERAGE BITS USED	325785.988	499998.500	325142.342
MAXIMUM BITS USED	1024000.	800000.	1024000.
STD DEV BITS USED	301859.363	299999.778	301461.087
STATION UTILIZATION	100.000	100.000	100.000

STATION NAME	GNC	MASTER COMPUTER
LAN REQUESTS GRANTED	0	610
AVERAGE WAIT TIME	0.	3.494
MAXIMUM WAIT TIME	0.	9.600
STD DEV WAIT TIME	0.	4.619
DISK REQUESTS GRANTED	1	305
AVERAGE BITS USED	500000.000	1201250.000
MAXIMUM BITS USED	500000.	1201250.
STD DEV BITS USED	0.	0.
STATION UTILIZATION	100.000	.093

RECEIVED MESSAGE REPORT

FROM   0.   TO   28800. SECONDS

RECEIVER	COUNT	MESSAGE NAME
PNC		
	160	WORK ORDER TO PNC
INSPECTION		
	112	CODE TO INSPECTION
LOAD		
	6	MESSAGE TO LOAD
GNC		
	332	MESSAGE TO GNC

MESSAGE DELIVERY REPORT

FROM   0.   TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

MESSAGE NAME	CODE TO INSPECTION	MESSAGE TO LOAD	MESSAGE TO GNC
SOURCE STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
DESTINATION STATION	INSPECTION	LOAD	GNC
NUMBER SENT	112	6	332
AVG DELIVERY TIME	10192.000	442.000	50878.400
MAX DELIVERY TIME	10196.800	442.000	50883.199
MIN DELIVERY TIME	10187.200	442.000	50873.602
STD DEV DELIVERY TIME	4.800	0.	4.800

MESSAGE NAME	WORK ORDER TO PNC
SOURCE STATION	MASTER COMPUTER
DESTINATION STATION	PNC
NUMBER SENT	160
AVG DELIVERY TIME	1192.000
MAX DELIVERY TIME	1192.000
MIN DELIVERY TIME	1192.000
STD DEV DELIVERY TIME	0.

S N A P S H O T   R E P O R T

AT   28800. SECONDS

station S1/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (21)
      MR/WORK ORDER TO PNC (148) is in the station local queue
      MR/WORK ORDER TO PNC (155) is in the station local queue
      MR/WORK ORDER TO PNC (156) is in the station local queue
      MR/WORK ORDER TO PNC (157) is in the station local queue
      MR/WORK ORDER TO PNC (160) is in the station local queue
   disk S1/SD/PNC is IDLE and has 4696596480. bits available
      file WORDER is IDLE and contains   1024000. bits
station S2/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (22)
      MR/WORK ORDER TO PNC (138) is in the station local queue
      MR/WORK ORDER TO PNC (143) is in the station local queue
      MR/WORK ORDER TO PNC (144) is in the station local queue
      MR/WORK ORDER TO PNC (147) is in the station local queue
   disk S2/SD/PNC is IDLE and has 4696596480. bits available
      file WORDER is IDLE and contains   1024000. bits
station S3/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (23)
      MR/WORK ORDER TO PNC (137) is in the station local queue
      MR/WORK ORDER TO PNC (145) is in the station local queue
      MR/WORK ORDER TO PNC (146) is in the station local queue
      MR/WORK ORDER TO PNC (149) is in the station local queue
   disk S3/SD/PNC is IDLE and has 4696596480. bits available
      file WORDER is IDLE and contains   1024000. bits
station S4/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (24)
      MR/WORK ORDER TO PNC (139) is in the station local queue
      MR/WORK ORDER TO PNC (140) is in the station local queue
      MR/WORK ORDER TO PNC (141) is in the station local queue
      MR/WORK ORDER TO PNC (142) is in the station local queue
      MR/WORK ORDER TO PNC (150) is in the station local queue
      MR/WORK ORDER TO PNC (151) is in the station local queue
      MR/WORK ORDER TO PNC (152) is in the station local queue
      MR/WORK ORDER TO PNC (153) is in the station local queue
      MR/WORK ORDER TO PNC (154) is in the station local queue
      MR/WORK ORDER TO PNC (158) is in the station local queue
      MR/WORK ORDER TO PNC (159) is in the station local queue
   disk S4/SD/PNC is IDLE and has 4696596480. bits available
      file WORDER is IDLE and contains   1024000. bits
station S1/INSPECTION is BUSY executing action PROCESS CODE
      resident activity is INPUT CODE FROM MASTER (2)
      MR/CODE TO INSPECTION (57) is in the station local queue
      MR/CODE TO INSPECTION (58) is in the station local queue
      MR/CODE TO INSPECTION (59) is in the station local queue

CONFIGURATION #1
TOKEN RING
IEEE 802.5

TOKEN LAN UTILIZATION STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

LAN NAME	BUS1	RING1
LAN REQUESTS GRANTED	166	444
AVG REQUEST DELAY	0.	0.
MAX REQUEST DELAY	0.	0.
STD DEV REQUEST DELAY	0.	0.
COMPLETED TRANSFERS	166	444
AVG USAGE TIME	1164.892	100373.423
MAX USAGE TIME	1192.000	125750.000
STD DEV USAGE TIME	139.987	43691.109
AVG QUEUE SIZE	0.	0.
MAX QUEUE SIZE	1.000	1.000
STD DEV QUEUE SIZE	0.	0.
PER CENT OF TIME BUSY	.001	.155

COMPLETED ACTIVITY STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

ACTIVITY NAME	SEND MESSAGE TO LOAD	SEND G & M CODE TO GNC	SEND WORK ORDER
HOST STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
COMPLETED EXECUTIONS	3	166	80
AVG EXECUTION TIME	28884.000	279500.000	30384.000
MAX EXECUTION TIME	28884.000	279500.000	30384.000
MIN EXECUTION TIME	28884.000	279500.000	30384.000
STD DEV EXECUTION TIME	0.	0.	0.

ACTIVITY NAME	SEND CODE TO INSPECTION	GET WORK ORDER FROM MC	INPUT CODE FROM MASTER
HOST STATION	MASTER COMPUTER	PNC	INSPECTION
COMPLETED EXECUTIONS	56	20	1
AVG EXECUTION TIME	78300.000	4910496000.000	14400096000.000
MAX EXECUTION TIME	78300.000	18432096000.000	14400096000.000
MIN EXECUTION TIME	78300.000	72096000.000	14400096000.000
STD DEV EXECUTION TIME	0.	6954529160.195	0.

COMPLETED ACTIVITY STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

ACTIVITY NAME	RECEIVE LOAD FILE	G & M CODE FROM MASTER
HOST STATION	LOAD	GNC
COMPLETED EXECUTIONS	6	0
AVG EXECUTION TIME	4095096000.000	0.
MAX EXECUTION TIME	18432096000.000	0.
MIN EXECUTION TIME	18096000.000	0.
STD DEV EXECUTION TIME	6605221343.755	0.

STATION UTILIZATION STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

STATION NAME	MASTER COMPUTER	PNC	INSPECTION
LAN REQUESTS GRANTED	610	0	0
AVERAGE WAIT TIME	0.	0.	0.
MAXIMUM WAIT TIME	0.	0.	0.
STD DEV WAIT TIME	0.	0.	0.
DISK REQUESTS GRANTED	305	84	5
AVERAGE BITS USED	1201250.000	325785.988	499998.500
MAXIMUM BITS USED	1201250.	1024000.	800000.
STD DEV BITS USED	0.	301859.363	299999.778
STATION UTILIZATION	.185	100.000	100.000

STATION NAME	LOAD	GNC
LAN REQUESTS GRANTED	0	0
AVERAGE WAIT TIME	0.	0.
MAXIMUM WAIT TIME	0.	0.
STD DEV WAIT TIME	0.	0.
DISK REQUESTS GRANTED	25	1
AVERAGE BITS USED	325142.342	500000.000
MAXIMUM BITS USED	1024000.	500000.
STD DEV BITS USED	301461.087	0.
STATION UTILIZATION	100.000	100.000

FROM   0. TO   28800. SECONDS

RECEIVER	COUNT	MESSAGE NAME
PNC		
	160	WORK ORDER TO PNC
INSPECTION		
	112	CODE TO INSPECTION
LOAD		
	6	MESSAGE TO LOAD
GNC		
	332	MESSAGE TO GNC

FROM   0. TO   28800. SECONDS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

MESSAGE NAME	CODE TO INSPECTION	MESSAGE TO LOAD	MESSAGE TO GNC
SOURCE STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
DESTINATION STATION	INSPECTION	LOAD	GNC
NUMBER SENT	112	6	332
AVG DELIVERY TIME	25150.000	442.000	125750.000
MAX DELIVERY TIME	25150.000	442.000	125750.000
MIN DELIVERY TIME	25150.000	442.000	125750.000
STD DEV DELIVERY TIME	0.	0.	0.

MESSAGE NAME	WORK ORDER TO PNC
SOURCE STATION	MASTER COMPUTER
DESTINATION STATION	PNC
NUMBER SENT	160
AVG DELIVERY TIME	1192.000
MAX DELIVERY TIME	1192.000
MIN DELIVERY TIME	1192.000
STD DEV DELIVERY TIME	0.

AT   28800. SECONDS

station S1/MASTER COMPUTER is IDLE
   disk S1/SD/MASTER COMPUTER is IDLE and has 4528647070. bits available
      file GENERAL STORAGE is IDLE and contains   600000. bits
      file LD STORAGE is IDLE and contains   250. bits
      file GM STORAGE is IDLE and contains   500000. bits
      file WORDER STORAGE is IDLE and contains   1000. bits
      file INSP STORAGE is IDLE and contains   100000. bits
station S1/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (21)
      MR/WORK ORDER TO PNC (148) is in the station local queue
      MR/WORK ORDER TO PNC (155) is in the station local queue
      MR/WORK ORDER TO PNC (156) is in the station local queue
      MR/WORK ORDER TO PNC (157) is in the station local queue
      MR/WORK ORDER TO PNC (160) is in the station local queue
   disk S1/SD/PNC is IDLE and has 4696596480. bits available
      file WORDER is IDLE and contains   1024000. bits
station S2/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (22)
      MR/WORK ORDER TO PNC (138) is in the station local queue
      MR/WORK ORDER TO PNC (143) is in the station local queue
      MR/WORK ORDER TO PNC (144) is in the station local queue
      MR/WORK ORDER TO PNC (147) is in the station local queue
   disk S2/SD/PNC is IDLE and has 4696596480. bits available
      file WORDER is IDLE and contains   1024000. bits
station S3/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (23)
      MR/WORK ORDER TO PNC (137) is in the station local queue
      MR/WORK ORDER TO PNC (145) is in the station local queue
      MR/WORK ORDER TO PNC (146) is in the station local queue
      MR/WORK ORDER TO PNC (149) is in the station local queue
   disk S3/SD/PNC is IDLE and has 4696596480. bits available
      file WORDER is IDLE and contains   1024000. bits
station S4/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (24)
      MR/WORK ORDER TO PNC (139) is in the station local queue
      MR/WORK ORDER TO PNC (140) is in the station local queue
      MR/WORK ORDER TO PNC (141) is in the station local queue
      MR/WORK ORDER TO PNC (142) is in the station local queue
      MR/WORK ORDER TO PNC (150) is in the station local queue
      MR/WORK ORDER TO FNC (151) is in the station local queue
      MR/WORK ORDER TO PNC (152) is in the station local queue
      MR/WORK ORDER TO PNC (153) is in the station local queue
      MR/WORK ORDER TO PNC (154) is in the station local queue
      MR/WORK ORDER TO PNC (158) is in the station local queue
      MR/WORK ORDER TO PNC (159) is in the station local queue

