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Computer System Methodology: Case Study... Potomac Yard

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Final Report

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16. Abstract

This report documents the application of the railroad classification yard computer system methodology to Potomac Yard of the Richmond, Fredericksburg, and Potomac Railroad Company (RF&P). This case study entailed evaluation of the yard traffic capacity, development of computer systems requirements, analysis of alternative hardware configurations, assessment of benefits from upgrading the computer systems, and recommendations for system implementation and installation.

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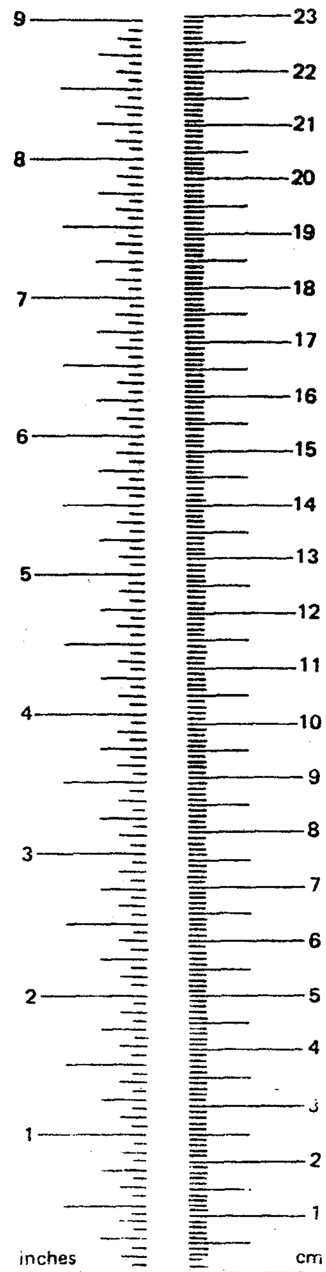
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

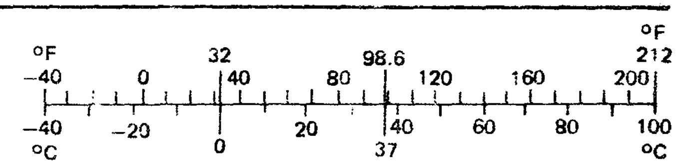
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in. = 2.54 cm (exactly). For other exact conversions and more detail tables see NBS Misc. Publ. 286. Units of Weight and Measures. Price $2.25 SD Catalog No. C13 10 286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

This work was performed by members of the Transportation Operations and Information System Center of SRI International for the Office of Research and Development, Federal Railroad Administration (FRA), Washington, D.C. Mr. William F. Cracker, Jr., of the FRA was technical monitor of the project (under Contract DOT-FR-9082).

The research was performed under the supervision of Dr. Peter J. Wong, Director, Transportation Operations Research Department. Mr. Neal P. Savage of SRI was the project technical leader. Ms. Mary Ann Hackworth was responsible for the traffic capacity analysis, and Dr. Paul L. Tuan provided valuable expertise in computer systems.

Mr. John F. McGinley, Superintendent of Potomac Yard, was the leader of the overall effort; he was assisted by Messrs. Earl W. Devine and Mike G. Gourley of Potomac Yard.

EXECUTIVE SUMMARY

Introduction and Background

This case study was conducted to provide data and experience to enhance the production of the Railroad Classification Yard Technology Manual, Volume II, Yard Computer Systems (FRA Report Number FRA/ORD 81/20.2). The study was conducted at the Potomac Yard of the Richmond, Fredericksburg, and Potomac Railroad (RF&P).

The Potomac Yard is a rail freight terminal handling north-south traffic for six tenant railroads. Facilities include northbound and southbound receiving and classification yards, an engine storage yard, a piggyback yard, and repair facilities. The holding capacity is 4,500 cars, with 54 northbound and 39 southbound classification tracks.

The RF&P and Potomac Yard managements have identified a need to assess their future computer systems requirements. One of the critical factors affecting future requirements is whether Potomac Yard will continue to be operated with separate northbound and southbound yards or whether the current northbound yard can be modified to handle both northbound and southbound traffic. The incentive for adopting the latter alternative is to accommodate more intense use of the facilities.

To assess the future computer systems requirements of Potomac Yard, SRI developed and implemented a systematic project plan consisting of the following five tasks:

- Task I--Conduct a traffic capacity (throughput) analysis of Potomac Yard.
- Task II--Determine the functional requirements of the yard computer systems.
- Task III--Develop, analyze, and recommend alternative hardware configurations for the yard computer systems.
- Task IV--Develop the functional specifications of the yard computer systems.
- Task V--Develop implementation planning.

Results of the Yard Capacity Analysis

The CAPACITY model simulated the combined northbound/southbound Potomac Yard traffic on April 5, 1980. Arriving traffic comprised 2,347 cars, of which 2,286 required humping. The combined northbound (NB) and southbound (SB) Potomac Yard consisted of the NB receiving yard, the NB double-lead hump, the NB classification yard, the NB advance and running tracks, and the SB receiving yard. The operational assumptions were that:

- Northbound arriving trains are stored in the NB receiving yard.
- Southbound arriving trains are stored in the SB receiving yard, except for B&O trains, which are stored in the NB yard.
- Departing trains can leave from the classification yard, northbound advance/running tracks, or SB yard as appropriate.
- The humping rate is three cars per minute.
- Two yard engines are available to hump cars during each 8-hour shift.
- Three yard engines are available to make up trains during each 8-hour shift.

The major finding from this analysis was that combining the northbound and southbound operations appears to be feasible. Recommendations arising from other findings are that Potomac Yard management should:

- Install process control equipment to allow humping at a rate greater than three cars per minute (four to five cars per minute, 2,500 cars per 24 hours).
- Realign the receiving yard to minimize hump engine interference.
- Add classification tracks, to the extent that space is available, to lessen the frequency of multiple pulls and shifts.
- Redesign the planning approach used to establish schedules to reduce conflicting engine movements.
- Increase the use of the NB receiving yard.

An additional option would be to use the double hump lead of the NB yard for simultaneous (A-B model) humping. This would require a distinct division in the northbound classification yard between northbound (tracks 1 to 24) and southbound (tracks 25 to 54) traffic. To make this division, addition of some tracks might be necessary. Inbound trains would have to be yarded so that no north-to-south or south-to-north crossovers would restrict simultaneous humping.

Improved operations are expected by increasing the capacity and throughput of the NB yard. This increase will require an upgrading of the present yard inventory system.

Alternative Computer Configurations

Three alternative computer hardware configurations were developed from an analysis of the functional requirements.

In Configuration I, the Management Information System (MIS) functions would remain on the present or similar computers while the Process Control (PC) computer system would be developed as a turnkey package by an independent PC systems vendor. The system would be designed for its expected maximum growth because of the cost of future modifications.

The greatest advantage of Configuration I is that the hardware and software currently used at Potomac Yard could be easily modified to interface with the PC computer. All functions, other than the limited number of PC functions, would reside in the MIS computers. Thus, the PC computer could be a small, independent module that would not often be changed. Major changes (data base, reports) could be made easily in-house because the PC computer would not be disturbed. Because the PC computer would be small, Potomac Yard could afford to purchase a second, redundant computer. Vital information kept in MIS computers would be available most of the time. No vital information would be kept in the PC computer, failures of that system being more likely because of the reliance on field equipment.

Under Configuration II, car inventory functions would reside in the PC computer and the MIS computer would operate independently, containing only communications functions. The current hardware could be used for the remaining communications functions. As cars moved through the yard, the inventory in the PC computer would change. When a car left the yard, the inventory record would be transferred to the MIS computer for advance consist transmission.

PC development probably will be done by a contractor who will deliver a turnkey system. With the inventory system locked into a packaged PC system, modifying software to expand inventory volume or change reporting details and options would be difficult. Modifications done by the PC vendor would be slow and costly. If changes were made by the Potomac Yard staff, the responsibility for the unmodified software would become unclear; this would also require additional work from a small staff. An advantage of this configuration is that if the communication computer is inoperable, switch lists may still be generated from inventory.

Grouping inventory and PC functions into the same computer is usually done when most MIS and inventory functions reside in a systemwide MIS computer. At Potomac Yard, considerable MIS processing and tenant communications are required, which can be performed best in a processor separate from the PC applications.

Configuration III is the use of a single PC/MIS computer for all yard information functions. This is the least flexible alternative. An additional disadvantage of this configuration is that asimilar functions would reside in the same computer, and significant engineering and systems software problems are likely to result.

Additional problems would arise because the current MIS software would have to be moved to a new processor or the PC software would have to be moved to the existing NCR computers. Modifying a PC vendor's packaged software for the NCR computers would be difficult and costly. A real-time operating system would be needed, but it would not run MIS applications efficiently. Similarly, moving MIS software to a new computer and redesigning hardware interfaces would be difficult and costly. Provision of redundancy would be expensive and complicated.

Recommended Configuration

The hardware configuration recommended for Potomac Yard is Configuration I, the development of independent MIS and PC computer systems. This structure would cause little disruption to current operations and software and would allow the PC computer to be an independent turnkey system. Functional specifications for the PC computer could be given to a contractor for development and hardware selection, and those specifications would include redundancy requirements.

PC functions are not expected to change. Once field and computer hardware and software have been completed, no changes should be made because they may adversely affect the system. Any functions that require periodic changes should reside in the MIS computer.

The MIS functions could remain in the existing NCR computers. The required additional functions and interfaces could be developed by Potomac Yard once the preliminary design of the PC computer has been completed. The upgrading of the MIS could be completed before installation of the PC computer. It is envisioned that MIS requirements for reports, communications, and inquiries will continue to change. The flexibility of having all MIS functions in one computer system will allow these changes to be made easily at any time. This is in clear contrast to the design of the PC computer.

Configuration I is attractive because the PC computer performs only the minimum functions necessary and the MIS computer performs all others. As a subordinate to the MIS computer, the PC computer can be much smaller, reducing cost and complexity and allowing funds to be spent on backup hardware to assure better reliability.

Reliability

Reliability is a very important consideration for the Potomac Yard computer system. As the yard operations rely more and more on the functions of the yard computers, the continued operation of the computers becomes more critical. Of the greatest importance is the continuous operation of the PC computer because its failure delays the actual physical movement of cars. A temporary failure of the MIS computer has no direct influence on yard throughput. Therefore, full redundancy is recommended for the PC computer, but formalized failure-recovery procedures and software should be adequate for the existing dual MIS computers to be used as an effective fail-soft system.

Implementation

The recommended configuration allows for independent implementation of MIS upgrades and the PC system. The development of additional MIS functions and interfaces, as required for the PC system, may be begun immediately by the Potomac Yard EDP staff. Design and procurement of the PC system may begin at any time and can continue independently of the MIS upgrade until conversion and installation.

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INTRODUCTION

Background

The Potomac Yard of the Richmond, Fredericksburg, and Potomac (RF&P) Railroad is a rail freight terminal handling north-south traffic for six tenant railroads. Facilities include northbound and southbound receiving and classification yards, an engine storage yard, a piggyback yard, and repair facilities. The holding capacity is 4,500 cars, with 54 northbound and 39 southbound classification tracks.

The managements of RF&P and Potomac Yard have identified a need to assess their future computer systems requirements. One of the critical factors affecting future requirements is whether Potomac Yard will continue to be operated with separate northbound and southbound yards or whether the current northbound yard can be modified to handle both northbound and southbound traffic. The incentive for adopting the latter alternative is that it would accommodate more intense use of the facilities.

This case study was conducted to provide data and experience to enhance the production of the Railroad Classification Yard Technology Manual, Volume II, Yard Computer Systems (FRA Report Number FRA/ORD 81/20.2). This manual was developed as a result of a classification yard design methodology project directed by the Transportation Systems Center under the sponsorship of the Federal Railroad Administration (FRA). Volume II documents the railroad classification yard computer systems methodology, and Volume I concerns the physical design of railroad classification yards.

Method of Approach

The systematic project plan consisted of the following five tasks:

- Task I--Conduct a traffic capacity (throughput) analysis of Potomac Yard.
- Task II--Determine the functional requirements of the yard computer systems.
- Task III--Develop, analyze, and recommend alternative hardware configurations for the yard computer systems.
- Task IV--Develop the functional specifications of the yard computer systems.
- Task V--Develop implementation planning.

In Task I, the CAPACITY model was used to evaluate the feasibility of operating a combined northbound and southbound yard. Traffic and operational data were supplied by Potomac Yard personnel.

Task II, a systematic determination of the functional requirements of the yard computer system, was completed in three steps: SRI defined the current operation of the yard information system, redesigned the clerical operations and computer system interfaces in an upgraded yard, and outlined the expected functional requirements of the computer systems in an upgraded yard.

In Task III, a number of alternative hardware configurations for the Management Information System (MIS) and the Process Control (PC) system were considered. Three alternative configurations were analyzed, and the best alternative was identified.

Task IV was to document changes to the current MIS computer system. A general-level functional specification covering both software and hardware components has been developed for the PC system. These specifications will be used to request bids from qualified PC system contractors.

Task V involved the development of a planning document for system implementation and installation. A preliminary implementation schedule and critical path diagram were prepared as an example of the steps required to implement the MIS software changes and to acquire and install the PC computer. Each step in the PC and MIS implementation cycle was also described.

The following sections of the report document the approach used in and the conclusions and recommendations that resulted from the execution of each project task.

TASK I: YARD CAPACITY ANALYSIS

Introduction and Summary of Results

Modification of the current northbound yard so that it can handle both northbound and southbound traffic would permit more intense use of the capital investments in facilities and create a potential for increased throughput at Potomac Yard. To evaluate the feasibility of combining the yards, SRI used the CAPACITY model and traffic and operational data supplied by Potomac Yard personnel. This analysis indicated that combining northbound and southbound operations appears to be feasible.

Developing a detailed yard design and operating plan for the most cost-effective new yard configuration was beyond the scope of this contract. However, recommendations for the new yard that should be investigated in a subsequent detailed yard design effort are presented.

CAPACITY Simulation

The CAPACITY model is a deterministic accounting model that represents block movements in the yard. This model was developed by SRI as part of the yard design methodology study sponsored by the FRA. A more detailed description of CAPACITY is presented in Volume I, Yard Design Methods, of the Railroad Classification Yard Technology Manual (FRA Report Number FRA/ORD 81/20.I).

The model is given an arrival and departure schedule of trains of a specific block mix. The operation of the yard is described by the time required to perform six major functions: receive inbound train, inspect and bleed cars, switch cars to classification tracks, makeup outbound trains, inspect and charge outbound trains, and depart outbound trains. The model tracks the use of yard resources (engines and crews) and the expected track occupancy.

The CAPACITY model simulated the combined northbound/southbound traffic at Potomac Yard on April 5, 1980. Arriving traffic totaled 2,347 cars, of which 2,286 required humping. Figure 1 depicts the simulation of a combined northbound (NB) and southbound (SB) Potomac Yard incorporating portions of the NB and SB yards as they currently exist--specifically, the NB receiving yard, the NB double-lead hump, the NB classification yard, the NB advance/running tracks, and the SB receiving yard.

The assumptions used in CAPACITY that apply to each part of the yard were as follows:

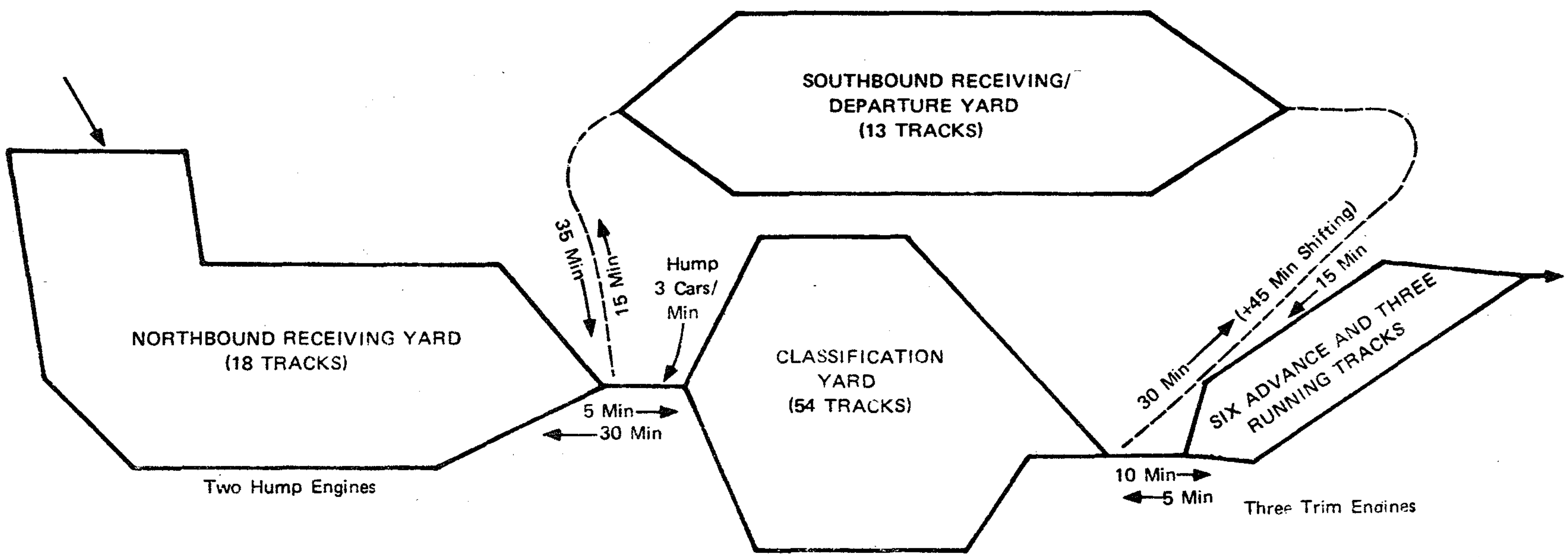

FIGURE 1 SCHEMATIC DIAGRAM OF SIMULATED COMBINED NORTH AND SOUTH POTOMAC YARD

- Arriving trains

  - Northbound trains are stored in the NB receiving yard.
  - Southbound trains are stored in the SB receiving yard, except for B&O trains, which are stored in the NB yard.

- Hump activities

  - Two yard engines are available to hump cars during each 8-hour shift.
  - Travel times to and from the hump and the NB and the SB receiving yards are 35 minutes and 50 minutes, respectively.
  - Trains are humped generally in order of arrival time, with allowances made for inspection time and travel time to the hump.
  - Not more than three arriving trains can be inspected simultaneously in each yard without an increase in the existing inspection crew.
  - A minimum of 5 minutes exists between trains.
  - The humping rate is three cars per minute.

- Makeup activities

  - Three yard engines are available to make up trains during each 8-hour shift.
  - Travel times from the classification yard to and from the advance/running tracks and the SB yard are 15 to 20 minutes and 45 minutes, respectively.
  - Shifting* a track with multiple classifications requires an additional 45 minutes. After shifting classifications, the cars are usually set onto a SB yard track.
  - Travel time for doubling in the classification yard is 15 minutes per double.
  - Travel time (light) between classification tracks is 10 minutes.
  - As classification tracks reach maximum capacity, they are pulled to the SB yard or to northbound advance/running tracks by a trim engine, if one is available.
  - Departing trains can leave from the classification yard, northbound advance/running tracks, or SB receiving yard as appropriate.

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*"Shifting" is a term used by Potomac Yard personnel referring to reswitching either by flat switching cars in the departure tracks or humping cars a second time.

Inbound Inspection

In the simulation, three inbound inspection crews per shift* were assigned to each receiving yard. The assumptions were that a single inspection crew is assigned to each arriving train and that the crew works for 15 minutes in preparing the inbound train for inspection and then inspects the train at a rate of 2 minutes per car.

The analysis revealed that six inbound inspection crews per shift were sufficient to inspect the given volume of 35 inbound trains. However, the inbound inspection crews for the NB receiving yards were used a higher percentage of time than the crews for the SB receiving yards, as shown in Table 1.

Table 1

UTILIZATION OF INBOUND INSPECTION CREWS
(Percent)

	Southbound Receiving Yard			Northbound Receiving Yard		
Shift	Crew 1	Crew 2	Crew 3	Crew 4	Crew 5	Crew 6
A	46	40	30	75	76	71
B	37	63	58	79	90	75
C	31	35	44	61	77	37
Overall	38	46	44	72	81	62

Consequently, the SB receiving yard could probably operate with two inspection crews, but the NB receiving yard should retain its three crews. The consequences of this inspection crew assignment should be evaluated through an additional CAPACITY analysis.

Hump Evaluation

The simulated traffic consisted of 35 trains, requiring humping or rehumping of 2,286 cars. Table 2 lists the simulated arriving trains in the NB and SB receiving yards and presents a history of humping activities.

At a humping rate of three cars per minute, the hump had sufficient capacity for this volume of traffic. Increasing the humping rate would produce a capacity to handle a greater volume of traffic, and installation of automatic PC equipment is required to accelerate the humping rate.

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*Potomac Yard divides 24 hours of work into three 8-hour shifts as follows: A Shift, 0001 to 0800 hours; B Shift, 0801 to 1600 hours; and C Shift, 1601 to 2400 hours.

Table 2

HISTORY OF TRAIN ARRIVALS AND HUMPING ACTIVITIES

Arrival Train	Receiving Yard	No. of Bypass Cars	No. of Hump Cars	Total Cars	Arrival Time	Start Hump Time	Hump Period	End Hump Time
RAMP		0	44	44		03:58	0:15	04:13
S118	NB	0	69	69	00:45	04:24	0:23	04:47
CRBW1	SB	0	67	67	01:20	05:03	0:22	05:25
SHOPA	NB	0	20	20	03:30	05:52	0:07	05:59
R110A	NB	0	108	108	01:00	06:30	0:36	07:06
R290	NB	22	50	72	05:15	07:15	0:17	07:32
CTV23	SB	0	29	29	06:45	08:33	0:10	08:43
S156A	NB	0	115	115	04:00	08:48	0:38	09:26
IRWG	SB	0	88	88	04:30	09:53	0:29	10:22
SPTY4	SB	0	124	124	05:35	10:33	0:41	11:14
S154	NB	0	158	158	06:20	11:56	0:56	12:48
RFP2	SB	0	19	19	07:20	12:53	0:06	12:59
NPY4B	SB	0	49	49	07:00	14:08	0:16	14:24
R120	NB	0	130	130	07:10	14:29	0:43	15:12
RUPY4	SB	0	30	30	08:35	15:17	0:10	15:27
RUPY4	SB	0	72	72	08:35	16:02	0:24	16:26
S158	NB	0	67	67	10:00	16:45	0:22	17:07
R112	NB	0	12	12	10:00	17:21	0:04	17:25
ERPY4	SB	0	63	63	09:00	17:57	0:21	18:18
R176	NB	27	14	41	10:55	18:23	0:05	18:28
SHOPP	NB	0	18	18	16:00	18:53	0:06	18:59
COX	NB	0	49	49	14:08	19:04	0:16	19:20
S222	NB	0	5	5	16:25	19:34	0:02	19:36
R190	NB	0	117	117	10:45	19:55	0:39	20:34
R110B	NB	0	110	110	11:40	20:39	0:36	21:15
NPY5A	SB	0	67	67	15:10	21:54	0:22	22:16
SPY4X	SB	0	102	102	15:10	22:35	0:34	23:09
R276	NB	12	37	49	17:30	23:14	0:12	23:26
CPY4A	SB	0	97	97	17:15	23:59	0:32	00:31
CRYD	SB	0	17	17	19:45	00:36	0:06	00:42
C490	NB	0	71	71	18:40	01:26	0:23	01:49
2RW6	NB	0	81	81	21:00	01:54	0:27	02:21
B0685	NB	0	62	62	21:30	02:38	0:20	02:58
S156B	NB	0	76	76	21:45	03:03	0:25	03:28
BOVGN	NB	0	49	49	22:00	03:33	0:16	03:49

Engines Used for Humping

In the CAPACITY model, the activities of two yard engines per shift were simulated. The engines were not restricted to either receiving yard during the simulation, and the assumption was that no conflicts exist between the two yard engines that hump, between arriving and departing trains, and between movements to the engine house. A detailed analysis of the yard engine activities was derived from the CAPACITY simulation reports.

The analysis demonstrated the theoretical feasibility of humping the simulated volume of combined northbound and southbound traffic at a rate of three cars per minute with two yard engines. The percentage of time each yard engine was used was calculated by dividing the total number of minutes worked by 480 minutes (8 hours). Table 3 presents the results.

Table 3

UTILIZATION OF ENGINES FOR HUMPING
(Percent)

Shift	Engine 1	Engine 2
A	76	73
B	70	73
C	86	75
Overall	79	74

To increase humping efficiency, the front of the yard should be designed to provide conflict-free movement of the engines to and from the hump and to provide access for a third yard engine to hump as needed. The approaches to the hump from either the north or the south receiving tracks should be designed to minimize interference with other yard engine activities or train movements.

Classification Yard Evaluation

In the CAPACITY simulation, northbound and southbound classifications currently assigned to the NB and SB classification yards were reassigned exclusively to the NB classification yard. Table 4 lists the new classification track assignments. The number and length of the NB classification tracks were not altered. Some trains departed directly from the classification tracks, but most classification tracks were pulled to the SB departure yard or NB advance/running tracks for storage as they reached capacity. (Those classification tracks from which trains can depart directly were allowed to overflow during outbound inspection in the bowl.)

The CAPACITY model reported when specified classification track lengths were exceeded for these tracks, optional early pulls were simulated so that most of the track limits were maintained. Table 5 indicates the extra pulls required from the classification yard to advance/running or departure yard tracks when track capacity was exceeded.