CONFIGURATION #1
TOKEN BUS(STAR)
IEEE 802.4

TOKEN LAN UTILIZATION STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

LAN NAME	BUS1	STAR1
LAN REQUESTS GRANTED	166	444
AVG REQUEST DELAY	0.	0.
MAX REQUEST DELAY	0.	0.
STD DEV REQUEST DELAY	0.	0.
COMPLETED TRANSFERS	166	444
AVG USAGE TIME	1164.892	80079.279
MAX USAGE TIME	1192.000	100320.000
STD DEV USAGE TIME	139.987	34848.654
AVG QUEUE SIZE	0.	0.
MAX QUEUE SIZE	1.000	1.000
STD DEV QUEUE SIZE	0.	0.
PER CENT OF TIME BUSY	.001	.123

COMPLETED ACTIVITY STATISTICS

FROM   0.   TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

ACTIVITY NAME	SEND MESSAGE TO LOAD	SEND G & M CODE TO GNC	SEND WORK ORDER
HOST STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
COMPLETED EXECUTIONS	3	166	80
AVG EXECUTION TIME	28884.000	228640.000	30384.000
MAX EXECUTION TIME	28884.000	228640.000	30384.000
MIN EXECUTION TIME	28884.000	228640.000	30384.000
STD DEV EXECUTION TIME	0.	0.	0.

ACTIVITY NAME	SEND CODE TO INSPECTION	GET WORK ORDER FROM MC	INPUT CODE FROM MASTER
HOST STATION	MASTER COMPUTER	PNC	INSPECTION
COMPLETED EXECUTIONS	56	20	1
AVG EXECUTION TIME	68160.000	4910496000.000	14400096000.000
MAX EXECUTION TIME	68160.000	18432096000.000	14400096000.000
MIN EXECUTION TIME	68160.000	72096000.000	14400096000.000
STD DEV EXECUTION TIME	0.	6954529160.195	0.

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

ACTIVITY NAME	RECEIVE LOAD FILE	G & M CODE FROM MASTER
HOST STATION	LOAD	GNC
COMPLETED EXECUTIONS	6	0
AVG EXECUTION TIME	4095096000.000	0.
MAX EXECUTION TIME	18432096000.000	0.
MIN EXECUTION TIME	18096000.000	0.
STD DEV EXECUTION TIME	6605221343.755	0.

STATION UTILIZATION STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

STATION NAME	MASTER COMPUTER	PNC	INSPECTION
LAN REQUESTS GRANTED	610	0	0
AVERAGE WAIT TIME	0.	0.	0.
MAXIMUM WAIT TIME	0.	0.	0.
STD DEV WAIT TIME	0.	0.	0.
DISK REQUESTS GRANTED	305	84	5
AVERAGE BITS USED	1201250.000	325785.988	499998.500
MAXIMUM BITS USED	1201250.	1024000.	800000.
STD DEV BITS USED	0.	301859.363	299999.778
STATION UTILIZATION	.154	100.000	100.000

STATION NAME	LOAD	GNC
LAN REQUESTS GRANTED	0	0
AVERAGE WAIT TIME	0.	0.
MAXIMUM WAIT TIME	0.	0.
STD DEV WAIT TIME	0.	0.
DISK REQUESTS GRANTED	25	1
AVERAGE BITS USED	325142.342	500000.000
MAXIMUM BITS USED	1024000.	500000.
STD DEV BITS USED	301461.087	0.
STATION UTILIZATION	100.000	100.000

RECEIVED MESSAGE REPORT

FROM   0. TO   28800. SECONDS

RECEIVER	COUNT	MESSAGE NAME
PNC		
	160	WORK ORDER TO PNC
INSPECTION		
	112	CODE TO INSPECTION
LOAD		
	6	MESSAGE TO LOAD
GNC		
	332	MESSAGE TO GNC

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

MESSAGE NAME	CODE TO INSPECTION	MESSAGE TO LOAD	MESSAGE TO GNC
SOURCE STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
DESTINATION STATION	INSPECTION	LOAD	GNC
NUMBER SENT	112	6	332
AVG DELIVERY TIME	20080.000	442.000	100320.000
MAX DELIVERY TIME	20080.000	442.000	100320.000
MIN DELIVERY TIME	20080.000	442.000	100320.000
STD DEV DELIVERY TIME	0.	0.	0.

MESSAGE NAME	WORK ORDER TO PNC
SOURCE STATION	MASTER COMPUTER
DESTINATION STATION	PNC
NUMBER SENT	160
AVG DELIVERY TIME	1192.000
MAX DELIVERY TIME	1192.000
MIN DELIVERY TIME	1192.000
STD DEV DELIVERY TIME	0.

AT   28800. SECONDS

station S1/MASTER COMPUTER is IDLE
   disk S1/SD/MASTER COMPUTER is IDLE and has 4528647070. bits available
         file GENERAL STORAGE is IDLE and contains   600000. bits
         file LD STORAGE is IDLE and contains   250. bits
         file GM STORAGE is IDLE and contains   500000. bits
         file WORDER STORAGE is IDLE and contains   1000. bits
         file INSP STORAGE is IDLE and contains   100000. bits
station S1/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (21)
      MR/WORK ORDER TO PNC (148) is in the station local queue
      MR/WORK ORDER TO PNC (155) is in the station local queue
      MR/WORK ORDER TO PNC (156) is in the station local queue
      MR/WORK ORDER TO PNC (157) is in the station local queue
      MR/WORK ORDER TO PNC (160) is in the station local queue
   disk S1/SD/PNC is IDLE and has 4696596480. bits available
         file WORDER is IDLE and contains   1024000. bits
station S2/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (22)
      MR/WORK ORDER TO PNC (138) is in the station local queue
      MR/WORK ORDER TO PNC (143) is in the station local queue
      MR/WORK ORDER TO PNC (144) is in the station local queue
      MR/WORK ORDER TO PNC (147) is in the station local queue
   disk S2/SD/PNC is IDLE and has 4696596480. bits available
         file WORDER is IDLE and contains   1024000. bits
station S3/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (23)
      MR/WORK ORDER TO PNC (137) is in the station local queue
      MR/WORK ORDER TO PNC (145) is in the station local queue
      MR/WORK ORDER TO PNC (146) is in the station local queue
      MR/WORK ORDER TO PNC (149) is in the station local queue
   disk S3/SD/PNC is IDLE and has 4696596480. bits available
         file WORDER is IDLE and contains   1024000. bits
station S4/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (24)
      MR/WORK ORDER TO PNC (139) is in the station local queue
      MR/WORK ORDER TO PNC (140) is in the station local queue
      MR/WORK ORDER TO PNC (141) is in the station local queue
      MR/WORK ORDER TO PNC (142) is in the station local queue
      MR/WORK ORDER TO PNC (150) is in the station local queue
      MR/WORK ORDER TO PNC (151) is in the station local queue
      MR/WORK ORDER TO PNC (152) is in the station local queue
      MR/WORK ORDER TO PNC (153) is in the station local queue
      MR/WORK ORDER TO PNC (154) is in the station local queue
      MR/WORK ORDER TO PNC (158) is in the station local queue
      MR/WORK ORDER TO PNC (159) is in the station local queue

CONFIGURATION #2
ETHERNET
IEEE 802.3

COLLISION LAN UTILIZATION STATISTICS

FROM   0.   TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

LAN NAME   ETHERNET

COLLISION EPISODES   0 .

COLLIDED TRANSFERS   0
AVG TO RESOLVE   0.
MAX TO RESOLVE   0

DEFERRALS   0
AVG DEFERRAL DELAY   0.
MAX DEFERRAL DELAY   0.
STD DEV DEFERRAL DELAY   0.

AVG DEFERRAL QUEUE   0.
MAX QUEUE SIZE   0.
STD DEV QUEUE SIZE   0.

MULTIPLE COLLISIONS   0
AVG MULT COLLISIONS   0.
MAX MULT COLLISIONS   0

SUCCESSFUL TRANSFERS   581
AVG USAGE TIME   34415.575
MAX USAGE TIME   50873.600
STD DEV USAGE TIME   21840.620

PER CENT OF TIME BUSY   .069

TOKEN LAN UTILIZATION STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

LAN NAME   BUS1

LAN REQUESTS GRANTED   26
AVG REQUEST DELAY   0.
MAX REQUEST DELAY   0.
STD DEV REQUEST DELAY   0.

COMPLETED TRANSFERS   26
AVG USAGE TIME   442.000
MAX USAGE TIME   442.000
STD DEV USAGE TIME   0.

AVG QUEUE SIZE   0.
MAX QUEUE SIZE   1.000
STD DEV QUEUE SIZE   0.

PER CENT OF TIME BUSY   .000

COMPLETED ACTIVITY STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

ACTIVITY NAME	SEND MESSAGE TO LOAD	SEND G & M CODE TO GNC	SEND CODE TO INSPECTION
HOST STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
COMPLETED EXECUTIONS	13	184	62
AVG EXECUTION TIME	28884.000	129756.800	48384.000
MAX EXECUTION TIME	28884.000	129756.800	48384.000
MIN EXECUTION TIME	28884.000	129756.800	48384.000
STD DEV EXECUTION TIME	0.	.009	.001

ACTIVITY NAME	SEND NC CODE TO PNC	GET WORK ORDER FROM MC	INPUT CODE FROM MASTER
HOST STATION	MASTER COMPUTER	PNC	INSPECTION
COMPLETED EXECUTIONS	89	5	1
AVG EXECUTION TIME	28120.800	4910496000.000	14400096000.000
MAX EXECUTION TIME	28120.800	18432096000.000	14400096000.000
MIN EXECUTION TIME	28120.800	72096000.000	14400096000.000
STD DEV EXECUTION TIME	.000	6954529160.195	0.

COMPLETED ACTIVITY STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

ACTIVITY NAME	RECEIVE LOAD FILE	G & M CODE FROM MASTER
HOST STATION	CONVEYOR	GNC
COMPLETED EXECUTIONS	6	0
AVG EXECUTION TIME	4095096000.000	0.
MAX EXECUTION TIME	18432096000.000	0.
MIN EXECUTION TIME	18096000.000	0.
STD DEV EXECUTION TIME	6605221343.755	0.