Table 4

NORTHBOUND CLASSIFICATION YARD

TRACK	TRACK CAPACITY (NO. CARS)	NO. CARS/ DAY*	BLOCK ASSIGNMENT	CLASSIFICATION
1	28	4	101,102,105	Jax- Slow TOFC- Bgham- Atla- Linwood TOFC
2	29	32	2,137	Emptys
3	34	43	3,136	Loads
4	33	24	112	Greensboro
5	31	18	131	Richmond
6	31	19	132	Clifton Forge
7	30	5	122	Jacksonville TOFC
8	34	12	118	Florida Points TOFC
9	32	19	106	Alexandria
10	35	33	103,110	Danville, Miller
11	33	34 (1)	8,9,10	Allentown, Park Jct, Phila. Port Rdg.
12	35	32	11	Abrams
13	35	35	13,12	Locust Point, Curtis Bay
14	33	55	115	SCL Florence
15	30	57 (8)	109	Atlanta
16	28	54	104	Macon
17	32	31	108	Birmingham
18	24	49 (5)	121,128	SCL Jax. FEC, Jax. Proper
19	26	72	126	SCL Waycorss
20	35	16	19,21	Phila. TOFC - Frankford Junction
21	35	18	22	Camden-Pavonia
22	39	28	23	Morrisville
23	41	31	119,120, 125,130	SOU Local, RFP Locals & Fbg., CO Locals
24	37	53	117	SCL Savannah
25	37	45	123	Richmond Proper
26	37	18	28	Conway
27	63	79	113	Rocky Mount
28	63	140	114	Hamlet - Slow
29	66	197	111	Linwood
30	70	34	30	Baltimore
31	72	8	27	Reading
32	74	75 (1)	29	Allentown
33	79	170	31,32	Enola
34	76	51	34	Abrams
35	71	56	33	Edgemoor
36	71	135	35,36	Selkirk
37	71	70	37	Cumberland
38	76	35	38	Kearny
39	64	33	26	Croxton

*Number of cars class track temporarily allowed to overflow indicated within parentheses.

Table 4 (concluded)

TRACK	TRACK CAPACITY (NO. CARS)	NO. CARS/ DAY*	BLOCK ASSIGNMENT	CLASSIFICATION
40	37	68	14,17,16,18	Bayview, Wilsmere, Mechvl.-BM, & DH Proper
41	32	8	42	Pennsylvania
42	29	23	43	Canadian
43	26	23	45	DH Others
44	25	51 (26)	39	Mechanicsville
45	24	7	6	Washington, D.C.
46	23	28 (5)	44,138	Hold Cars
47	18	1	20	Metuchen
48	18	4	48	Washington
49	28	27	49	Brunswick
50	26	27 (1)	4,129,139	FGE Alexandria, Industrial Cars
51	24	47 (3)	24	Oak Island
52	25	17	51,52,135	Lading-Shop Cars
53	25	32	50	TOFC Cars
54	25	3	124,116	SCL Atlanta, SCL Hamlet TOFC

*Number of cars class track temporarily allowed to overflow indicated within parentheses.

Table 5

EXTRA PULLS REQUIRED WHEN TRACK CAPACITY IS EXCEEDED

Track	Cars	Destination
29	65	SB Yard
36	71	Advance/running Track
15&16	62	SB Yard
28	17	SB Yard
40	31	Advance/Running Track
18	29	SB Yard
51	20	Advance/Running Track
19	20	SB Yard
33	26	Advance/Running Track

The classification yard remained fluid as long as space in the SB departure yard was adequate to pull full tracks and yard engines were available. If yard engines were not available or tracks were out of service, the classification yard could become a critical bottleneck.

Lengthening and/or adding classification tracks would reduce the number of multiple pulls to set cars onto departure or advance/running tracks and would reduce the number of shifts of classification tracks.

Engines Used for Train Makeup

To analyze utilization of engines used for train makeup, the CAPACITY simulation assumed that no conflicts exist between yard engines used for train makeup, between arriving and departing trains, and between movements to the engine house. The CAPACITY analysis revealed that three yard engines appear to be adequate (under the conflict-free assumptions) to keep the classification yard relatively fluid and to make up the departing trains as scheduled in Table 6. The yard engines were used for train makeup during their 8-hour shifts as shown in Table 7.

Table 7

UTILIZATION OF ENGINES USED FOR TRAIN MAKEUP (Percent)

Shift	Engine 1	Engine 2	Engine 3
A	60	43	80
B	59	62	43
C	73	79	70
Overall	67	58	63

Table 6

DEPARTING TRAIN SCHEDULE

(COMBINED NORTHBOUND/SOUTHBOUND POTOMAC YARD)

RF&P, SOU, C&O, ConRail, DH, & B&O - Outbound Trains

SOU 159 - Ord. 12:45 am

Locals
Danville
Linwood

RF&P 105 - Ord. 2:00 am

Locals
Fredericksburg
Richmond
Hamlets
Rocky Mount
Florence
Savannah
Waycross

B&O - PY-97 - Ord. 2:15 am

Washington, DC
Brunswick
Cumberland

CR -PYSE-A - Ord. 2:30 am

Selkirk
Oak Island

SOU 173 - Ord. 3:45 am

Atlanta
Macon
Birmingham

SOU 219 - Ord. 6:15 am

Jacksonville
Atlanta TOFC
Birmingham & Linwood TOFC

RF&P 275 - Ord. 6:45 am

Raleigh - TOFC
Hamlet - TOFC
Jacksonville - TOFC
Florida Points - TOFC

RF&P A227 - Ord. 9:15 am

Richmond
Hamlet
Rocky Mount
Florence
Savannah

SOU 221 - Ord. 8:45 am

Linwood
Macon

RF&P 227 - Ord. 10:45 am

Atlanta - TOFC

RF&P 109 - Ord. 11:45 am

Jacksonville - FEC
Jacksonville Proper
Waycross
Jacksonville - TOFC
Florida Points - TOFC

B&O NE-84 Ord. 11:55 am

Bayview
Wilsmere
Mechvl.-BM
DH-Proper

Table 6 (concluded)

CR - PYAB - Ord. 2:15 pm

Edgemoor
Abrams

CR - PYENA-A - Ord. 3:30 pm

Enola

SOU Alex Yard - Ord. C.T.

Alexandria

SOU 155 - Ord. 4:30 pm

Miller
Greensboro
Linwood

CR - PYSE-B - Ord. 4:30 pm

Selkirk

DH WR-7 - Ord. 5:00 pm

Pennsylvania
Canadian
D&H Others
D&H-Mechvl-BM

C&O 495 - Ord. C.T.

Richmond
Charlottesville
Clifton Forge
Gordonville, Orange

CR - PYAL - Ord. 6:00 pm

Reading
Baltimore
Allentown

CR - PYMO - Ord. 6:30 pm

Phila.-TOFC & Pble.
Frankford Junction
Camden-Pavonia
Morrisville

CR - TV-24 - Ord. 7:45 pm

Metuchen
Kearny
Croxton

RF&P 111 - Ord 6:15 pm

Locals
Hamlets
Rocky Mount
Florence
Savannah
Waycross

B&O 682 - Ord. 10:15 pm

Locust Point
Curtis Bay
Abrams
Allentown
Park Junction
Phila.-Port Rdg.

CR - PYEN-B - Ord. 10:30 pm

Conway
Enola

CR - Wash. Yard - C.T.

Washington, DC

It is recommended that the yard be modified as necessary to provide conflict-free trim-engine movements and/or use part of a fourth engine as appropriate during some shifts.

Outbound Inspection

In the analysis of outbound train inspection, the assumptions in the CAPACITY simulation were that four inspection crews per shift are available for outbound trains and that a single inspection crew is assigned to each departing train. The crew could inspect departing trains on either a SB departure track or a NB advance/running track. (The CAPACITY simulation currently does not provide for outbound inspection of trains departing directly from the classification yard.) The outbound inspection included 10 minutes of travel time between SB departure and NB advance/running tracks when applicable, 15 minutes of preinspection work per train, and an inspection rate of two cars per minute.

The results of the simulation of outbound inspection activities were that two outbound inspection crews were adequate to inspect the departing trains during the A and B shifts but that a third crew was required during the C shift, as shown in Table 8. (The percentages listed do not reflect inspection of trains departing from the classification tracks.)

Table 8

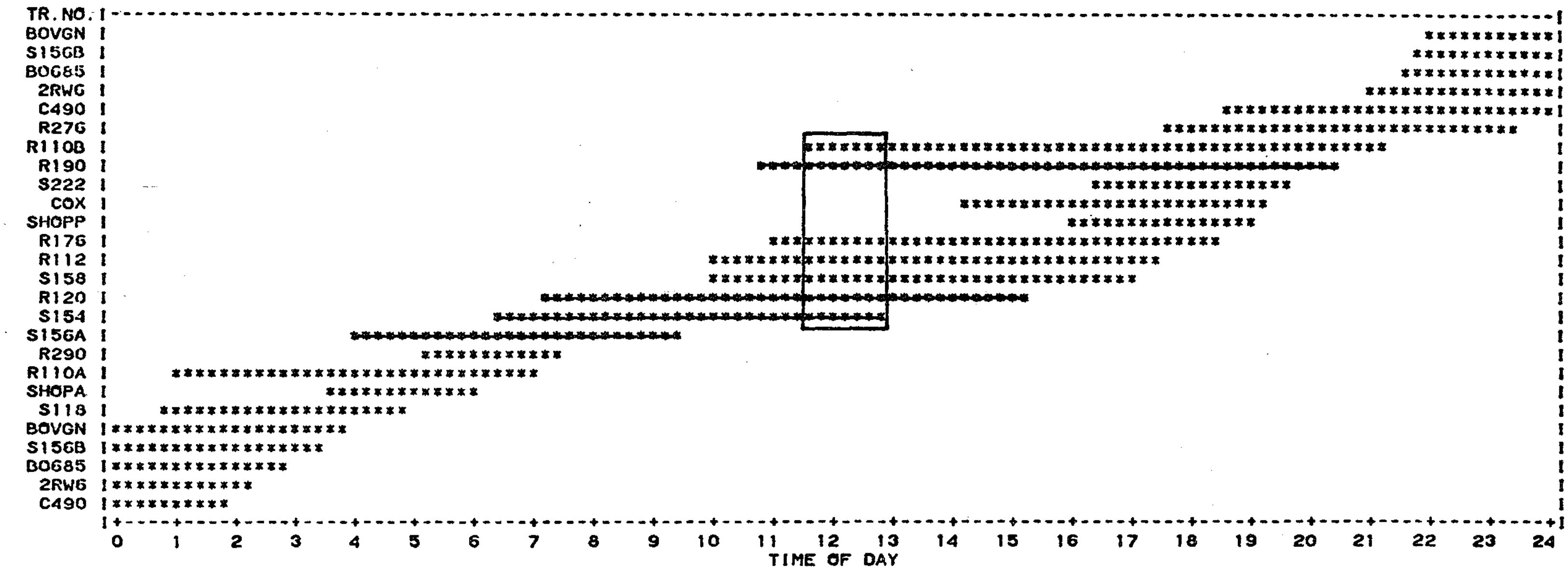
UTILIZATION OF OUTBOUND INSPECTION CREWS
(Percent)

Shift	Crew 1	Crew 2	Crew 3
A	21	--	38
B	30	--	34
C	40	37	42
Overall	29	37	38

The efficiency of outbound inspection crews could be improved if all trains were inspected in and departed from a single departure yard.

Evaluation of Receiving and Departure Yards

In the CAPACITY simulation, 21 arriving trains (17 northbound trains, 2 B&O southbound trains, and 2 shop trains) were stored before humping in the NB receiving yard. Figure 2 is a diagram of the NB receiving yard occupancy for a 24-hour period. Four trains required a second receiving yard track. The remaining 13 southbound arriving trains were inspected and stored in the SB receiving yard and then brought to the NB hump lead just before humping. Figure 3 is a diagram of the SB receiving yard occupancy by only arriving trains over a 24-hour period.