(ALL TIMES REPORTED IN MICROSECONDS)

STATION NAME	MASTER COMPUTER	PNC	INSPECTION
LAN REQUESTS GRANTED	607	0	0
AVERAGE WAIT TIME	3.891	0.	0.
MAXIMUM WAIT TIME	9.600	0.	0.
STD DEV WAIT TIME	4.713	0.	0.
DISK REQUESTS GRANTED	348	21	5
AVERAGE BITS USED	1201250.000	325785.988	499998.500
MAXIMUM BITS USED	1201250.	1024000.	800000.
STD DEV BITS USED	0.	301859.363	299999.778
STATION UTILIZATION	.103	100.000	100.000

STATION NAME	CONVEYOR	GNC
LAN REQUESTS GRANTED	0	0
AVERAGE WAIT TIME	0.	0.
MAXIMUM WAIT TIME	0.	0.
STD DEV WAIT TIME	0.	0.
DISK REQUESTS GRANTED	25	1
AVERAGE BITS USED	325142.342	500000.000
MAXIMUM BITS USED	1024000.	500000.
STD DEV BITS USED	301461.087	0.
STATION UTILIZATION	100.000	100.000

RECEIVED MESSAGE REPORT

FROM   0.   TO   28800. SECONDS

RECEIVER   COUNT   MESSAGE NAME

PNC
              89   NC CODE TO PNC

INSPECTION
              124   CODE TO INSPECTION

CONVEYOR
              26   MESSAGE TO LOAD   .

GNC
              368   MESSAGE TO GNC

FROM   0.   TO   28800. SECONDS

MESSAGE DELIVERY REPORT

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

MESSAGE NAME	CODE TO INSPECTION	MESSAGE TO LOAD	MESSAGE TO GNC
SOURCE STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
DESTINATION STATION	INSPECTION	CONVEYOR	GNC
NUMBER SENT	124	26	368
AVG DELIVERY TIME	10192.000	442.000	50878.400
MAX DELIVERY TIME	10196.800	442.000	50883.199
MIN DELIVERY TIME	10187.200	442.000	50873.602
STD DEV DELIVERY TIME	4.800	0.	4.800

MESSAGE NAME	NC CODE TO PNC
SOURCE STATION	MASTER COMPUTER
DESTINATION STATION	PNC
NUMBER SENT	89
AVG DELIVERY TIME	120.800
MAX DELIVERY TIME	120.800
MIN DELIVERY TIME	120.800
STD DEV DELIVERY TIME	.000

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

AT   28800. SECONDS

station S1/MASTER COMPUTER is IDLE
  disk S1/SD/MASTER COMPUTER is IDLE and has 4528647070. bits available
      file GENERAL STORAGE is IDLE and contains   600000. bits
      file LD STORAGE is IDLE and contains   250. bits
      file GM STORAGE is IDLE and contains   500000. bits
      file WORDER STORAGE is IDLE and contains   1000. bits
      file INSP STORAGE is IDLE and contains   100000. bits
station S1/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (6)
      MR/NC CODE TO PNC (77) is in the station local queue
      MR/NC CODE TO PNC (78) is in the station local queue
      MR/NC CODE TO PNC (79) is in the station local queue
      MR/NC CODE TO PNC (80) is in the station local queue
      MR/NC CODE TO PNC (81) is in the station local queue
      MR/NC CODE TO PNC (82) is in the station local queue
      MR/NC CODE TO PNC (83) is in the station local queue
      MR/NC CODE TO PNC (84) is in the station local queue
      MR/NC CODE TO PNC (85) is in the station local queue
      MR/NC CODE TO PNC (86) is in the station local queue
      MR/NC CODE TO PNC (87) is in the station local queue
      MR/NC CODE TO PNC (88) is in the station local queue
      MR/NC CODE TO PNC (89) is in the station local queue
  disk S1/SD/PNC is IDLE and has 4696596480. bits available
      file WORDER is IDLE and contains   1024000. bits
station S1/INSPECTION is BUSY executing action PROCESS CODE
      resident activity is INPUT CODE FROM MASTER (2)
      MR/CODE TO INSPECTION (63) is in the station local queue
      MR/CODE TC INSPECTION (64) is in the station local queue
      MR/CODE TO INSPECTION (65) is in the station local queue
      MR/CODE TO INSPECTION (66) is in the station local queue
      MR/CODE TO INSPECTION (67) is in the station local queue
      MR/CODE TO INSPECTION (68) is in the station local queue
      MR/CODE TO INSPECTION (69) is in the station local queue
      MR/CODE TO INSPECTION (70) is in the station local queue
      MR/CODE TO INSPECTION (71) is in the station local queue
      MR/CODE TO INSPECTION (72) is in the station local queue
      MR/CODE TO INSPECTION (73) is in the station local queue
      MR/CODE TO INSPECTION (74) is in the station local queue
      MR/CODE TO INSPECTION (75) is in the station local queue
      MR/CODE TO INSPECTION (76) is in the station local queue
      MR/CODE TO INSPECTION (77) is in the station local queue
      MR/CODE TO INSPECTION (78) is in the station local queue
      MR/CODE TO INSPECTION (79) is in the station local queue
      MR/CODE TO INSPECTION (80) is in the station local queue
      MR/CODE TO INSPECTION (81) is in the station local queue

CONFIGURATION #2
TOKEN RING
IEEE 802.5

TOKEN LAN UTILIZATION STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

LAN NAME	BUS1	RING1
LAN REQUESTS GRANTED	26	670
AVG REQUEST DELAY	0.	0.
MAX REQUEST DELAY	0.	0.
STD DEV REQUEST DELAY	0.	. 0.
COMPLETED TRANSFERS	26	670
AVG USAGE TIME	442.000	73802.985
MAX USAGE TIME	442.000	125750.000
STD DEV USAGE TIME	0.	57927.461
AVG QUEUE SIZE	0.	0.
MAX QUEUE SIZE	1.000	1.000
STD DEV QUEUE SIZE	0.	0.
PER CENT OF TIME BUSY	.000	.172

COMPLETED ACTIVITY STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

ACTIVITY NAME	SEND MESSAGE TO LOAD	SEND G & M CODE TO GNC	SEND CODE TO INSPECTION
HOST STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
COMPLETED EXECUTIONS	13	184	62
AVG EXECUTION TIME	28884.000	279500.000	78300.000
MAX EXECUTION TIME	28884.000	279500.000	78300.000
MIN EXECUTION TIME	28884.000	279500.000	78300.000
STD DEV EXECUTION TIME	0.	0.	0.

ACTIVITY NAME	SEND NC CODE TO PNC	GET WORK ORDER FROM MC	INPUT CODE FROM MASTER
HOST STATION	MASTER COMPUTER	PNC	INSPECTION
COMPLETED EXECUTIONS	89	5	1
AVG EXECUTION TIME	28600.000	4910496000.000	14400096000.000
MAX EXECUTION TIME	28600.000	18432096000.000	14400096000.000
MIN EXECUTION TIME	28600.000	72096000.000	14400096000.000
STD DEV EXECUTION TIME	0.	6954529160.195	0.

ACTIVITY NAME	G & M CODE FROM MASTER	RECEIVE LOAD FILE
HOST STATION	GNC ·	CONVEYOR
COMPLETED EXECUTIONS	0	6
AVG EXECUTION TIME	0.	4095096000.000
MAX EXECUTION TIME	0.	18432096000.000
MIN EXECUTION TIME	0.	18096000.000
STD DEV EXECUTION TIME	0.	6605221343.755

FROM 0. TO 28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

STATION NAME	MASTER COMPUTER	PNC	INSPECTION
LAN REQUESTS GRANTED	696	0	0
AVERAGE WAIT TIME	0.	0.	0.
MAXIMUM WAIT TIME	0.	0.	0.
STD DEV WAIT TIME	0.	0.	0.
DISK REQUESTS GRANTED	348	21	5
AVERAGE BITS USED	1201250.000	325785.988	499998.500
MAXIMUM BITS USED	1201250.	1024000.	800000.
STD DEV BITS USED	0.	301859.363	299999.778
STATION UTILIZATION	.206	100.000	100.000

STATION NAME	GNC	CONVEYOR
LAN REQUESTS GRANTED	0	0
AVERAGE WAIT TIME	0.	0.
MAXIMUM WAIT TIME	0.	0.
STD DEV WAIT TIME	0.	0.
DISK REQUESTS GRANTED	1	25
AVERAGE BITS USED	500000.000	325142.342
MAXIMUM BITS USED	500000.	1024000.
STD DEV BITS USED	0.	301461.087
STATION UTILIZATION	100.000	100.000

FROM   0.   TO   28800. SECONDS

RECEIVER	COUNT	MESSAGE NAME
PNC		
	178	NC CODE TO PNC
INSPECTION		
	124	CODE TO INSPECTION
GNC		
	368	MESSAGE TO GNC
CONVEYOR		
	26	MESSAGE TO LOAD

RECEIVER   COUNT   MESSAGE NAME

PNC

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

MESSAGE NAME	CODE TO INSPECTION	MESSAGE TO LOAD	MESSAGE TO GNC
SOURCE STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
DESTINATION STATION	INSPECTION	CONVEYOR	GNC
NUMBER SENT	124	26	368
AVG DELIVERY TIME	25150.000	442.000	125750.000
MAX DELIVERY TIME	25150.000	442.000	125750.000
MIN DELIVERY TIME	25150.000	442.000	125750.000
STD DEV DELIVERY TIME	0.	0.	0.

MESSAGE NAME	NC CODE TO PNC
SOURCE STATION	MASTER COMPUTER
DESTINATION STATION	PNC
NUMBER SENT	178
AVG DELIVERY TIME	300.000
MAX DELIVERY TIME	300.000
MIN DELIVERY TIME	300.000
STD DEV DELIVERY TIME	0.

AT   28800. SECONDS

station S1/MASTER COMPUTER is IDLE
   disk S1/SD/MASTER COMPUTER is IDLE and has   4528647070. bits available
      file GENERAL STORAGE is IDLE and contains   600000. bits
      file LD STORAGE is IDLE and contains   250. bits
      file GM STORAGE is IDLE and contains   500000. bits
      file WORDER STORAGE is IDLE and contains   1000. bits
      file INSP STORAGE is IDLE and contains   100000. bits
station S1/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (6)
      MR/NC CODE TO PNC (153) is in the station local queue
      MR/NC CODE TO PNC (154) is in the station local queue
      MR/NC CODE TO PNC (155) is in the station local queue
      MR/NC CODE TO PNC (156) is in the station local queue
      MR/NC CODE TO PNC (157) is in the station local queue
      MR/NC CODE TO PNC (158) is in the station local queue
      MR/NC CODE TO PNC (159) is in the station local queue
      MR/NC CODE TO PNC (160) is in the station local queue
      MR/NC CODE TO PNC (161) is in the station local queue
      MR/NC CODE TO PNC (162) is in the station local queue
      MR/NC CODE TO PNC (163) is in the station local queue
      MR/NC CODE TO PNC (164) is in the station local queue
      MR/NC CODE TO PNC (165) is in the station local queue
      MR/NC CODE TO PNC (166) is in the station local queue
      MR/NC CODE TO PNC (167) is in the station local queue
      MR/NC CODE TO PNC (168) is in the station local queue
      MR/NC CODE TO PNC (169) is in the station local queue
      MR/NC CODE TO PNC (170) is in the station local queue
      MR/NC CODE TO PNC (171) is in the station local queue
      MR/NC CODE TO PNC (172) is in the station local queue
      MR/NC CODE TO PNC (173) is in the station local queue
      MR/NC CODE TO PNC (174) is in the station local queue
      MR/NC CODE TO PNC (175) is in the station local queue
      MR/NC CODE TO PNC (176) is in the station local queue
      MR/NC CODE TO PNC (177) is in the station local queue
      MR/NC CODE TO PNC (178) is in the station local queue
   disk S1/SD/PNC is IDLE and has   4696596480. bits available
      file WORDER is IDLE and contains   1024000. bits
station S1/INSPECTION is BUSY executing action PROCESS CODE
      resident activity is INPUT CODE FROM MASTER (2)
      MR/CODE TO INSPECTION (63) is in the station local queue
      MR/CODE TO INSPECTION (64) is in the station local queue
      MR/CODE TO INSPECTION (65) is in the station local queue
      MR/CODE TO INSPECTION (66) is in the station local queue
      MR/CODE TO INSPECTION (67) is in the station local queue
      MR/CODE TO INSPECTION (68) is in the station local queue

CONFIGURATION #2
TOKEN BUS(STAR)
IEEE 802.4

TOKEN LAN UTILIZATION STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

LAN NAME	BUS1	STAR1
LAN REQUESTS GRANTED	26	670
AVG REQUEST DELAY	0.	0.
MAX REQUEST DELAY	0.	0.
STD DEV REQUEST DELAY	0.	0.
COMPLETED TRANSFERS	26	670
AVG USAGE TIME	442.000	58881.194
MAX USAGE TIME	442.000	100320.000
STD DEV USAGE TIME	0.	46210.273
AVG QUEUE SIZE	0.	0.
MAX QUEUE SIZE	1.000	1.000
STD DEV QUEUE SIZE	0.	0.
PER CENT OF TIME BUSY	.000	.137

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

ACTIVITY NAME	SEND MESSAGE TO LOAD	SEND G & M CODE TO GNC	SEND CODE TO INSPECTION
HOST STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
COMPLETED EXECUTIONS	13	184	62
AVG EXECUTION TIME	28884.000	228640.000	68160.000
MAX EXECUTION TIME	28884.000	228640.000	68160.000
MIN EXECUTION TIME	28884.000	228640.000	68160.000
STD DEV EXECUTION TIME	0.	0.	0.

ACTIVITY NAME	SEND NC CODE TO PNC	GET WORK ORDER FROM MC	INPUT CODE FROM MASTER
HOST STATION	MASTER COMPUTER	PNC	INSPECTION
COMPLETED EXECUTIONS	89	5	1
AVG EXECUTION TIME	28480.000	4910496000.000	14400096000.000
MAX EXECUTION TIME	28480.000	18432096000.000	14400096000.000
MIN EXECUTION TIME	28480.000	72096000.000	14400096000.000
STD DEV EXECUTION TIME	0.	6954529160.195	0.

COMPLETED ACTIVITY STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

ACTIVITY NAME	RECEIVE LOAD FILE	G & M CODE FROM MASTER
HOST STATION	CONVEYOR	GNC
COMPLETED EXECUTIONS	6	0
AVG EXECUTION TIME	4095096000.000	0.
MAX EXECUTION TIME	18432096000.000	0.
MIN EXECUTION TIME	18096000.000	0.
STD DEV EXECUTION TIME	6605221343.755	0.

STATION UTILIZATION STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

STATION NAME	MASTER COMPUTER	PNC	INSPECTION
LAN REQUESTS GRANTED	696	0	0
AVERAGE WAIT TIME	0.	0.	0.
MAXIMUM WAIT TIME	0.	0.	0.
STD DEV WAIT TIME	0.	. 0.	0.
DISK REQUESTS GRANTED	348	21	5
AVERAGE BITS USED	1201250.000	325785.988	499998.500
MAXIMUM BITS USED	1201250.	1024000.	800000.
STD DEV BITS USED	0.	301859.363	299999.778
STATION UTILIZATION	.171	100.000	100.000

STATION NAME	CONVEYOR	GNC
LAN REQUESTS GRANTED	0	0
AVERAGE WAIT TIME	0.	0.
MAXIMUM WAIT TIME	0.	0.
STD DEV WAIT TIME	0.	0.
DISK REQUESTS GRANTED	25	1
AVERAGE BITS USED	325142.342	500000.000
MAXIMUM BITS USED	1024000.	500000.
STD DEV BITS USED	301461.087	0.
STATION UTILIZATION	100.000	100.000

RECEIVED MESSAGE REPORT

FROM   0. TO   28800. SECONDS

RECEIVER   COUNT   MESSAGE NAME

PNC
             178   NC CODE TO PNC

INSPECTION
             124   CODE TO INSPECTION

CONVEYOR
             26   MESSAGE TO LOAD

GNC
             368   MESSAGE TO GNC

MESSAGE DELIVERY REPORT

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

MESSAGE NAME	CODE TO INSPECTION	MESSAGE TO LOAD	MESSAGE TO GNC
SOURCE STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
DESTINATION STATION	INSPECTION	CONVEYOR	GNC
NUMBER SENT	124	26	368
AVG DELIVERY TIME	20080.000	442.000	100320.000
MAX DELIVERY TIME	20080.000	442.000	100320.000
MIN DELIVERY TIME	20080.000	442.000	100320.000
STD DEV DELIVERY TIME	0.	0.	0.

MESSAGE NAME	NC CODE TO PNC
SOURCE STATION	MASTER COMPUTER
DESTINATION STATION	PNC
NUMBER SENT	178
AVG DELIVERY TIME	240.000
MAX DELIVERY TIME	240.000
MIN DELIVERY TIME	240.000
STD DEV DELIVERY TIME	0.

AT   28800. SECONDS

station S1/MASTER COMPUTER is IDLE
  disk S1/SD/MASTER COMPUTER is IDLE and has 4528647070. bits available
      file GENERAL STORAGE is IDLE and contains   600000. bits
      file LD STORAGE is IDLE and contains   250. bits
      file GM STORAGE is IDLE and contains   500000. bits
      file WORDER STORAGE is IDLE and contains   1000. bits
      file INSP STORAGE is IDLE and contains   100000. bits
station S1/PNC is BUSY executing action PROCESS CODE
     resident activity is GET WORK ORDER FROM MC (6)
     MR/NC CODE TO PNC (153) is in the station local queue
     MR/NC CODE TO PNC (154) is in the station local queue
     MR/NC CODE TO PNC (155) is in the station local queue
     MR/NC CODE TO PNC (156) is in the station local queue
     MR/NC CODE TO PNC (157) is in the station local queue
     MR/NC CODE TO PNC (158) is in the station local queue
     MR/NC CODE TO PNC (159) is in the station local queue
     MR/NC CODE TO PNC (160) is in the station local queue
     MR/NC CODE TO PNC (161) is in the station local queue
     MR/NC CODE TO PNC (162) is in the station local queue
     MR/NC CODE TO PNC (163) is in the station local queue
     MR/NC CODE TO PNC (164) is in the station local queue
     MR/NC CODE TO PNC (165) is in the station local queue
     MR/NC CODE TO PNC (166) is in the station local queue
     MR/NC CODE TO PNC (167) is in the station local queue
     MR/NC CODE TO PNC (168) is in the station local queue
     MR/NC CODE TO PNC (169) is in the station local queue
     MR/NC CODE TO PNC (170) is in the station local queue
     MR/NC CODE TO PNC (171) is in the station local queue
     MR/NC CODE TO PNC (172) is in the station local queue
     MR/NC CODE TO PNC (173) is in the station local queue
     MR/NC CODE TO PNC (174) is in the station local queue
     MR/NC CODE TO PNC (175) is in the station local queue
     MR/NC CODE TO PNC (176) is in the station local queue
     MR/NC CODE TO PNC (177) is in the station local queue
     MR/NC CODE TO PNC (178) is in the station local queue
  disk S1/SD/PNC is IDLE and has 4696596480. bits available
      file WORDER is IDLE and contains   1024000. bits
station S1/INSPECTION is BUSY executing action PROCESS CODE
     resident activity is INPUT CODE FROM MASTER (2)
     MR/CODE TO INSPECTION (63) is in the station local queue
     MR/CODE TO INSPECTION (64) is in the station local queue
     MR/CODE TO INSPECTION (65) is in the station local queue
     MR/CODE TO INSPECTION (66) is in the station local queue
     MR/CODE TO INSPECTION (67) is in the station local queue
     MR/CODE TO INSPECTION (68) is in the station local queue

CONFIGURATION #3
ETHERNET
IEEE 802.3

FROM   0.   TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

LAN NAME   ETHERNET

COLLISION EPISODES   0

COLLIDED TRANSFERS   0
AVG TO RESOLVE   0.
MAX TO RESOLVE   0

DEFERRALS   0
AVG DEFERRAL DELAY   0.
MAX DEFERRAL DELAY   0.
STD DEV DEFERRAL DELAY   0.

AVG DEFERRAL QUEUE   0.
MAX QUEUE SIZE   0.
STD DEV QUEUE SIZE   0.

MULTIPLE COLLISIONS   0
AVG MULT COLLISIONS   0.
MAX MULT COLLISIONS   0

SUCCESSFUL TRANSFERS   134
AVG USAGE TIME   4477.899
MAX USAGE TIME   10187.200
STD DEV USAGE TIME   4987.583

PER CENT OF TIME BUSY   .002

LAN NAME   BUS1

LAN REQUESTS GRANTED   6
AVG REQUEST DELAY   0.
MAX REQUEST DELAY   0.
STD DEV REQUEST DELAY   0.

COMPLETED TRANSFERS   6
AVG USAGE TIME   442.000
MAX USAGE TIME   442.000
STD DEV USAGE TIME   0.

AVG QUEUE SIZE   0.
MAX QUEUE SIZE   1.000
STD DEV QUEUE SIZE   0.

PER CENT OF TIME BUSY   .000

COMPLETED ACTIVITY STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

ACTIVITY NAME	SEND MESSAGE TO LOAD	SEND CODE TO INSPECTION	SEND NC CODE TO PNC
HOST STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
COMPLETED EXECUTIONS	3	29	38
AVG EXECUTION TIME	28884.000	48384.000	28251.200
MAX EXECUTION TIME	28884.000	48384.000	28251.200
MIN EXECUTION TIME	28884.000	48384.000	28251.200
STD DEV EXECUTION TIME	0.	0.	0.