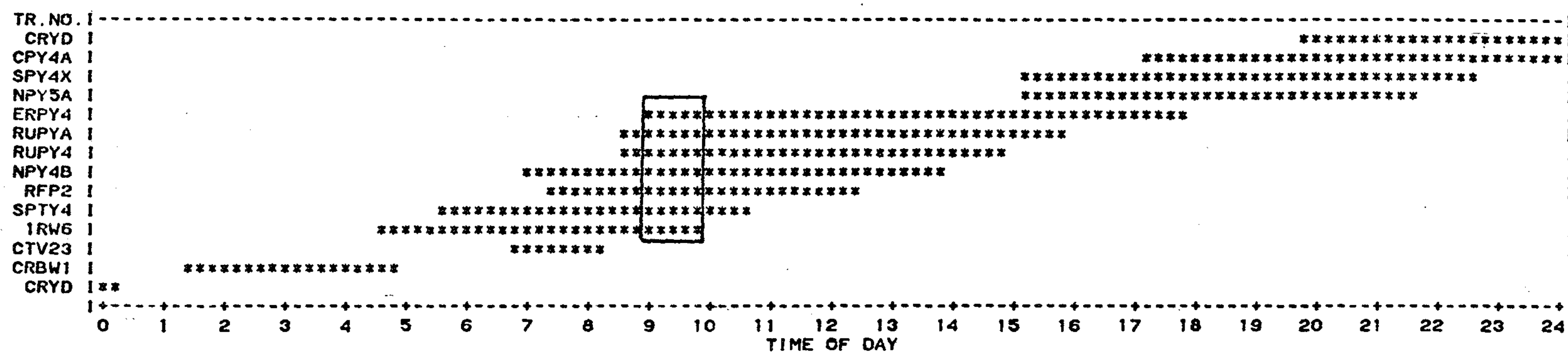


NORTH RECEIVING YARD TRACK REQUIREMENTS -

TRACK NO.	MIN. LENG. REQUIRED (CARS)
1	158
2	130
3	117
4	110
5	69
6	62
7	49
8	5

*** INDICATES TWO TRACKS OCCUPIED

FIGURE 2 NORTH RECEIVING YARD REQUIREMENTS



SOUTH RECEIVING YARD TRACK REQUIREMENTS -

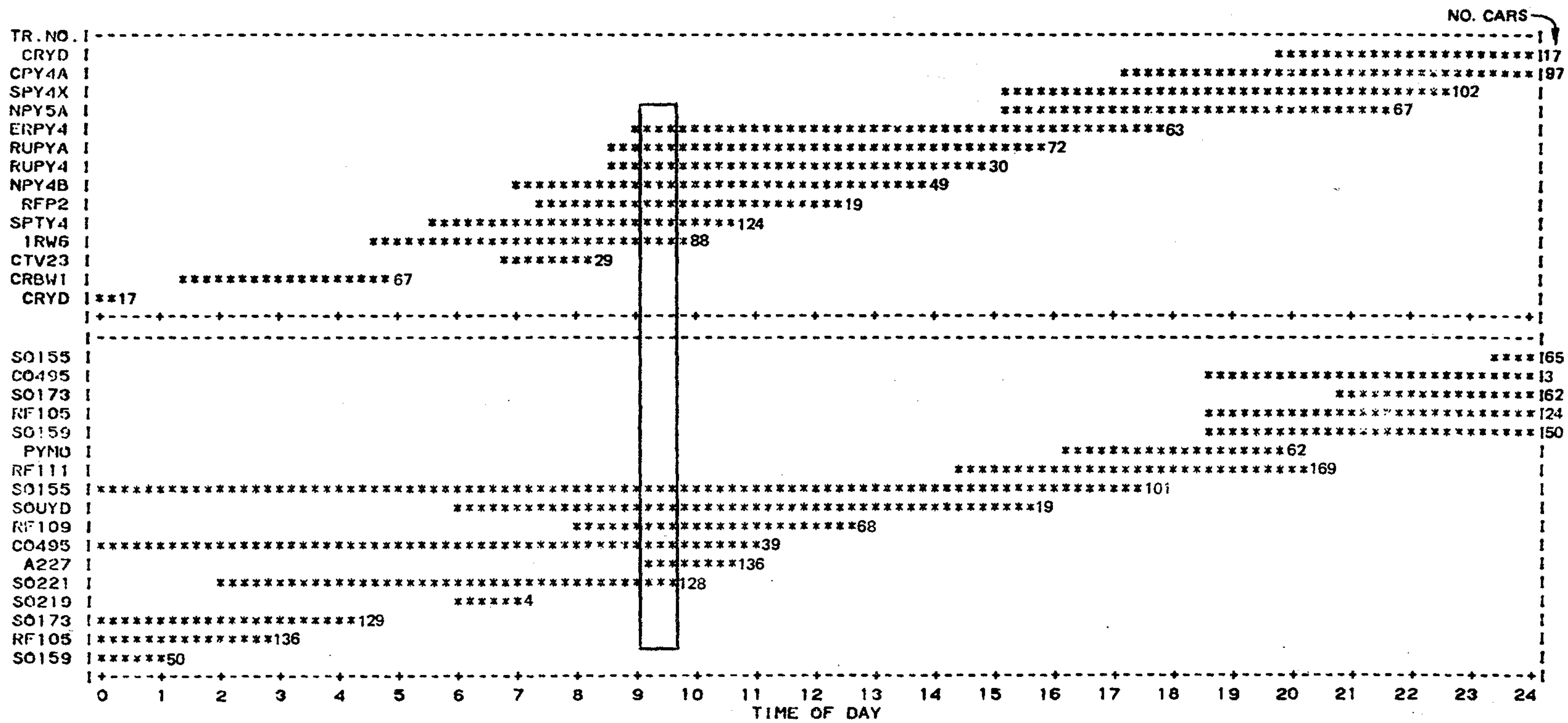
TRACK NO.	MIN. LENG. REQUIRED (CARS)
1	124
2	97
3	72
4	63
5	49
6	30
7	19

FIGURE 3 SOUTH RECEIVING YARD REQUIREMENTS

The SB receiving yard was also used for departing train makeup and storage--For example, cars in classification tracks that require shifting and extra pulls made before the ordered departure train makeup because of classification track overflows. Figure 4 is a diagram of combined SB receiving/departure yard occupancy over a 24-hour period, and Figure 5 is an occupancy diagram for the NB advance/running tracks.

A maximum of 10 receiving tracks were required in the NB receiving yard as simulated by CAPACITY. Seven SB receiving tracks were required to store southbound arrivals, as shown in Figure 2. At least 7 additional tracks were required to store cars for departing trains. More than 14 southbound receiving/departure tracks may be required for different train-to-track assignments or if additional early pulls from the classification yard are made to clear the tracks that are still overflowing (i.e., classification tracks 11, 15, 18, 32, 44, 46, 50, and 51).

The NB receiving yard is underused. Some or all of the southbound arriving trains should be diverted to the NB receiving yard to free the SB yard for use solely as a departure yard. A further investigation should be directed to determining the feasibility of using the current NB receiving yard as a combined north and south receiving yard and of using the current SB receiving yard as a combined north and south departure yard. The possibility of incorporating a mini-hump yard (similar to Barstow Yard) into a combined north/south departure yard should be considered in any detailed yard design effort.



Southbound Receiving/Departure
Yard Requirements: 14 Tracks

FIGURE 4 SOUTHBOUND RECEIVING/DEPARTURE YARD OCCUPANCY DIAGRAM

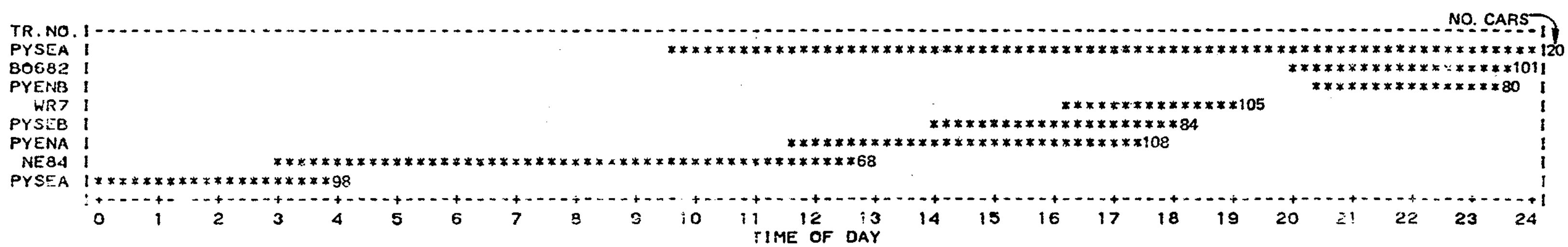


FIGURE 5 NORTHBOUND ADVANCE/RUNNING TRACK OCCUPANCY DIAGRAM

TASK II: PROCESS CONTROL AND MANAGEMENT INFORMATION SYSTEM REQUIREMENTS

Functional Definition of Current Operations

The current operations at Potomac Yard were analyzed to specify the clerical and MIS functions. This step was a prelude to formulating a detailed functional design of clerical operations in an upgraded computer system. Figure 6 shows the current clerical functions organized by the movement of waybills. Figure 7 shows the input and output of the current MIS computer programs. Clerical and MIS functions are currently parallel, independent operations. The purpose of the clerical functions is to process cars through the yard, while the MIS functions provide a record of yard operations. The only direct contact the clerical staff has with the MIS computer is in verifying and upgrading consist records. Inventory and other MIS functions are currently processed only after the fact. Batch programs are run one after the other in chronological order.

Functional Design of Upgraded Operations

The next step in defining functional requirements was to establish a detailed design of the expected new clerical functions. First, assumptions were made about the main functions of the computer systems envisioned for Potomac Yard. The role of the MIS function will be to accumulate car handling data and format the data as necessary to provide for required reporting of car movement activity to the user lines and to provide timely information for management decisions. An additional Potomac Yard MIS function is to interface with the information systems of each of the six tenant railroads. The role of the PC function will be to perform automatic classification, car speed control, and routing functions in the yard. Exhibit 1 lists these functions.

This list of expected functions was then used to hypothesize future clerical operations. Figure 8 is a flowchart of the expected clerical operations. The upgraded design will incorporate a new data processing philosophy. That is, the MIS functions will be to keep up-to-the-minute operational information, and the clerical functions will be to keep MIS records up to date. Thus, clerical and MIS functions will become interdependent, and each clerical operation will be completed concurrently with a parallel MIS function. To provide an accurate real-time inventory, any event in the yard that affects inventory must be posted directly to the computer. The MIS computer will thereby become more than a delayed record keeper.

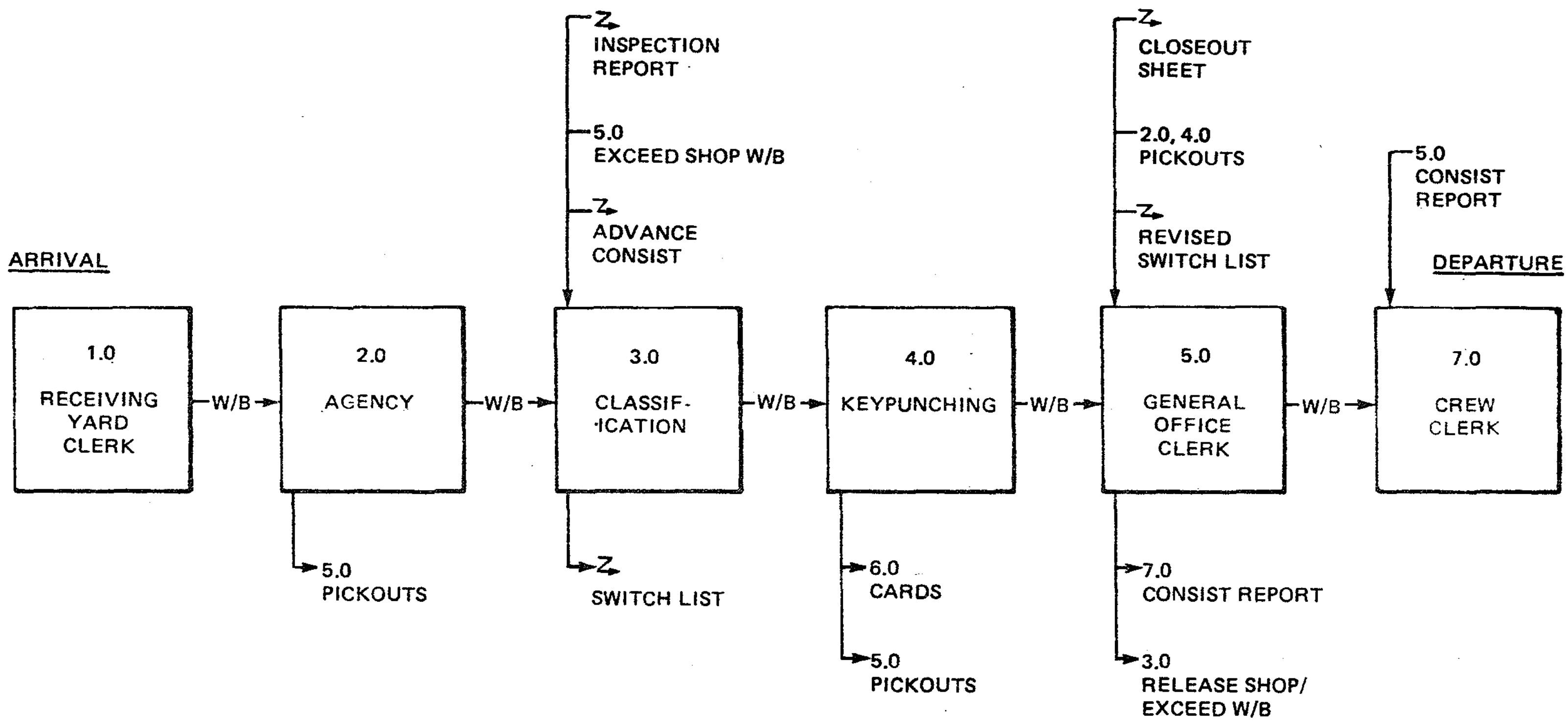
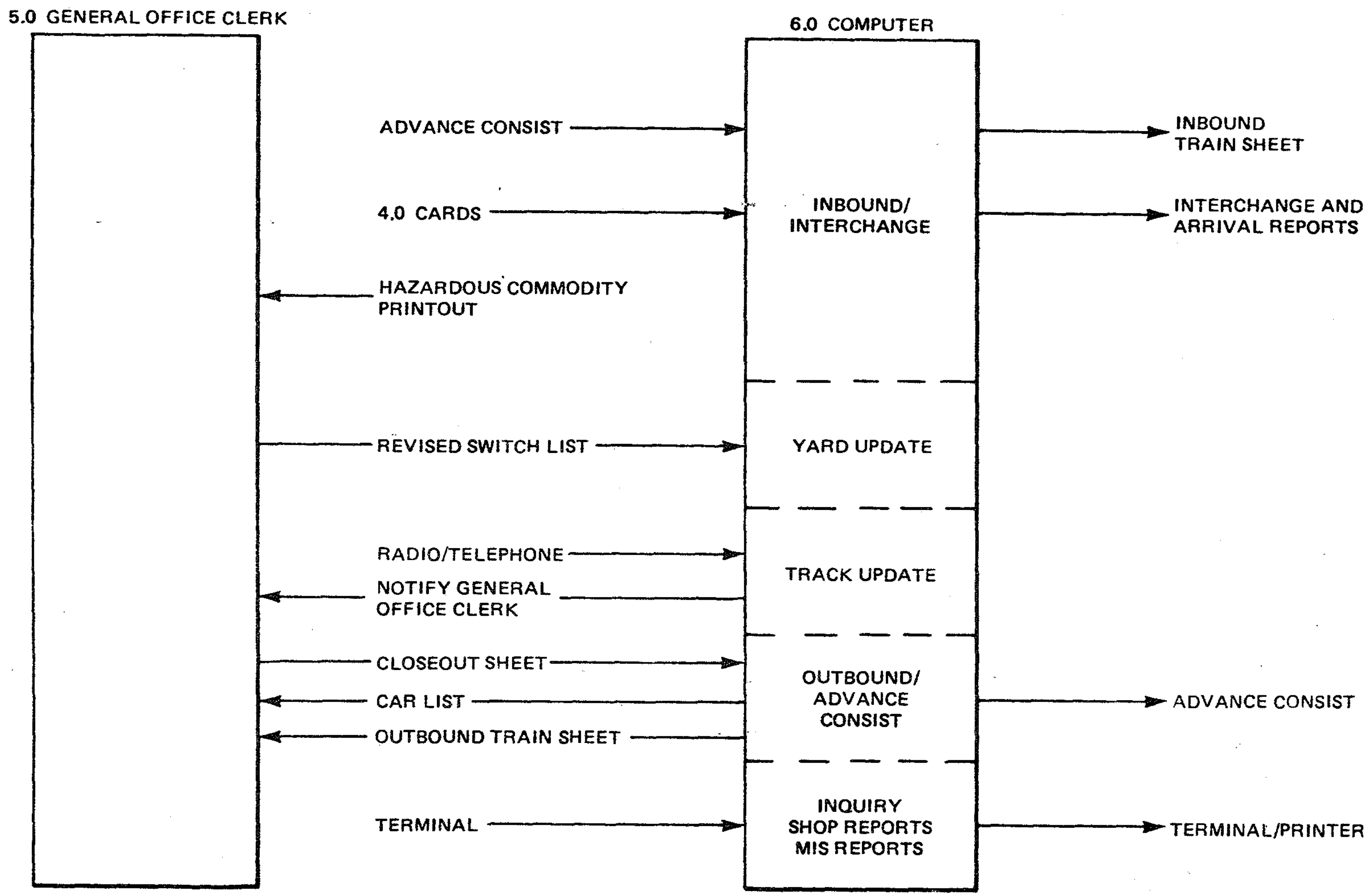


FIGURE 6 FLOW DIAGRAM OF WAYBILL PROCEDURES



*Refer to Figure 6

FIGURE 7 CURRENT COMPUTER PROGRAMS

Exhibit 1

FUNCTIONS OF THE MANAGEMENT INFORMATION AND PROCESS CONTROL SYSTEMS

MANAGEMENT INFORMATION SYSTEM

Communications Subsystem

Tenant communications and translation
Advanced consists to/from tenants
Empty car disposition inquiry
Terminal communications and inquiry I/O
Verification of car order and upgrade of advance consists with waybill information

Yard Inventory Subsystem

Inventory records in track standing order
Detailed car records--car location, consist information, history
Train history, arrival/departure records
Inventory of industrial tracks
Switch list
Swing tracks by block number
Car movement in yard
MIS report and inquiry processing
Outbound car list (booking)
Generate advance consists

PROCESS CONTROL SYSTEM

(Physical Control of Cars)

Speed control
Automatic routing and switch control
Return inventory updates to MIS
Reports
Distance to couple--track occupancy
Warnings--height, cornering, catchup, and lockouts

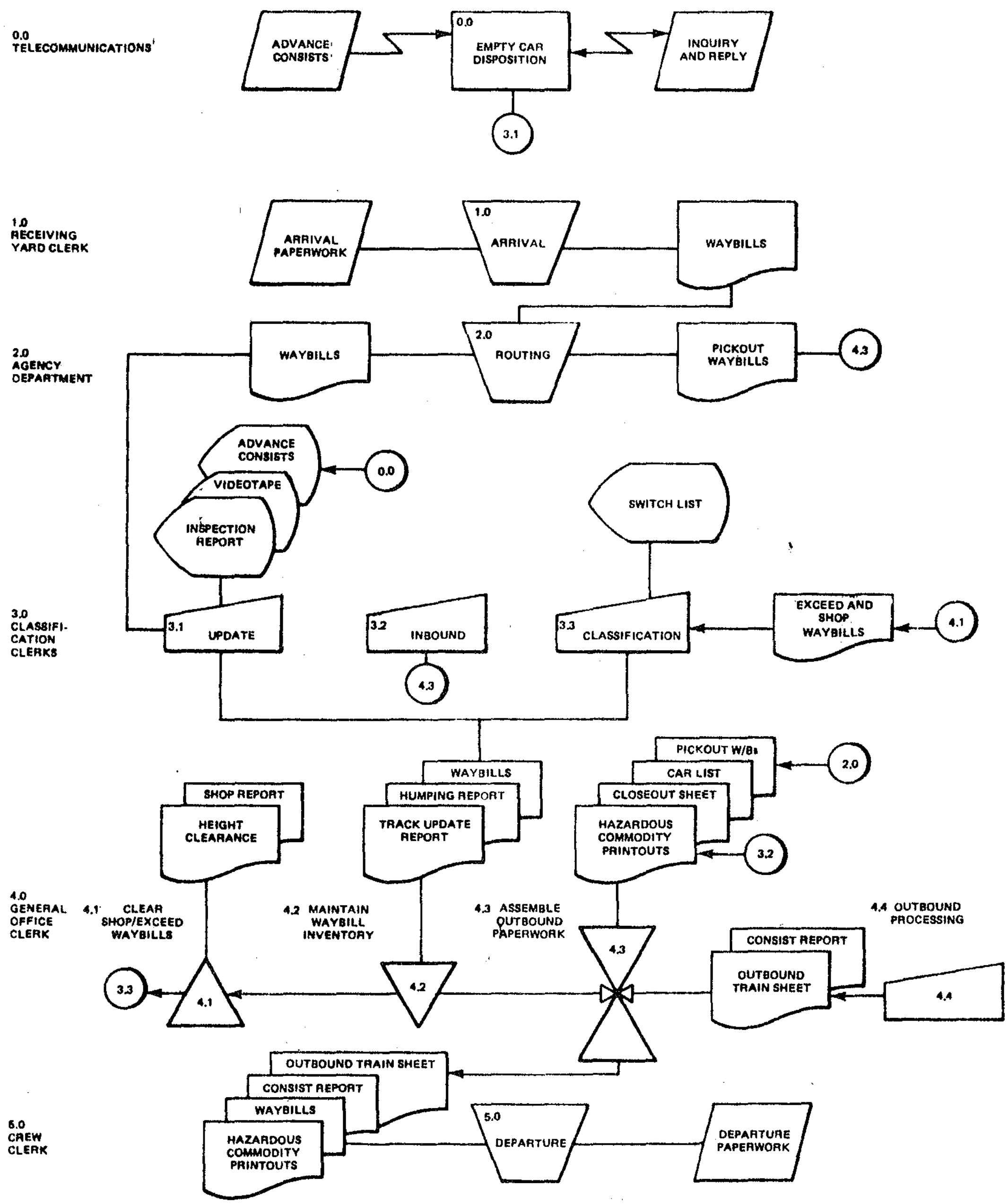


FIGURE 8 FLOWCHART OF FUTURE CLERICAL OPERATIONS AT CASE STUDY YARD

Hypothetical clerical procedures and expected MIS programs were produced from an analysis of the expected clerical operations. Consistent with current operations, the envisioned upgraded MIS computer can be divided into two subsystems, yard inventory and communications. The programs of the yard inventory subsystem are expected to be inbound, classification, inventory update, outbound, and inquiry and reports. The communications subsystem will provide tenant communications, empty car disposition, and consist verification.

Process Control Functions

The PC function may apply to the entire yard or only to specific areas of the yard. The most common application of PC systems is to perform automatic control at the hump end only. The hump PC computer receives a switch list* and car data from the inventory computer and on-line instructions from yard personnel. The sampling and control software in the PC computer then transforms field inputs into control signals to perform hump engine speed control, retarder control, switch activation (for automatic routing), and system monitoring (display of system status), and it provides the inventory computer with the outcome of the control process (i.e., misswitches and exceptions) for inventory update. The information that usually resides in a hump PC computer includes switch lists, hump speed control parameters, and retarder control parameters. The PC computer must send inventory updates as each car clears into its classification track to provide an accurate real-time inventory.

As part of Task II, a preliminary PC design was developed in conjunction with Potomac Yard personnel. We assumed that PC functions are to be limited to the hump and that no independent PC computers will operate elsewhere in the yard. An exception being considered is monitoring of skate retarders and track lock/unlock.

Figure 9 shows the relationship of PC functions to field equipment, yard personnel, and inventory functions.

Yard Inventory Subsystem Functions

The function of the yard inventory subsystem is to maintain a trackstanding inventory of the yard. The current inventory system maintained by the Potomac Yard MIS computer must be functionally upgraded for the proper operation of the envisioned PC system. Functions that must be added are real-time inventory for all areas of the yard, the capability of producing switch lists, and the use of terminals to input information from field locations.

Figure 10 depicts the relationship of inventory functions to the communication functions, PC functions, and yard personnel.

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*Switch list, a more widely used name, is used in place of classification guide throughout this report.