ACTIVITY NAME	GET WORK ORDER FROM MC	INPUT CODE FROM MASTER	RECEIVE LOAD FILE
HOST STATION	PNC	INSPECTION	ROBOT
COMPLETED EXECUTIONS	10	1	6
AVG EXECUTION TIME	4910496000.000	14400096000.000	4095096000.000
MAX EXECUTION TIME	18432096000.000	14400096000.000	18432096000.000
MIN EXECUTION TIME	72096000.000	14400096000.000	18096000.000
STD DEV EXECUTION TIME	6954529160.195	0.	6605221343.755

STATION UTILIZATION STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

STATION NAME	MASTER COMPUTER	PNC	INSPECTION
LAN REQUESTS GRANTED	140	0	0
AVERAGE WAIT TIME	4.594	0.	0.
MAXIMUM WAIT TIME	9.600	0.	0.
STD DEV WAIT TIME	4.796	0.	0.
DISK REQUESTS GRANTED	70	42	5
AVERAGE BITS USED	1201250.000	325785.988	499998.500
MAXIMUM BITS USED	1201250.	1024000.	800000.
STD DEV BITS USED	0.	301859.363	299999.778
STATION UTILIZATION	.009	100.000	100.000

STATION NAME	ROBOT
LAN REQUESTS GRANTED	0
AVERAGE WAIT TIME	0.
MAXIMUM WAIT TIME	0.
STD DEV WAIT TIME	0.
DISK REQUESTS GRANTED	25
AVERAGE BITS USED	325142.342
MAXIMUM BITS USED	1024000.
STD DEV BITS USED	301461.087
STATION UTILIZATION	100.000

FROM   0. TO   28800. SECONDS

RECEIVER	COUNT	MESSAGE NAME
PNC		
	76	NC CODE TO PNC
INSPECTION		
	58	CODE TO INSPECTION
ROBOT		
	6	MESSAGE TO LOAD

MESSAGE DELIVERY REPORT

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

MESSAGE NAME	CODE TO INSPECTION	MESSAGE TO LOAD	NC CODE TO PNC
SOURCE STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
DESTINATION STATION	INSPECTION	ROBOT	PNC
NUMBER SENT	58	6	76
AVG DELIVERY TIME	10192.000	442.000	125.600
MAX DELIVERY TIME	10196.800	442.000	130.400
MIN DELIVERY TIME	10187.200	442.000	120.800
STD DEV DELIVERY TIME	4.800	0.	4.800

AT   28800. SECONDS

```
station S1/MASTER COMPUTER is IDLE
   disk S1/SD/MASTER COMPUTER is IDLE and has  4528647070. bits available
      file GENERAL STORAGE is IDLE and contains     600000. bits
      file LD STORAGE is IDLE and contains         250. bits
      file GM STORAGE is IDLE and contains     500000. bits
      file WORDER STORAGE is IDLE and contains      1000. bits
      file INSP STORAGE is IDLE and contains     100000. bits
station S1/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (11)
      MR/NC CODE TO PNC (69) is in the station local queue
      MR/NC CODE TO PNC (71) is in the station local queue
      MR/NC CODE TO PNC (73) is in the station local queue
      MR/NC CODE TO PNC (74) is in the station local queue
      MR/NC CODE TO PNC (76) is in the station local queue
   disk S1/SD/PNC is IDLE and has  4696596480. bits available
      file WORDER is IDLE and contains    1024000. bits
station S2/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (12)
      MR/NC CODE TO PNC (65) is in the station local queue
      MR/NC CODE TO PNC (66) is in the station local queue
      MR/NC CODE TO PNC (67) is in the station local queue
      MR/NC CODE TO PNC (68) is in the station local queue
      MR/NC CODE TO PNC (70) is in the station local queue
      MR/NC CODE TO PNC (72) is in the station local queue
      MR/NC CODE TO PNC (75) is in the station local queue
   disk S2/SD/PNC is IDLE and has  4696596480. bits available
      file WORDER is IDLE and contains    1024000. bits
station S1/INSPECTION is BUSY executing action PROCESS CODE
      resident activity is INPUT CODE FROM MASTER (2)
      MR/CODE TO INSPECTION (31) is in the station local queue
      MR/CODE TO INSPECTION (32) is in the station local queue
      MR/CODE TO INSPECTION (33) is in the station local queue
      MR/CODE TO INSPECTION (34) is in the station local queue
      MR/CODE TO INSPECTION (35) is in the station local queue
      MR/CODE TO INSPECTION (36) is in the station local queue
      MR/CODE TO INSPECTION (37) is in the station local queue
      MR/CODE TO INSPECTION (38) is in the station local queue
      MR/CODE TO INSPECTION (39) is in the station local queue
      MR/CODE TO INSPECTION (40) is in the station local queue
      MR/CODE TO INSPECTION (41) is in the station local queue
      MR/CODE TO INSPECTION (42) is in the station local queue
      MR/CODE TO INSPECTION (43) is in the station local queue
      MR/CODE TO INSPECTION (44) is in the station local queue
      MR/CODE TO INSPECTION (45) is in the station local queue
      MR/CODE TO INSPECTION (46) is in the station local queue
```

CONFIGURATION #3
TOKEN RING
IEEE 802.5

TOKEN LAN UTILIZATION STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

LAN NAME	BUS1	RING1
LAN REQUESTS GRANTED	6	134
AVG REQUEST DELAY	0.	0.
MAX REQUEST DELAY	0.	0.
STD DEV REQUEST DELAY	0.	0.
COMPLETED TRANSFERS	6	134
AVG USAGE TIME	442.000	11055.970
MAX USAGE TIME	442.000	25150.000
STD DEV USAGE TIME	0.	12312.391
AVG QUEUE SIZE	0.	0.
MAX QUEUE SIZE	1.000	1.000
STD DEV QUEUE SIZE	0.	0.
PER CENT OF TIME BUSY	.000	.005

COMPLETED ACTIVITY STATISTICS

FROM 0. TO 28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

ACTIVITY NAME	SEND MESSAGE TO LOAD	SEND CODE TO INSPECTION	SEND NC CODE TO PNC
HOST STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
COMPLETED EXECUTIONS	3	29	38
AVG EXECUTION TIME	28884.000	78300.000	28600.000
MAX EXECUTION TIME	28884.000	78300.000	28600.000
MIN EXECUTION TIME	28884.000	78300.000	28600.000
STD DEV EXECUTION TIME	0.	0.	0.

ACTIVITY NAME	GET WORK ORDER FROM MC	INPUT CODE FROM MASTER	RECEIVE LOAD FILE
HOST STATION	PNC	INSPECTION	ROBOT
COMPLETED EXECUTIONS	10	1	6
AVG EXECUTION TIME	4910496000.000	14400096000.000	4095096000.000
MAX EXECUTION TIME	18432096000.000	14400096000.000	18432096000.000
MIN EXECUTION TIME	72096000.000	14400096000.000	18096000.000
STD DEV EXECUTION TIME	6954529160.195	0.	6605221343.755

STATION UTILIZATION STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

STATION NAME	MASTER COMPUTER	PNC	INSPECTION
LAN REQUESTS GRANTED	140	0	0
AVERAGE WAIT TIME	0.	0.	0.
MAXIMUM WAIT TIME	0.	0.	0.
STD DEV WAIT TIME	0.	0.	0.
DISK REQUESTS GRANTED	70	42	5
AVERAGE BITS USED	1201250.000	325785.988	499998.500
MAXIMUM BITS USED	1201250.	1024000.	800000.
STD DEV BITS USED	0.	301859.363	299999.778
STATION UTILIZATION	.012	100.000	99.965

STATION NAME	ROBOT
LAN REQUESTS GRANTED	0
AVERAGE WAIT TIME	0.
MAXIMUM WAIT TIME	0.
STD DEV WAIT TIME	0.
DISK REQUESTS GRANTED	25
AVERAGE BITS USED	325142.342
MAXIMUM BITS USED	1024000.
STD DEV BITS USED	301461.087
STATION UTILIZATION	100.000

FROM   0.   TO   28800. SECONDS

RECEIVER	COUNT	MESSAGE NAME
PNC		
	76	CN CODE TO PNC
INSPECTION		
	58	CODE TO INSPECTION
ROBOT		
	6	MESSAGE TO LOAD

FROM   0.   TO   28800. SECONDS

| RECEIVER | COUNT | MESSAGE NAME |

MESSAGE DELIVERY REPORT

FROM   0.   TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

MESSAGE NAME	CODE TO INSPECTION	MESSAGE TO LOAD	CN CODE TO PNC
SOURCE STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
DESTINATION STATION	INSPECTION	ROBOT	PNC
NUMBER SENT	58	6	76
AVG DELIVERY TIME	25150.000	442.000	300.000
MAX DELIVERY TIME	25150.000	442.000	300.000
MIN DELIVERY TIME	25150.000	442.000	300.000
STD DEV DELIVERY TIME	0.	0.	0.

station S1/MASTER COMPUTER is IDLE
   disk S1/SD/MASTER COMPUTER is IDLE and has 4528647070. bits available
      file GENERAL STORAGE is IDLE and contains   600000. bits
      file LD STORAGE is IDLE and contains   250. bits
      file GM STORAGE is IDLE and contains   500000. bits
      file WORDER STORAGE is IDLE and contains   1000. bits
      file INSP STORAGE is IDLE and contains   100000. bits
station S1/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (11)
      MR/CN CODE TO PNC (69) is in the station local queue
      MR/CN CODE TO PNC (71) is in the station local queue
      MR/CN CODE TO PNC (73) is in the station local queue
      MR/CN CODE TO PNC (74) is in the station local queue
      MR/CN CODE TO PNC (76) is in the station local queue
   disk S1/SD/PNC is IDLE and has 4696596480. bits available
      file WORDER is IDLE and contains   1024000. bits
station S2/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (12)
      MR/CN CODE TO PNC (65) is in the station local queue
      MR/CN CODE TO PNC (66) is in the station local queue
      MR/CN CODE TO PNC (67) is in the station local queue
      MR/CN CODE TO PNC (68) is in the station local queue
      MR/CN CODE TO PNC (70) is in the station local queue
      MR/CN CODE TO PNC (72) is in the station local queue
      MR/CN CODE TO PNC (75) is in the station local queue
   disk S2/SD/PNC is IDLE and has 4696596480. bits available
      file WORDER is IDLE and contains   1024000. bits
station S1/INSPECTION is BUSY executing action PROCESS CODE
      resident activity is INPUT CODE FROM MASTER (2)
      MR/CODE TO INSPECTION (31) is in the station local queue
      MR/CODE TO INSPECTION (32) is in the station local queue
      MR/CODE TO INSPECTION (33) is in the station local queue
      MR/CODE TO INSPECTION (34) is in the station local queue
      MR/CODE TO INSPECTION (35) is in the station local queue
      MR/CODE TO INSPECTION (36) is in the station local queue
      MR/CODE TO INSPECTION (37) is in the station local queue
      MR/CODE TO INSPECTION (38) is in the station local queue
      MR/CODE TO INSPECTION (39) is in the station local queue
      MR/CODE TO INSPECTION (40) is in the station local queue
      MR/CODE TO INSPECTION (41) is in the station local queue
      MR/CODE TO INSPECTION (42) is in the station local queue
      MR/CODE TO INSPECTION (43) is in the station local queue
      MR/CODE TO INSPECTION (44) is in the station local queue
      MR/CODE TO INSPECTION (45) is in the station local queue
      MR/CODE TO INSPECTION (46) is in the station local queue

CONFIGURATION #3
TOKEN BUS(STAR)
IEEE 802.4

TOKEN LAN UTILIZATION STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

LAN NAME	BUS1	STAR1
LAN REQUESTS GRANTED	6	134
AVG REQUEST DELAY	0.	0.
MAX REQUEST DELAY	0.	0.
STD DEV REQUEST DELAY	0.	. 0.
COMPLETED TRANSFERS	6	134
AVG USAGE TIME	442.000	8827.463
MAX USAGE TIME	442.000	20080.000
STD DEV USAGE TIME	0.	9830.094
AVG QUEUE SIZE	0.	0.
MAX QUEUE SIZE	1.000	1.000
STD DEV QUEUE SIZE	0.	0.
PER CENT OF TIME BUSY	.000	.004

COMPLETED ACTIVITY STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

ACTIVITY NAME	SEND MESSAGE TO LOAD	SEND CODE TO INSPECTION	SEND NC CODE TO PNC
HOST STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
COMPLETED EXECUTIONS	3	29	38
AVG EXECUTION TIME	28884.000	68160.000	28480.000
MAX EXECUTION TIME	28884.000	68160.000	28480.000
MIN EXECUTION TIME	28884.000	68160.000	28480.000
STD DEV EXECUTION TIME	0.	0.	0.

ACTIVITY NAME	GET WORK ORDER FROM MC	INPUT CODE FROM MASTER	RECEIVE LOAD FILE
HOST STATION	PNC	INSPECTION	ROBOT
COMPLETED EXECUTIONS	10	1	6
AVG EXECUTION TIME	4910496000.000	14400096000.000	4095096000.000
MAX EXECUTION TIME	18432096000.000	14400096000.000	18432096000.000
MIN EXECUTION TIME	72096000.000	14400096000.000	18096000.000
STD DEV EXECUTION TIME	6954529160.195	0.	6605221343.755

STATION UTILIZATION STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

STATION NAME	MASTER COMPUTER	PNC	INSPECTION
LAN REQUESTS GRANTED	140	0	0
AVERAGE WAIT TIME	0.	0.	0.
MAXIMUM WAIT TIME	0.	0.	0.
STD DEV WAIT TIME	0.	0.	0.
DISK REQUESTS GRANTED	70	42	5
AVERAGE BITS USED	1201250.000	325785.988	499998.500
MAXIMUM BITS USED	1201250.	1024000.	800000.
STD DEV BITS USED	0.	301859.363	299999.778
STATION UTILIZATION	.011	100.000	100.000

STATION NAME	ROBOT
LAN REQUESTS GRANTED	0
AVERAGE WAIT TIME	0.
MAXIMUM WAIT TIME	0.
STD DEV WAIT TIME	0.
DISK REQUESTS GRANTED	25
AVERAGE BITS USED	325142.342
MAXIMUM BITS USED	1024000.
STD DEV BITS USED	301461.087
STATION UTILIZATION	100.000

FROM   0. TO   28800. SECONDS

RECEIVER   COUNT   MESSAGE NAME

PNC
              76   NC CODE TO PNC

INSPECTION
              58   CODE TO INSPECTION

ROBOT
              6   MESSAGE TO LOAD

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

MESSAGE NAME	CODE TO INSPECTION	MESSAGE TO LOAD	NC CODE TO PNC
SOURCE STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
DESTINATION STATION	INSPECTION	ROBOT	PNC
NUMBER SENT	58	6	76
AVG DELIVERY TIME	20080.000	442.000	240.000
MAX DELIVERY TIME	20080.000	442.000	240.000
MIN DELIVERY TIME	20080.000	442.000	240.000
STD DEV DELIVERY TIME	0.	0.	0.

AT   28800. SECONDS

station S1/MASTER COMPUTER is IDLE
   disk S1/SD/MASTER COMPUTER is IDLE and has 4528647070. bits available
      file GENERAL STORAGE is IDLE and contains   600000. bits
      file LD STORAGE is IDLE and contains   250. bits
      file GM STORAGE is IDLE and contains   500000. bits
      file WORDER STORAGE is IDLE and contains   1000. bits
      file INSP STORAGE is IDLE and contains   100000. bits
station S1/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (11)
      MR/NC CODE TO PNC (69) is in the station local queue
      MR/NC CODE TO PNC (71) is in the station local queue
      MR/NC CODE TO PNC (73) is in the station local queue
      MR/NC CODE TO PNC (74) is in the station local queue
      MR/NC CODE TO PNC (76) is in the station local queue
   disk S1/SD/PNC is IDLE and has 4696596480. bits available
      file WORDER is IDLE and contains   1024000. bits
station S2/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (12)
      MR/NC CODE TO PNC (65) is in the station local queue
      MR/NC CODE TO PNC (66) is in the station local queue
      MR/NC CODE TO PNC (67) is in the station local queue
      MR/NC CODE TO PNC (68) is in the station local queue
      MR/NC CODE TO PNC (70) is in the station local queue
      MR/NC CODE TO PNC (72) is in the station local queue
      MR/NC CODE TO PNC (75) is in the station local queue
   disk S2/SD/PNC is IDLE and has 4696596480. bits available
      file WORDER is IDLE and contains   1024000. bits
station S1/INSPECTION is BUSY executing action PROCESS CODE
      resident activity is INPUT CODE FROM MASTER (2)
      MR/CODE TO INSPECTION (31) is in the station local queue
      MR/CODE TO INSPECTION (32) is in the station local queue
      MR/CODE TO INSPECTION (33) is in the station local queue
      MR/CODE TO INSPECTION (34) is in the station local queue
      MR/CODE TO INSPECTION (35) is in the station local queue
      MR/CODE TO INSPECTION (36) is in the station local queue
      MR/CODE TO INSPECTION (37) is in the station local queue
      MR/CODE TO INSPECTION (38) is in the station local queue
      MR/CODE TO INSPECTION (39) is in the station local queue
      MR/CODE TO INSPECTION (40) is in the station local queue
      MR/CODE TO INSPECTION (41) is in the station local queue
      MR/CODE TO INSPECTION (42) is in the station local queue
      MR/CODE TO INSPECTION (43) is in the station local queue
      MR/CODE TO INSPECTION (44) is in the station local queue
      MR/CODE TO INSPECTION (45) is in the station local queue
      MR/CODE TO INSPECTION (46) is in the station local queue

CONFIGURATION #4
ETHERNET
IEEE 802.3

COLLISION LAN UTILIZATION STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

```
LAN NAME                    ETHERNET


COLLISION EPISODES          0

COLLIDED TRANSFERS          0
AVG TO RESOLVE              0.
MAX TO RESOLVE              0

DEFERRALS                   0
AVG DEFERRAL DELAY          0.
MAX DEFERRAL DELAY          0.
STD DEV DEFERRAL DELAY      0.

AVG DEFERRAL QUEUE          0.
MAX QUEUE SIZE              0.
STD DEV QUEUE SIZE          0.

MULTIPLE COLLISIONS         0
AVG MULT COLLISIONS         0.
MAX MULT COLLISIONS         0

SUCCESSFUL TRANSFERS        272
AVG USAGE TIME              40100.612
MAX USAGE TIME              61040.000
STD DEV USAGE TIME          25027.356

PER CENT OF TIME BUSY          .038
```

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

LAN NAME   BUS1

LAN REQUESTS GRANTED   8
AVG REQUEST DELAY   0.
MAX REQUEST DELAY   0.
STD DEV REQUEST DELAY   0.

COMPLETED TRANSFERS   8
AVG USAGE TIME   442.000
MAX USAGE TIME   442.000
STD DEV USAGE TIME   0.

AVG QUEUE SIZE   0.
MAX QUEUE SIZE   1.000
STD DEV QUEUE SIZE   0.

PER CENT OF TIME BUSY   .000

FROM   0.   TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

ACTIVITY NAME	SEND CODE TO INSPECTION	SEND MESSAGE TO CART	SEND NC CODE TO PNC
HOST STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
COMPLETED EXECUTIONS	56	4	80
AVG EXECUTION TIME	48384.000	28884.000	178089.600
MAX EXECUTION TIME	48384.000	28884.000	178089.600
MIN EXECUTION TIME	48384.000	28884.000	178089.600
STD DEV EXECUTION TIME	0.	0.	.005

ACTIVITY NAME	GET WORK ORDER FROM MC	INPUT CODE FROM MASTER	RECEIVE LOAD FILE
HOST STATION	PNC	INSPECTION	CART
COMPLETED EXECUTIONS	10	1	6
AVG EXECUTION TIME	4910496000.000	14400096000.000	4095096000.000
MAX EXECUTION TIME	18432096000.000	14400096000.000	18432096000.000
MIN EXECUTION TIME	72096000.000	14400096000.000	18096000.000
STD DEV EXECUTION TIME	6954529160.195	0.	6605221343.755

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

STATION NAME	MASTER COMPUTER	PNC	INSPECTION
LAN REQUESTS GRANTED	280	0	0
AVERAGE WAIT TIME	4.663	0.	0.
MAXIMUM WAIT TIME	9.600	0.	0.
STD DEV WAIT TIME	4.798	0.	0.
DISK REQUESTS GRANTED	140	42	5
AVERAGE BITS USED	1201250.000	325785.988	499998.500
MAXIMUM BITS USED	1201250.	1024000.	800000.
STD DEV BITS USED	0.	301859.363	299999.778
STATION UTILIZATION	.059	100.000	100.000

STATION NAME	CART
LAN REQUESTS GRANTED	0
AVERAGE WAIT TIME	0.
MAXIMUM WAIT TIME	0.
STD DEV WAIT TIME	0.
DISK REQUESTS GRANTED	25
AVERAGE BITS USED	325142.342
MAXIMUM BITS USED	1024000.
STD DEV BITS USED	301461.087
STATION UTILIZATION	100.000

RECEIVED MESSAGE REPORT

FROM   0.   TO   28800. SECONDS

RECEIVER	COUNT	MESSAGE NAME
PNC		
	160	NC CODE TO PNC
INSPECTION		
	112	CODE TO INSPECTION
CART		
	8	CODE TO CART

MESSAGE DELIVERY REPORT

FROM   0.   TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

MESSAGE NAME	CODE TO INSPECTION	NC CODE TO PNC	CODE TO CART
SOURCE STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
DESTINATION STATION	INSPECTION	PNC	CART
NUMBER SENT	112	160	8
AVG DELIVERY TIME	10192.000	61044.800	442.000
MAX DELIVERY TIME	10196.800	61049.602	442.000
MIN DELIVERY TIME	10187.200	61040.000	442.000
STD DEV DELIVERY TIME	4.800	4.800	0.