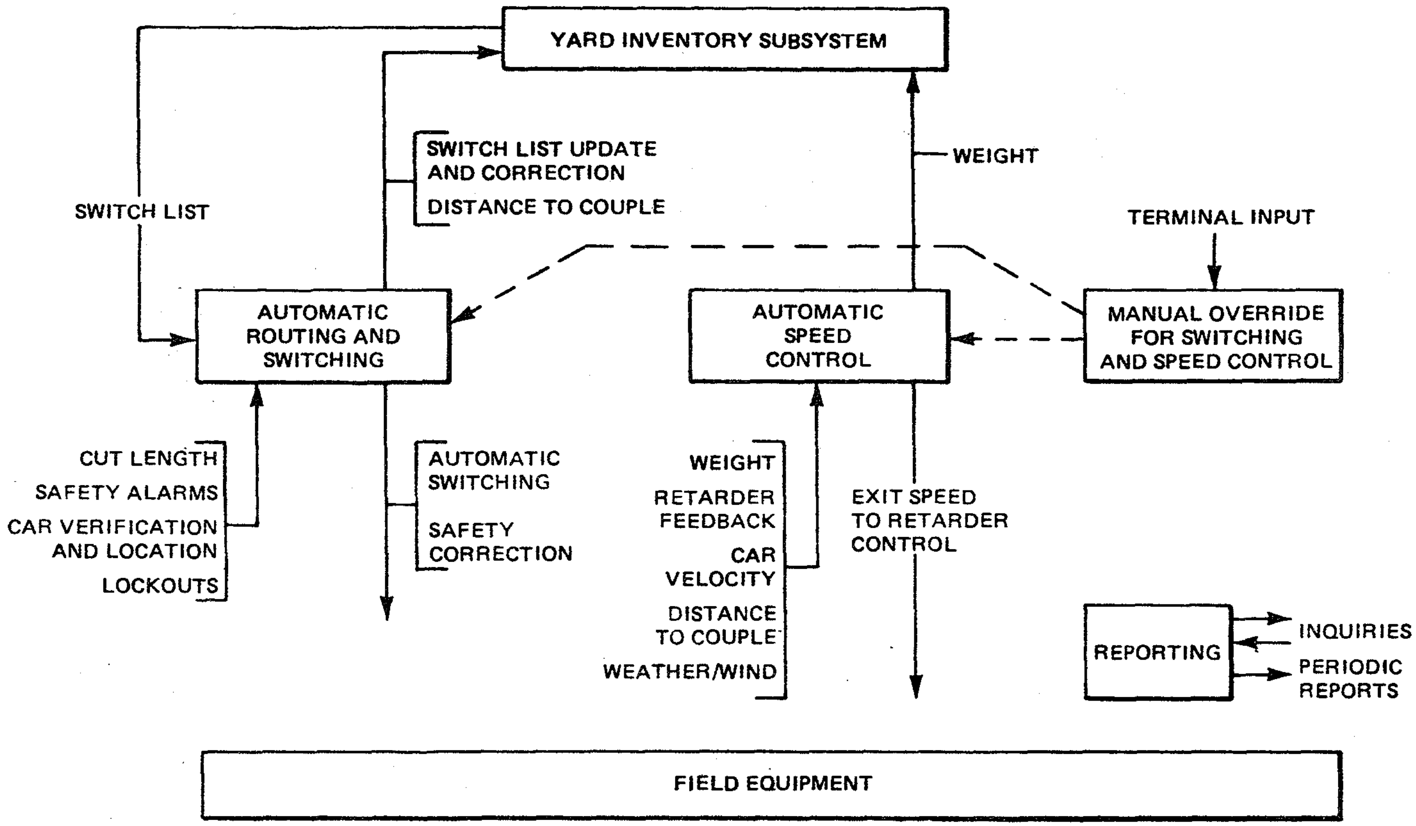
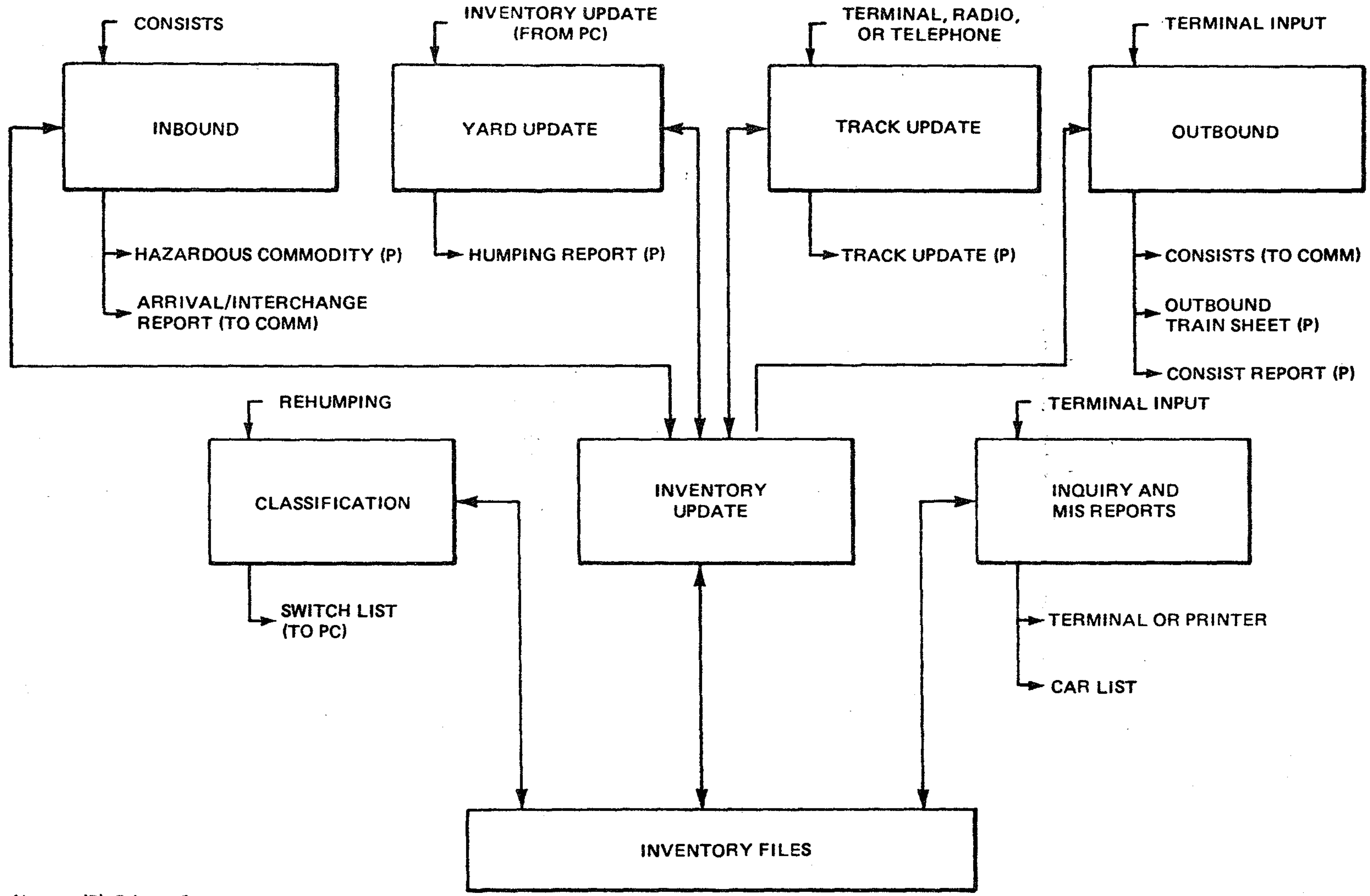


FIGURE 9 PROCESS CONTROL COMPUTER



Note: (P), Printed Output
(PC), Process Control System
COMM, Communications Subsystem

FIGURE 10 YARD INVENTORY SUBSYSTEMS

Communication Subsystem Functions

Upgrading of communication functions must be completed before a real-time inventory can be kept. Advance consists must be received directly by the communication computer from all tenant computers. Only in this manner will the information be available for immediate verification and updating upon train arrival. This procedure will provide up-to-the minute information for a real-time inventory and will allow immediate production of switch lists. An empty car inquiry to the tenant railroads can be made with advance consists before train arrival. Figure 11 shows the interface between each of the three major systems--PC, yard inventory, and communications.

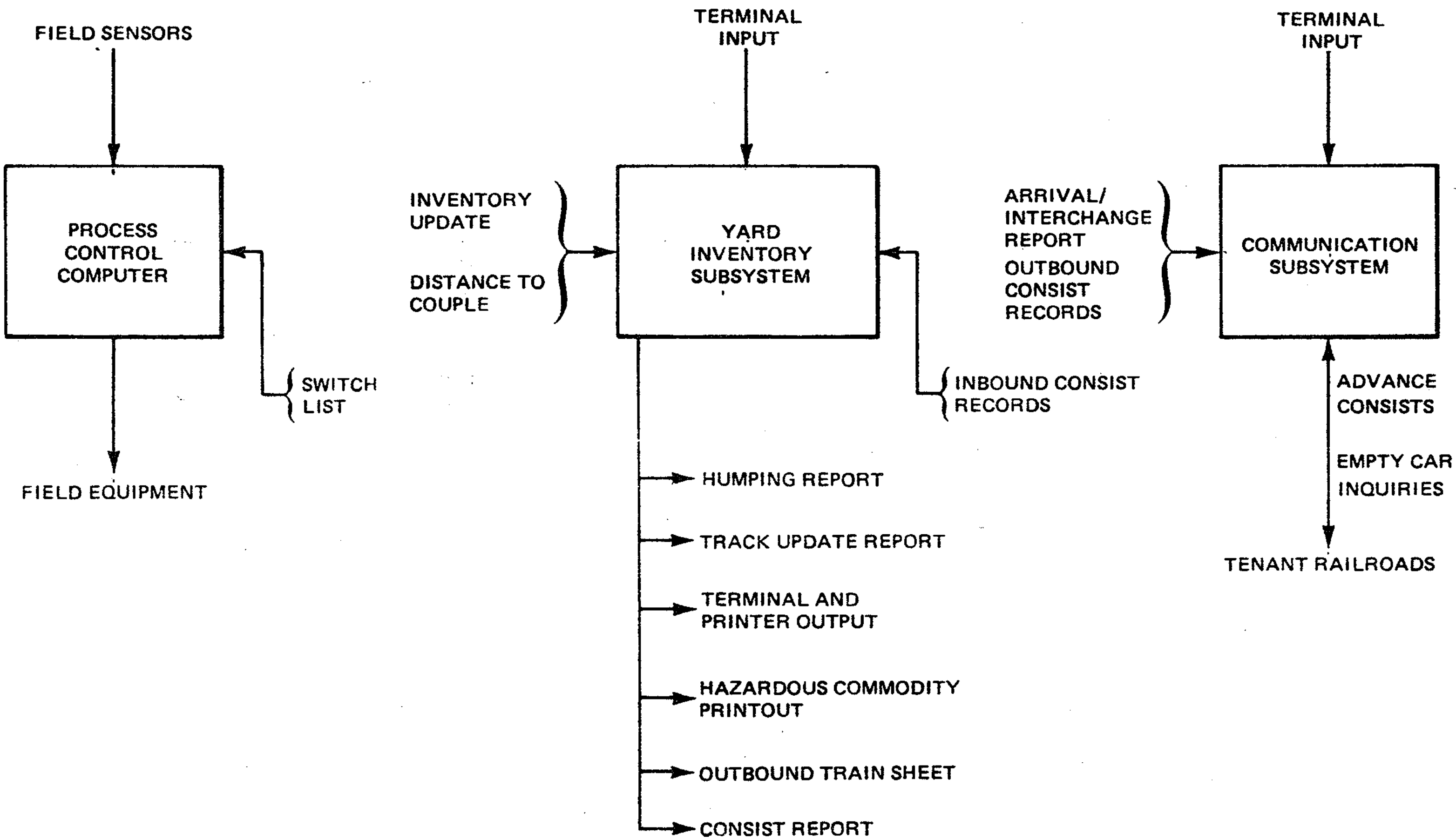


FIGURE 11 SYSTEM INTERFACES

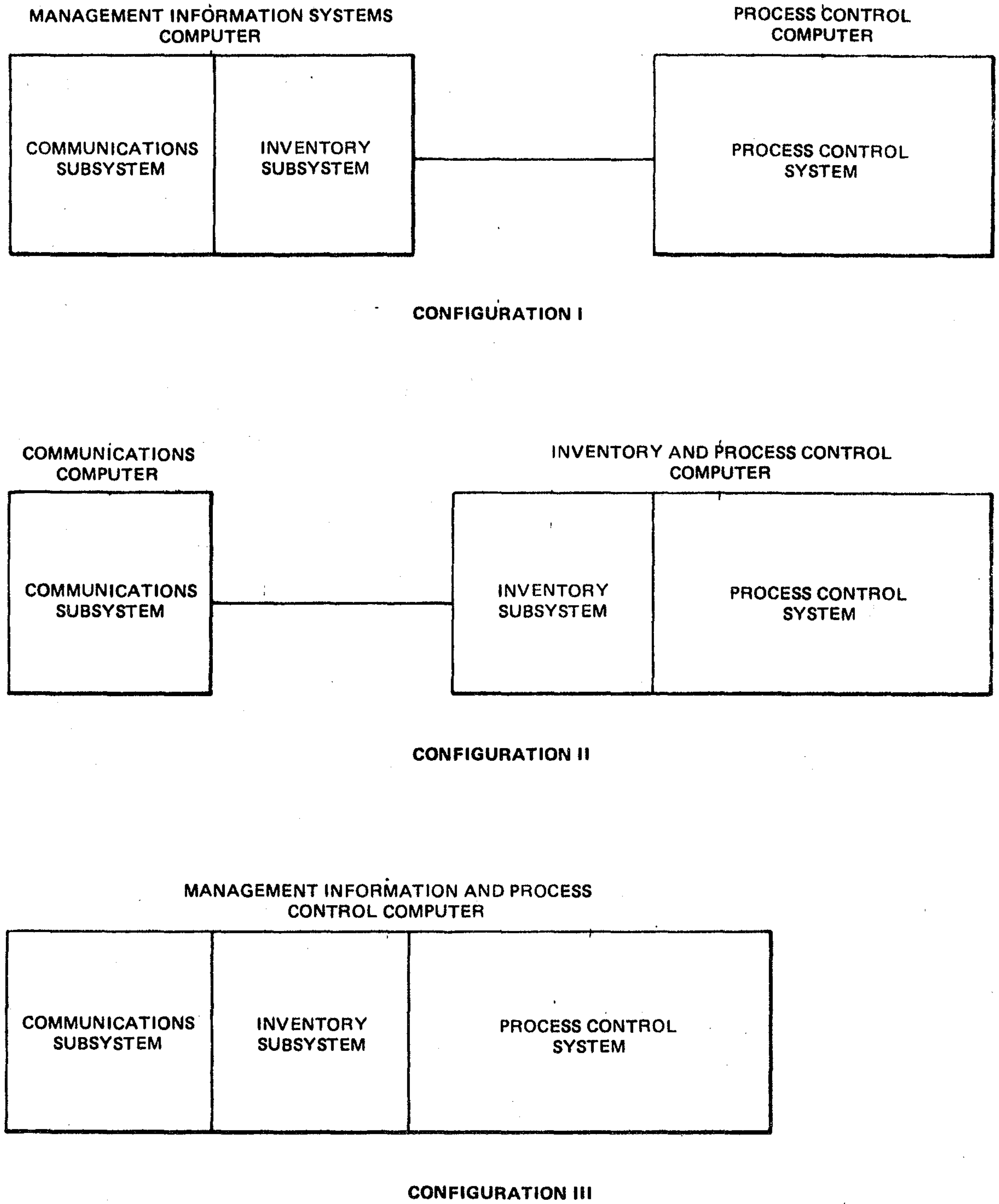


FIGURE 12 FUNCTIONAL ALLOCATIONS OF EACH ALTERNATIVE CONFIGURATION

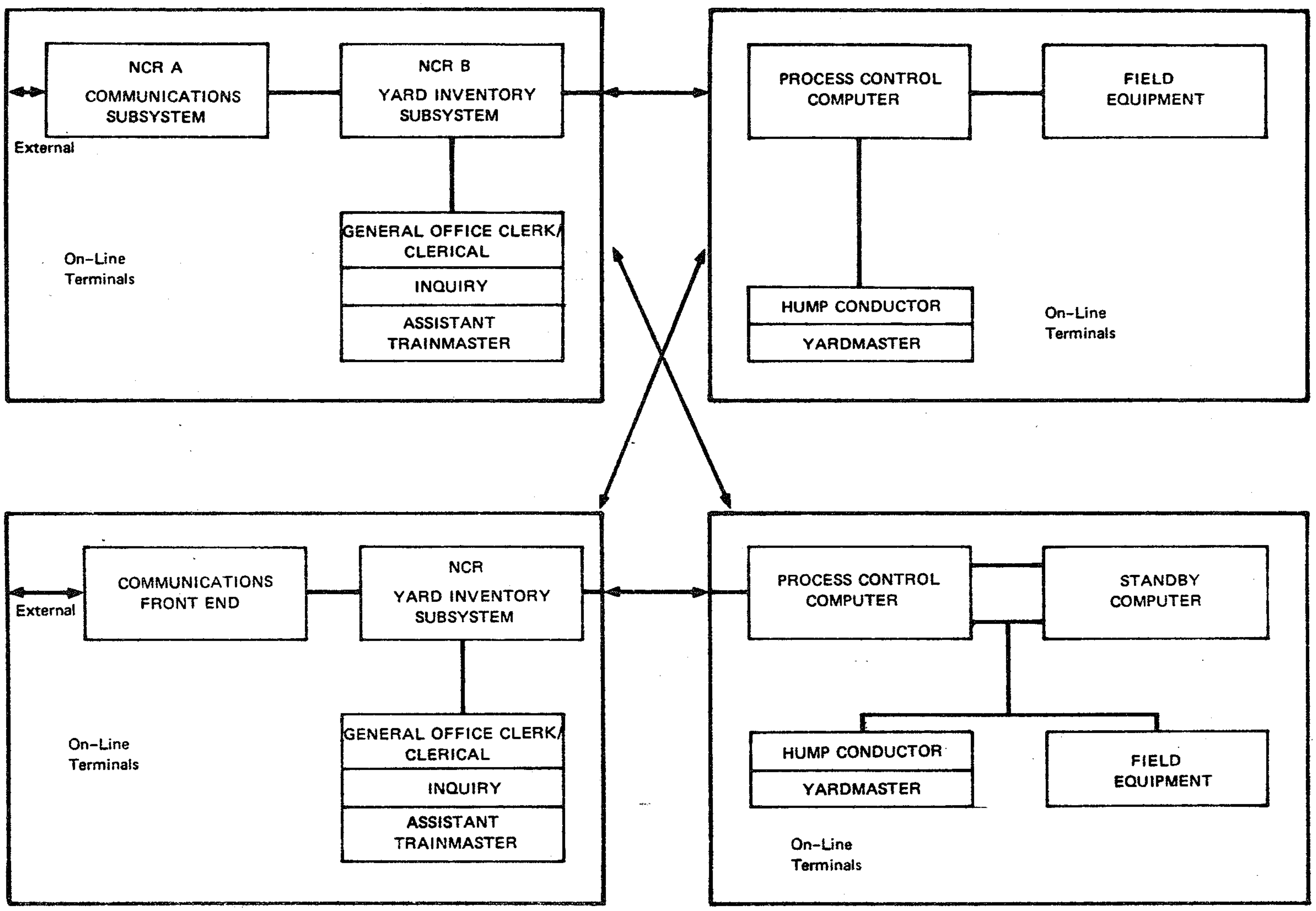


FIGURE 13 HARDWARE ALTERNATIVES FOR CONFIGURATION I: MIS IN ONE SYSTEM AND PROCESS CONTROL IN ANOTHER

The disadvantage of this alternative is that it probably does not represent the most efficient use of the computers. It had been estimated that the two computers are not currently used to capacity. Moreover, additional capacity may be found when the more efficient virtual-memory time-sharing operating system is installed.

The second MIS alternative is to eliminate one of the NCR computers. If a front-end processor were still required for communications, a smaller, specialized processor could be used for communications only, once the consist verification and updating functions were moved to the remaining NCR computer. This alternative need not be used immediately. The two-processor alternative could be used first and one could be eliminated later if this were found feasible. The disadvantage of this alternative is that it provides no redundancy.

The first PC alternative is the use of a single computer. This is the least expensive alternative, but it does not provide redundancy. Use of two PC computers would double the cost but would provide some redundancy. The most likely alternative would be full redundancy because no subset of the PC functions exists that can take advantage of partial redundancy. Communications between the two systems would consist of switch lists sent to the PC computer and weight, in- ventory changes, closed tracks, and distance-to-couple measurements sent to the MIS computer.

The greatest advantage of Configuration I is that the hardware and software currently used at Potomac Yard could be easily modified to interface with the PC computer. All functions, other than the limited number of PC functions, would reside in the MIS computers, which would allow the PC computer to be a small, independent module that would not often be changed. Major changes (data base, reports) could be made easily in-house because the PC computer would not be disturbed. Because the PC computer would be limited to a smaller size, Potomac Yard could afford a second redundant computer. Vital information kept in MIS computers is expected to be available most of the time. No vital information is to be kept in the PC computer, failures of the PC system being more likely because of the reliance on field equipment.

Configuration II--Communications Computer/Inventory and Process Control Computer--Under Configuration II, car inventory functions would reside in the PC computer and the MIS computer would operate independently, containing only communications functions. The current hardware could be used for the remaining communications functions. As cars moved through the yard, the inventory in the PC computer would change. When a car left the yard, the inventory record would be transferred to the MIS computer for advance consist transmission.

That PC development will probably be done by a contractor who will deliver a turnkey system. Because the inventory system is locked into a packaged PC system, modifying software to expand inventory volume or change reporting details and options will be difficult. Modifications done by the PC vendor would be slow and costly, and if changes were made by the Potomac Yard staff, the responsibility for the unmodified software would become unclear. This would also require additional work from a small staff. An advantage of this configuration is that if the communication computer is inoperable, switch lists may still be generated from inventory.

Figure 14 depicts various hardware alternatives for this split of functions. In one alternative, the NCR computers would be retained for communications functions. This would permit use of current hardware, software, and interfaces to tenants. The disadvantage is that this is an inefficient use of hardware because the processor would not be used fully. As an alternative, a smaller communications processor could be substituted. Neither alternative provides redundancy, however.

Two alternatives are shown for the PC computer. One is to use a single computer for both PC and inventory functions. This would require a computer bigger than either of the current NCR computers. Disadvantages are that no redundancy is provided and that the same computer must perform both real-time process control routines and large file management and reporting programs for inventory.

A second alternative is to use two computers, one each for process control and inventory. This would provide partial redundancy but would be difficult to implement. This alternative is similar to using one computer for communications and another for inventory but has the disadvantage that the functions are not similar. If full redundancy is required, very large computers will be required, and the cost is expected to be great.

Grouping inventory and PC functions into the same computer is usually done when most MIS and inventory functions reside in a systemwide MIS computer. At Potomac Yard, considerable MIS processing and complex tenant communications are required. which can be best performed in a processor separate from the PC applications.

The communication between the two computers would consist of inquiries, interchange reports, advance consists, and empty car inquiries.

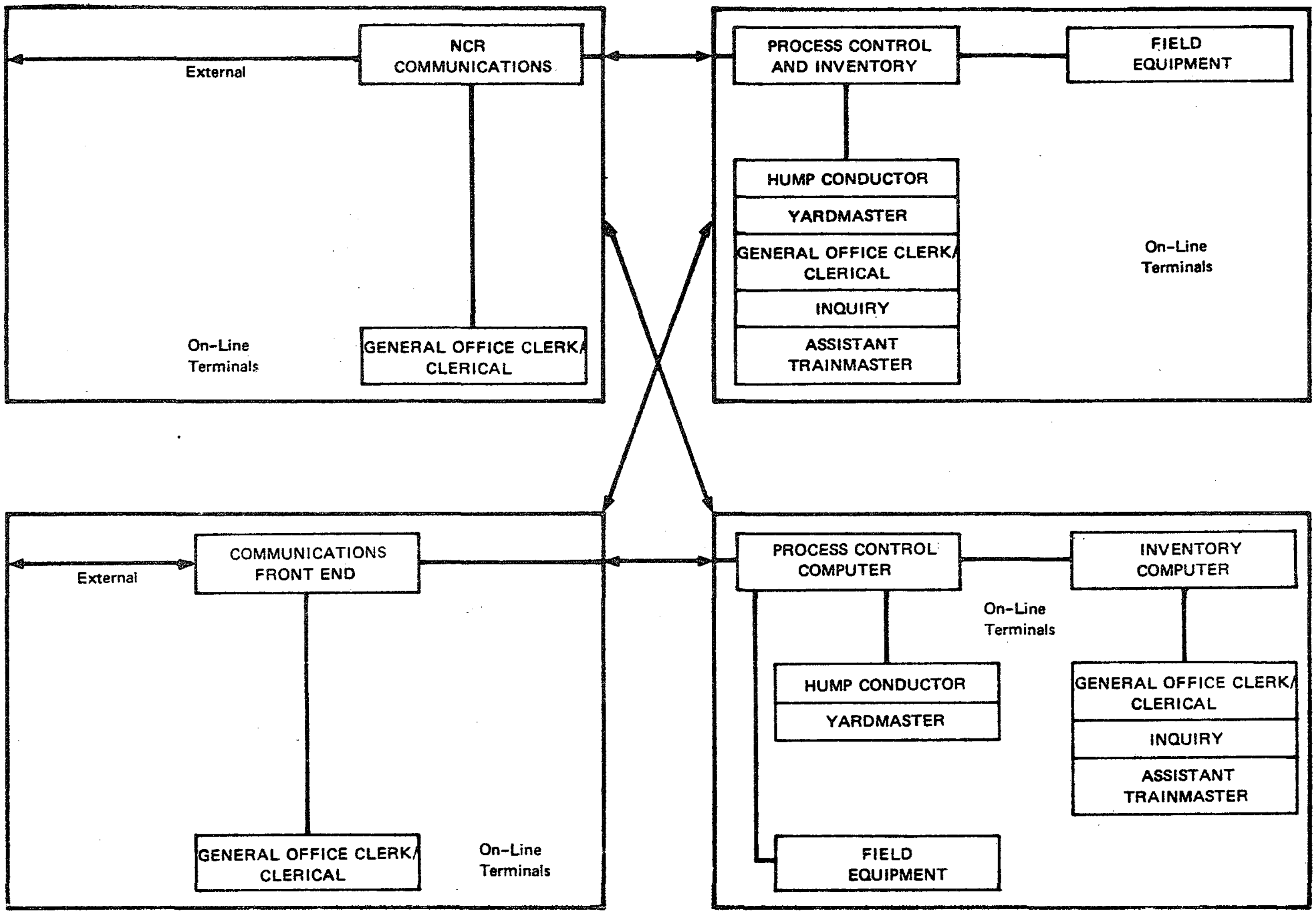


FIGURE 14 HARDWARE ALTERNATIVES FOR CONFIGURATION II: COMMUNICATIONS IN ONE SYSTEM AND PROCESS CONTROL AND INVENTORY IN ANOTHER

Configuration III--Management Information and Process Control Systems Computer--Configuration III is the use of a single PC/MIS computer for all yard information functions. Figure 15 represents this configuration.

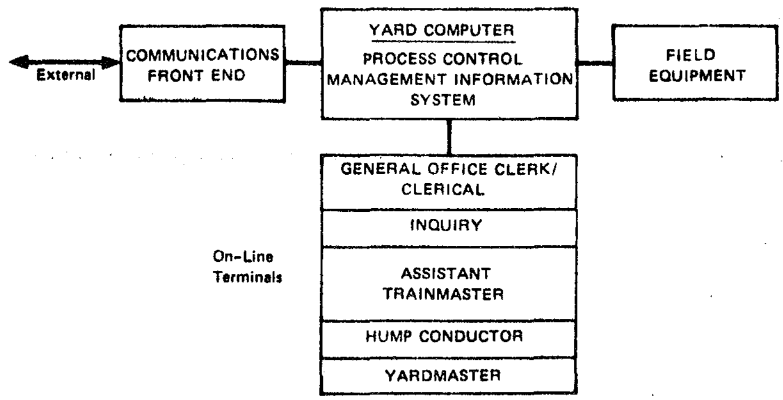


FIGURE 15 HARDWARE ALTERNATIVES FOR CONFIGURATION III: MANAGEMENT INFORMATION SYSTEMS AND PROCESS CONTROL IN ONE SYSTEM

Use of a single computer for both MIS and PC functions is the least flexible alternative. The disadvantage of this configuration is that asimilar functions would be residing in the same computer, and significant engineering and systems software problems are likely to result.