station S1/MASTER COMPUTER is IDLE
   disk S1/SD/MASTER COMPUTER is IDLE and has   4528647070. bits available
      file GENERAL STORAGE is IDLE and contains   600000. bits
      file LD STORAGE is IDLE and contains   250. bits
      file GM STORAGE is IDLE and contains   500000. bits
      file WORDER STORAGE is IDLE and contains   1000. bits
      file INSP STORAGE is IDLE and contains   100000. bits
station S1/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (11)
      MR/NC CODE TO PNC (138) is in the station local queue
      MR/NC CODE TO PNC (143) is in the station local queue
      MR/NC CODE TO PNC (144) is in the station local queue
      MR/NC CODE TO PNC (147) is in the station local queue
      MR/NC CODE TO PNC (148) is in the station local queue
      MR/NC CODE TO PNC (155) is in the station local queue
      MR/NC CODE TO PNC (156) is in the station local queue
      MR/NC CODE TO PNC (157) is in the station local queue
      MR/NC CODE TO PNC (160) is in the station local queue
   disk S1/SD/PNC is IDLE and has   4696596480. bits available
      file WORDER is IDLE and contains   1024000. bits
station S2/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (12)
      MR/NC CODE TO PNC (137) is in the station local queue
      MR/NC CODE TO PNC (139) is in the station local queue
      MR/NC CODE TO PNC (140) is in the station local queue
      MR/NC CODE TO PNC (141) is in the station local queue
      MR/NC CODE TO PNC (142) is in the station local queue
      MR/NC CODE TO PNC (145) is in the station local queue
      MR/NC CODE TO PNC (146) is in the station local queue
      MR/NC CODE TO PNC (149) is in the station local queue
      MR/NC CODE TO PNC (150) is in the station local queue
      MR/NC CODE TO PNC (151) is in the station local queue
      MR/NC CODE TO PNC (152) is in the station local queue
      MR/NC CODE TO PNC (153) is in the station local queue
      MR/NC CODE TO PNC (154) is in the station local queue
      MR/NC CODE TO PNC (158) is in the station local queue
      MR/NC CODE TO PNC (159) is in the station local queue
   disk S2/SD/PNC is IDLE and has   4696596480. bits available
      file WORDER is IDLE and contains   1024000. bits
station S1/INSPECTION is BUSY executing action PROCESS CODE
      resident activity is INPUT CODE FROM MASTER (2)
      MR/CODE TO INSPECTION (57) is in the station local queue
      MR/CODE TO INSPECTION (58) is in the station local queue
      MR/CODE TO INSPECTION (59) is in the station local queue
      MR/CODE TO INSPECTION (60) is in the station local queue

CONFIGURATION #4
TOKEN RING
IEEE 802.5

TOKEN LAN UTILIZATION STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

LAN NAME	BUS1	RING1
LAN REQUESTS GRANTED	8	272
AVG REQUEST DELAY	0.	0.
MAX REQUEST DELAY	0.	0.
STD DEV REQUEST DELAY	0.	0.
COMPLETED TRANSFERS	8	272
AVG USAGE TIME	442.000	10532.353
MAX USAGE TIME	442.000	25150.000
STD DEV USAGE TIME	0.	12230.001
AVG QUEUE SIZE	0.	0.
MAX QUEUE SIZE	1.000	1.000
STD DEV QUEUE SIZE	0.	0.
PER CENT OF TIME BUSY	.000	.010

COMPLETED ACTIVITY STATISTICS

FROM   0.   TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

ACTIVITY NAME	SEND CODE TO INSPECTION	SEND MESSAGE TO CART	SEND NC CODE TO PNC
HOST STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
COMPLETED EXECUTIONS	56	4	80
AVG EXECUTION TIME	78300.000	28884.000	28600.000
MAX EXECUTION TIME	78300.000	28884.000	28600.000
MIN EXECUTION TIME	78300.000	28884.000	28600.000
STD DEV EXECUTION TIME	0.	0.	0.

ACTIVITY NAME	GET WORK ORDER FROM MC	INPUT CODE FROM MASTER	RECEIVE LOAD FILE
HOST STATION	PNC	INSPECTION	CART
COMPLETED EXECUTIONS	10	1	6
AVG EXECUTION TIME	4910496000.000	14400096000.000	4095096000.000
MAX EXECUTION TIME	18432096000.000	14400096000.000	18432096000.000
MIN EXECUTION TIME	72096000.000	14400096000.000	18096000.000
STD DEV EXECUTION TIME	6954529160.195	0.	6605221343.755

STATION UTILIZATION STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

STATION NAME	MASTER COMPUTER	PNC	INSPECTION
LAN REQUESTS GRANTED	280	0	0
AVERAGE WAIT TIME	0.	0.	0.
MAXIMUM WAIT TIME	0.	0.	0.
STD DEV WAIT TIME	0.	0.	0.
DISK REQUESTS GRANTED	140	42	5
AVERAGE BITS USED	1201250.000	325785.988	499998.500
MAXIMUM BITS USED	1201250.	1024000.	800000.
STD DEV BITS USED	0.	301859.363	299999.778
STATION UTILIZATION	.024	100.000	100.000

STATION NAME	CART
LAN REQUESTS GRANTED	0
AVERAGE WAIT TIME	0.
MAXIMUM WAIT TIME	0.
STD DEV WAIT TIME	0.
DISK REQUESTS GRANTED	25
AVERAGE BITS USED	325142.342
MAXIMUM BITS USED	1024000.
STD DEV BITS USED	301461.087
STATION UTILIZATION	100.000

RECEIVED MESSAGE REPORT

FROM   0. TO   28800. SECONDS

RECEIVER	COUNT	MESSAGE NAME
PNC		
	160	NC CODE TO PNC
INSPECTION		
	112	CODE TO INSPECTION
CART		
	8	MESSAGE TO CART

FROM   0. TO   28800. SECONDS

MESSAGE DELIVERY REPORT

FROM   0.   TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

MESSAGE NAME	CODE TO INSPECTION	MESSAGE TO CART	NC CODE TO PNC
SOURCE STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
DESTINATION STATION	INSPECTION	CART	PNC
NUMBER SENT	112	8	160
AVG DELIVERY TIME	25150.000	442.000	300.000
MAX DELIVERY TIME	25150.000	442.000	300.000
MIN DELIVERY TIME	25150.000	442.000	300.000
STD DEV DELIVERY TIME	0.	0.	0.

AT   28800. SECONDS

station S1/MASTER COMPUTER is IDLE
   disk S1/SD/MASTER COMPUTER is IDLE and has 4528647070. bits available
      file GENERAL STORAGE is IDLE and contains   600000. bits
      file LD STORAGE is IDLE and contains   250. bits
      file GM STORAGE is IDLE and contains   500000. bits
      file WORDER STORAGE is IDLE and contains   1000. bits
      file INSP STORAGE is IDLE and contains   100000. bits
station S1/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (11)
      MR/NC CODE TO PNC (143) is in the station local queue
      MR/NC CODE TO PNC (144) is in the station local queue
      MR/NC CODE TO PNC (147) is in the station local queue
      MR/NC CODE TO PNC (148) is in the station local queue
      MR/NC CODE TO PNC (155) is in the station local queue
      MR/NC CODE TO PNC (156) is in the station local queue
      MR/NC CODE TO PNC (157) is in the station local queue
      MR/NC CODE TO PNC (160) is in the station local queue
   disk S1/SD/PNC is IDLE and has 4696596480. bits available
      file WORDER is IDLE and contains   1024000. bits
station S2/PNC is BUSY executing action PROCESS CODE
      resident activity is GET WORK ORDER FROM MC (12)
      MR/NC CODE TO PNC (139) is in the station local queue
      MR/NC CODE TO PNC (140) is in the station local queue
      MR/NC CODE TO PNC (141) is in the station local queue
      MR/NC CODE TO PNC (142) is in the station local queue
      MR/NC CODE TO PNC (145) is in the station local queue
      MR/NC CODE TO PNC (146) is in the station local queue
      MR/NC CODE TO PNC (149) is in the station local queue
      MR/NC CODE TO PNC (150) is in the station local queue
      MR/NC CODE TO PNC (151) is in the station local queue
      MR/NC CODE TO PNC (152) is in the station local queue
      MR/NC CODE TO PNC (153) is in the station local queue
      MR/NC CODE TO PNC (154) is in the station local queue
      MR/NC CODE TO PNC (158) is in the station local queue
      MR/NC CODE TO PNC (159) is in the station local queue
   disk S2/SD/PNC is IDLE and has 4696596480. bits available
      file WORDER is IDLE and contains   1024000. bits
station S1/INSPECTION is BUSY executing action PROCESS CODE
      resident activity is INPUT CODE FROM MASTER (2)
      MR/CODE TO INSPECTION (57) is in the station local queue
      MR/CODE TO INSPECTION (58) is in the station local queue
      MR/CODE TO INSPECTION (59) is in the station local queue
      MR/CODE TO INSPECTION (60) is in the station local queue
      MR/CODE TO INSPECTION (61) is in the station local queue
      MR/CODE TO INSPECTION (62) is in the station local queue

CONFIGURATION #4
TOKEN BUS(STAR)
IEEE 802.4

TOKEN LAN UTILIZATION STATISTICS

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

LAN NAME	BUS1	STAR
LAN REQUESTS GRANTED	8	192
AVG REQUEST DELAY	0.	0.
MAX REQUEST DELAY	0.	0.
STD DEV REQUEST DELAY	0.	0.
COMPLETED TRANSFERS	8	192
AVG USAGE TIME	1192.000	11813.333
MAX USAGE TIME	1192.000	20080.000
STD DEV USAGE TIME	0.	9781.252
AVG QUEUE SIZE	0.	0.
MAX QUEUE SIZE	1.000	1.000
STD DEV QUEUE SIZE	0.	0.
PER CENT OF TIME BUSY	.000	.008

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

ACTIVITY NAME	SEND CODE TO INSPECTION	SEND NC CODE TO PNC	SEND MESSAGE TO CART
HOST STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
COMPLETED EXECUTIONS	56	80	4
AVG EXECUTION TIME	68160.000	28240.000	30384.000
MAX EXECUTION TIME	68160.000	28240.000	30384.000
MIN EXECUTION TIME	68160.000	28240.000	30384.000
STD DEV EXECUTION TIME	0.	0.	0.

ACTIVITY NAME	GET WORK ORDER FROM MC	INPUT CODE FROM MASTER	RECEIVE LOAD FILE
HOST STATION	PNC	INSPECTION	CART
COMPLETED EXECUTIONS	10	1	6
AVG EXECUTION TIME	4910496000.000	14400096000.000	4095096000.000
MAX EXECUTION TIME	18432096000.000	14400096000.000	18432096000.000
MIN EXECUTION TIME	72096000.000	14400096000.000	18096000.000
STD DEV EXECUTION TIME	6954529160.195	0.	6605221343.755

FROM   0.   TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

STATION NAME	MASTER COMPUTER	PNC	INSPECTION
LAN REQUESTS GRANTED	200	0	0
AVERAGE WAIT TIME	0.	0.	0.
MAXIMUM WAIT TIME	0.	0.	0.
STD DEV WAIT TIME	0.	0.	0.
DISK REQUESTS GRANTED	140	42	5
AVERAGE BITS USED	1201250.000	325785.988	499998.500
MAXIMUM BITS USED	1201250.	1024000.	800000.
STD DEV BITS USED	0.	301859.363	299999.778
STATION UTILIZATION	.022	100.000	100.000

STATION NAME	CART
LAN REQUESTS GRANTED	0
AVERAGE WAIT TIME	0.
MAXIMUM WAIT TIME	0.
STD DEV WAIT TIME	0.
DISK REQUESTS GRANTED	25
AVERAGE BITS USED	325142.342
MAXIMUM BITS USED	1024000.
STD DEV BITS USED	301461.087
STATION UTILIZATION	100.000

FROM   0.   TO   28800. SECONDS

RECEIVER	COUNT	MESSAGE NAME
PNC		
	80	NC CODE TO PNC
INSPECTION		
	112	CODE TO INSPECTION
CART		
	8	MESSAGE TO CART

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

MESSAGE NAME	CODE TO INSPECTION	NC CODE TO PNC	MESSAGE TO CART
SOURCE STATION	MASTER COMPUTER	MASTER COMPUTER	MASTER COMPUTER
DESTINATION STATION	INSPECTION	PNC .	CART
NUMBER SENT	112	80	8
AVG DELIVERY TIME	20080.000	240.000	1192.000
MAX DELIVERY TIME	20080.000	240.000	1192.000
MIN DELIVERY TIME	20080.000	240.000	1192.000
STD DEV DELIVERY TIME	0.	0.	0.

FROM   0. TO   28800. SECONDS

(ALL TIMES REPORTED IN MICROSECONDS)

S N A P S H O T   R E P O R T

AT   28800. SECONDS

station S1/MASTER COMPUTER is IDLE
   disk S1/SD/MASTER COMPUTER is IDLE and has 4528647070. bits available
        file GENERAL STORAGE is IDLE and contains   600000. bits
        file LD STORAGE is IDLE and contains   250. bits
        file GM STORAGE is IDLE and contains   500000. bits
        file WORDER STORAGE is IDLE and contains   1000. bits
        file INSP STORAGE is IDLE and contains   100000. bits
station S1/PNC is BUSY executing action PROCESS CODE
        resident activity is GET WORK ORDER FROM MC (11)
        MR/NC CODE TO PNC (71) is in the station local queue
        MR/NC CODE TO PNC (73) is in the station local queue
        MR/NC CODE TO PNC (74) is in the station local queue
        MR/NC CODE TO PNC (76) is in the station local queue
        MR/NC CODE TO PNC (79) is in the station local queue
        MR/NC CODE TO PNC (80) is in the station local queue
   disk S1/SD/PNC is IDLE and has 4696596480. bits available
        file WORDER is IDLE and contains   1024000. bits
station S2/PNC is BUSY executing action PROCESS CODE
        resident activity is GET WORK ORDER FROM MC (12)
        MR/NC CODE TO PNC (70) is in the station local queue
        MR/NC CODE TO PNC (72) is in the station local queue
        MR/NC CODE TO PNC (75) is in the station local queue
        MR/NC CODE TO PNC (77) is in the station local queue
        MR/NC CODE TO PNC (78) is in the station local queue
   disk S2/SD/PNC is IDLE and has 4696596480. bits available
        file WORDER is IDLE and contains   1024000. bits
station S1/INSPECTION is BUSY executing action PROCESS CODE
        resident activity is INPUT CODE FROM MASTER (2)
        MR/CODE TO INSPECTION (57) is in the station local queue
        MR/CODE TO INSPECTION (58) is in the station local queue
        MR/CODE TO INSPECTION (59) is in the station local queue
        MR/CODE TO INSPECTION (60) is in the station local queue
        MR/CODE TO INSPECTION (61) is in the station local queue
        MR/CODE TO INSPECTION (62) is in the station local queue
        MR/CODE TO INSPECTION (63) is in the station local queue
        MR/CODE TO INSPECTION (64) is in the station local queue
        MR/CODE TO INSPECTION (65) is in the station local queue
        MR/CODE TO INSPECTION (66) is in the station local queue
        MR/CODE TO INSPECTION (67) is in the station local queue
        MR/CODE TO INSPECTION (68) is in the station local queue
        MR/CODE TO INSPECTION (69) is in the station local queue
        MR/CODE TO INSPECTION (70) is in the station local queue
        MR/CODE TO INSPECTION (71) is in the station local queue
        MR/CODE TO INSPECTION (72) is in the station local queue
        MR/CODE TO INSPECTION (73) is in the station local queue

REFERENCES

1. Adiga, S., and Gadre, M. Object-oriented software modeling of a flexible manufacturing system. Journal of Intelligent and Robotics Systems, 3:147-165. 1990.

2. Agrawal, Jagan P. Model of the contention resolution time for binary tree protocols. In 1992 ACM Computer Science Conference Kansas City, MO, USA, Mar 3-5 1992 (1992).New York, NY, USA Publ by ACM 1992.

3. Alfonzetti, S. Performance evaluation of the LIC layer of an optical fiber LAN. In Mediterranean Electrotechnical Conference (MELECON'89) - Proceedings Lisbon, Portugal, Apr 11-13 1989 (1989). Piscataway, NJ, USA Publ by IEEE 1989.

4. Barad, M. Impact of some flexibility factors in FMSs - a performance evaluation approach. In International Journal of Production Research v 30, n 11, (Nov, 1992). 1992.

5. Bilberg, A., and Alting, L. When Simulation takes control. Journal of Manufacturing Systems, Volume 10/No. 3.

6. Blusseau, Florinane. Simulation model of the NFS service on an Ethernet local are network. In Winter Simulation Conference Proceedings Washington, DC, USA, Dec 4-6 1989 (1989). Piscataway, NJ, USA Publ by IEEE 1989.

7. Chan, Chu-Chai. Design and development of a stochastic high-level Petri net system for FMS performance evaluation. In International Journal of Production Research v 31, n 10, (Oct, 1993). 1993.

8. Ciardo, Gianfranco. Decomposition approach for stochastic reward net models. In Performance Evaluation v 18, n 1, (Jul, 1993). 1993.

9. Dotan, Yoheved. Modeling flexible manufacturing systems. The concurrent logic programming approach. In IEEE Transactions on Robotics and Automation v 7, n 1, (Feb, 1991). 1991.

10. Economou, E.G. Skipnet: a two channel token access scheme. In Computer Communications v 12, n 5, (Oct, 1989). 1989.

11. Faro, A., Mirabella, O., and Nigro, C., 1986. Performance evaluation of the standard Proway network for process control. . IEEE Transactions on Industrial Electronics, 33 (1), 9-20.

12. Fischer, Wolfgang. Approximations for the per-class waiting time and interdeparture time in the $Sigma$-i$/GI$-i$//GI$-i$//1 queue. In Performance Evaluation v 14, n 2, (Jan 16, 1992). 1992.

13. Ghosh, B.K., and Wysk, R.A., 1989. Models for communication system performance in computer integrated manufacturing systems. Computers and Industrial Engineering, 16 (1), 55-64.

14. Ghosh, Somnath. Flexinet. A token bus protocol for local area networks interconnecting low cost data communicating devices. In Journal of Microcomputer Applications v 12, n 4, (Oct 1989). 1989.

15. Guardieiro, Paulo Roberto. Integrated voice/data services on a plastic optical fiber local area network. In IEEE Global Telecommunications Conference and Exhibition Dallas, TX, USA, Nov 27-30 1989 v 2, (1989). Piscataway, NJ, USA Publ by IEEE 1989.

16. Hassanein, Hossam S. Performance evaluation of prioritized collision-avoidance star local area networks. In IEEE Pacific RIM Conference on Communications, Computers and Signal Processing Victoria, BC, Canada, Jun 1-2 1989 (1989). Piscataway, NJ, USA Publ by IEEE 1989.

17. Ilic, B., Lazic, B., and Screckovic, S. Local area network in flexible manufacturing networks.Robotics and Computer Integrated Manufacturing, Vol. 5, No. 2/3, (1989), 243-247.

18. Jayasuma, A.P., and Jayasuma, G.G., 1989. On the use of the IEEE 802.4 token bus in distributed real-time control systems. IEEE Transactions on Industrial Electronics, 36 (3), 391-397.

19. Kamel, Tarek. New protocol for the integration of voice and data on LAN. In Mediterranean Electrotechnical Conference (MELECON'89) - Proceedings Lisbon, Portugal, Apr 11-13 1989 (1989). Piscataway, NJ, USA Publ by IEEE 1989.

20. Lee, Victor. Performance evaluation of an integraged bridged token ring/Ethernet environment. In Conference Proceedings - Annual Phoenix Conference Scottsdale, AZ, USA, Mar 27-30 1991 (Mar 1991). Piscataway, NJ, USA Publ by IEEE 1991.

21. Melamed, B. TES-based traffic modeling for performance evaluation of integrated networks. In Proceedings - IEEE INFOCOM Florence, Italy, May 6-8 1992 v 1, (1992). Piscataway, NJ, USA Publ by IEEE 1992.

22. Mishra, P.K. Simulation modeling of batch job shop type flexible manufacturing systems. In Journal of Mechanical Working Technology Cookeville, TN, USA, Jun 1-2 1989 v 20, (Sep 1899). 1989.

23. Noto La Diega, S. Lower and upper bounds of manufacturing cost in FMS. In CIRP annals v 42, n 1, (1993). 1993.

24. Pimentel, J.R., 1990. Communication Networks for Manufacturing (Prentice Hall, Englewood Cliffs, New Jersey).

25. Prakash, Avneesh. Performance evaluation of flexible manufacturing systems using factorial design techniques. In Communications, Computers and Power in the Modern Environment Saskatoon, Sask, Can, May 17-18 1993 (1993). Piscataway, NJ, USA Publ by IEEE 1993.

26. Ram, R. Performance evaluation of cellular flexible manufacturing systems. A decomposition approach. In European Journal of Operational Research v 57, n 2, (Mar 11,1992). 1992.

27. Samchenko, A.V. Analysis of local-area network bridge structures. In Automatic Control and Computer Sciences (English translation of Avtomatika i Vychislitel'naya Tekhnika) v 23, n 5, (1989). 1989.

28. Satoyoshi, Tsutomu. Evaluation of token ring characteristics containing subnetworks of CSMA/CD-LAN. In Electronics & Communications in Japan, Part I: Communications (English translation of Denshi Tsushin Gakkai Ronbunshi) v 74, n 2, (Feb, 1991). 1991.

29. Schmickler, Leonhard. Performance evaluation of a new CSMA/CD protocol based on the SRPT principle. In IEEE Global Telecommunications Conference and Exhibition Dallas, TX, USA, Nov 27-30 1989 v 2, (1989). Piscataway, NJ, USA Publ by IEEE 1989.

30. Son, Young K. Cost estimation model for advanced manufacturing systems. In International Journal for Production Research v 29, n 3, (Mar 1991). 1991.

31. Stecke, Kathryn E. Performance evaluation for systems of pooled machines of unequal sizes. Unbalancing versus balancing. In European Journal of Operational Research v 42, n 1, (Sep 5, 1989). 1989.

32. Stecke, Kathryn E. Procedures to determine part mix ratios for independent demands in flexible manufacturing systems. In IEEE Transactions on Engineering Management v 39, n 4, (Nov 1992). 1992.

33. Tempelmeier, Horst. Performance evaluation of flexible manufacturing systems with blocking. In International Journal of Production Research v 27, n 11, (Nov, 1989). 1989.

34. Weaver, A.C., and Summers, C.F., 1988. The IEEE token bus - A performance bound on GM MAP., . IEEE Transactions on Industrial Electronics, 35 (1), 13-17.

35. Xie, Hai. Performance evaluation of a system of interconnected CSMA/CD LANs via an N-port bridge. In Conference Record - International Conference on

Communications Boston, MA, USA, Jun 11-14 1989 v 2, (1989). Piscataway, NJ, USA Publ by IEEE 1989.

36. Zhuang, Li. Convolution algorithm for closed queueing network models of flexible manufacturing systems with limited buffers. In Information and Decision Technologies v 17, n 2, (1991). 1991.