Additional problems would arise because the current MIS software would have to be moved to a new processor or the PC software would have to be moved to the existing NCR computers. Moving a PC vendor's packaged software to the NCR computers would be difficult and costly. A real-time operating system would be needed, but it would not run MIS applications efficiently. Similarly, moving MIS software to a new computer and redesigning hardware interfaces would be difficult and costly. Incorporating redundancy would be expensive and complicated.

Recommended Configuration

The recommended hardware configuration for Potomac Yard is Configuration I, which consists of independent MIS and PC computer systems. This structure would cause little disruption to current operations and software and would allow the PC computer to be an independent turnkey system. It is envisioned that functional specifications for the PC computer would be given to a contractor for development and hardware selection, and those specifications would include redundancy.

In the design of yard computer systems, the PC functions are not expected to change. Once the field and computer hardware and software have been completed, no changes should be made because they may adversely affect the system. Any functions that require periodic changes should reside in the MIS computer.

The MIS functions could remain in the existing NCR computers. The required additional functions and interfaces could be developed by Potomac Yard once the preliminary design of the PC computer has been completed. The upgrading of the MIS system could be completed before installation of the PC computer. MIS requirements for reports, communications, and inquiries most likely will continue to change. Having all MIS functions in one computer system will ensure that these changes can be made easily at any time. This is in clear contrast to the design of the PC computer.

Because Potomac Yard has no system-wide MIS computer, its MIS computer must perform many functions locally. The MIS must communicate with each tenant promptly and in a unique format. Therefore, an MIS communications processor would be required.

Configuration I is attractive because the PC computer performs only the minimum functions necessary and the MIS computer performs all others. As a subordinate to the MIS computer, the PC computer can be much smaller, reducing cost and complexity and allowing funds to be spent on backup hardware to assure better reliability.

Redundant Configurations

A number of methods can be used for increasing the availability of yard computers. Of the greatest importance will be the continuous operation of the PC computer because its failure will delay the actual physical movement of cars. A temporary failure of the MIS computer(s) will have no direct influence on yard throughput. An obvious approach is to use a backup computer so that it can be quickly put into operation during failure of the primary system (Figure 16). A backup computer that can provide full redundancy is called a fail-safe system. If the second processor does not have equivalent capacity, it is called fail-soft. In the latter case, when the primary computer fails, less critical functions must be shed for a degraded operation.

Hardware redundancy can also be obtained by linking a number of smaller computers together to provide the processing capability required for a particular set of functions. When one of the components fails, the remaining computers take up the lost functions. If an insufficient processing capacity remains, the total system cannot operate at full functional capacity. In this case, the network of computers sheds less critical functions until a manageable processing load is reached.

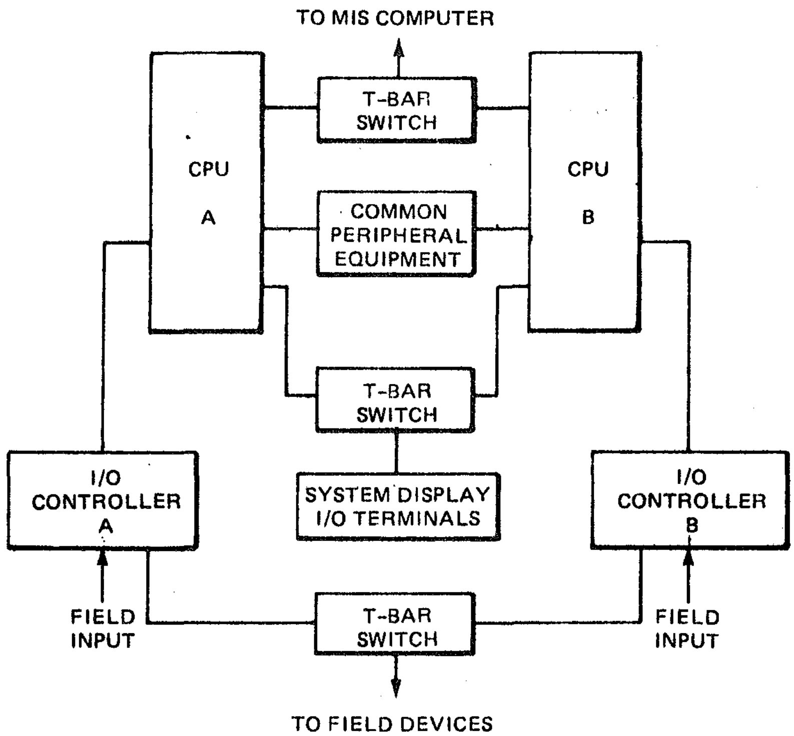


FIGURE 16 CONFIGURATION OF HOT-STANDBY DUAL-PROCESSOR SYSTEM

This method requires a thorough design of system architecture to ensure that sufficient capacity remains for all critical functions. This is a fail-soft hardware configuration because it provides backup processing but does not provide complete redundancy. The hardware is generally less expensive than full computer backup because smaller computers can be used, but it can be more costly because of additional specialized software.

Process Control--The simplest alternative for providing redundancy when the PC computer fails is to use a manual backup. One method is to use a semi-automatic switching system, like that now in Potomac Yard. This requires, however, that both systems be kept in operating condition. A switch list must be printed from the MIS computer and manually entered. Humping exceptions must be manually entered via a CRT to update the inventory. A second method is to design a manual control of switches and retarders at the field equipment control panel.

Use of the NB yard is expected to increase by 35% with the addition of a PC computer. The hump utilization will increase more during certain periods of the day. At these volumes, a manual backup will only be sufficient for a short period of time, as the cost of an inoperative hump is very high.

A failure of the PC computer will stop the hump immediately, but its inoperation will not become critical for a number of minutes--a delay often experienced during the normal course of humping operations. A hot standby computer configuration is required only for immediate system restarts; therefore, a cold standby computer configuration can be considered to be sufficient. A fail-safe configuration will be required because all the expected functions of the PC computer are critical for yard operations and efficient data transmission to the MIS computer.

When the primary PC computer fails, the standby computer cannot instantly take over the current PC functions because it does not have the switch list or the state variables of the current control process in its working storage. It must first unload its non-PC applications and then initiate PC software and data tables. Field input can be switched to the new computer and the MIS computer can reload humping information.

A number of alternatives are available to provide redundancy for the PC computer. The decision must be made considering the cost of alternatives versus the cost of losing the NB hump. The PC computer has been designed with limited functions so that hardware can be smaller and less expensive to back up.

Many of the failures on the NB hump will be failures of field equipment. The cost of installing duplicate field equipment is prohibitive. When failures do occur, it is hoped that they can be isolated to allow operation of a subset of the yard.

MIS--The current MIS configuration at Potomac Yard is two NCR computers. This system has been developed over a number of years, and a major consideration in the configuration selection was the software investment in the current system. One processor is used for external communication with tenants, and the other is used for the current MIS programs. These computers communicate through a direct processor-to-processor communications channel and share a number of disk drives.

All disk memory, peripherals, and communications hardware are switchable between processors. If one processor fails, the other can be used to run the critical functions of both computers. The availability of the current hardware is very high. Any malfunctions that occur are usually repaired within 3 to 4 hours and often involve communications equipment.

The MIS functions are not as time critical as PC functions. A number of functions, such as with communications tenants and receiving yard inventory, only become critical in a number of hours as opposed to a number of minutes. In addition, a number of functions of the MIS, such as monthly management reports, are required infrequently. Although other functions are required frequently, such as some inquiries, they are not critical to yard operations.

Potomac Yard personnel believe that neither NCR processor is used to capacity. The new virtual-memory time-share operating system that will soon be implemented should save additional resources. These factors indicate that a high percentage of critical tasks can be performed with only one processor in operation.

For the proper design of a new fail-soft system, all new and old programs must be ranked by priority. This list will be used to designate the programs that will continue to run when one processor fails. Exhibit 2 suggests one order of priority.

Exhibit 2

PRIORITY SEQUENCE FOR MIS PROGRAMS

- Generate switch list
- Maintain receiving yard inventory
- Receive advance consists
- Complete inbound program
- Receive inventory update from PC computer
- Maintain classification yard inventory
- Process on-line inquiries (real time)
- Maintain departure yard inventory
- Compile outbound train consists
- Send advance consists
- Compile interchange reports
- Process on-line inquiries (history)
- Print MIS reports
- Print shop reports.

Software and File Redundancy--Although the PC computer will be designed for maximum availability, the PC system will still rely on a number of MIS functions. In normal operation, the MIS system will periodically provide new switch lists as assembled from the receiving yard inventory and the classification table. Continuous humping therefore will rely on the completion of these MIS functions in a timely manner. This dependence can be eased by having redundant functions and files in the PC computer.

Two schemes may be used to establish this redundancy. The first is to store a number of switch lists for upcoming trains in the PC computer, and the second is to store the receiving yard inventory and the classification table in the PC computer. The choice depends on the expected repair time for MIS computer failures and available storage and processing in the PC computer. Because the repair time is expected to be short and the MIS system can be quickly reconfigured to a downgraded single computer that can provide switch lists, only a small number of lists need to be kept in the PC computer to ensure continuous humping.

If longer or complete failures of the MIS computers were expected, better software redundancy would be required. In this case, the receiving yard inventory and a classification table would be stored in the PC computer and used by redundant software to generate switch lists when required.

In both cases, the final inventory location of humped cars must be stored until the yard inventory can be updated on the MIS computer(s). These records may be stored on the PC computer disk or as punched cards.

TASK IV: GENERAL-LEVEL FUNCTIONAL SPECIFICATIONS

The analysis of alternative hardware configurations revealed that the recommended configuration for adding PC functions to the NB hump of Potomac Yard is to retain the current MIS hardware and add independent PC hardware. The current MIS hardware is believed to have sufficient excess memory and processing capacity to accommodate the new functions. The specifications presented here document the changes to the MIS hardware and software that must be made, probably by in-house data processing personnel.

PC hardware and software can be procured as a package from a PC systems vendor. The specifications will be prepared for use in system design and as part of a request for proposal (RFP) sent to PC system vendors. The specifications will document the layout of the NB classification yard, functional requirements, and suggested performance requirements. More detailed specifications, as used for an RFP, would also include sections on hardware and on the responsibilities of the vendor and of railroad management for system installation.

Process Control Specifications

The PC specifications will be used to guide the design of the PC computer and the purchase of field equipment. The yard layout will be documented, including the hump profile, existing field equipment, and the requirements for additional field equipment.

The functional specifications will document the existing relay PC system, expected functions, and required performance measurements for each function. The detailed functional specifications will also include estimates of potential traffic growth within the life of the PC system so that the capacity for this expansion will be included in the system design. Exhibit 3 outlines the functions of the PC computer.

The goal of the new process control system is to increase the humping throughput by 35%, so that in the future 2,500 cars per day could be moved over the NB hump. Thus, the humping speed must be increased to five cars per minute.

Yard Layout--The profile of the hump was designed and constructed a number of years ago when the retarders were upgraded, and it was designed specifically for later use with a PC computer. (In an actual specification, a profile of the hump and classification yard and a detailed track diagram would be attached.)

Exhibit 3

PROCESS CONTROL FUNCTIONS

A. Automatic Routing and Switching

Switch list received from MIS
Cut length detection
Car ID verification
Pin-pullers, list or display
Automatic switching--crest to clear point
Double hump lead
Safety alarms and correction/avoidance--
conflict, cornering, catchup, stalls, short track circuit, equipment failure, car out of order
Immediate individual inventory update to MIS computer as car clears
Distance-to-couple, occupancy measurement

B. Automatic Speed Control

Weight scale input
Distance-to-couple input
Weather input
Calculate rollability
Master retarder-speed calculation (single and multiple car cuts)
Group retarder-speed calculation (single and multiple car cuts)

C. Manual Routing and Switch Alignment

Manual reroute switching
Add or delete missing or extra cars
Swing car to B/O or rehump
Swing when track closed
Set switches for backing over the hump

D. Trim End

Track lock/unlock (last switch set away from blue-flag track)

E. Reports and Alarms

Track status (blue flag)
Track occupancy (distance to couple)
Speed control error log
Speed distribution report
Equipment failure log

Exhibit 3 (concluded)

Manual switch operations and route changes
Hump utilization
Hazardous cars
Stalls, cornering/catchup error log
Extra cars, missing cars, resequenced cuts

F. <u>Returned to MIS Computer</u>
Weight or weight class for each car
Distance to couple for each track
Inventory update (flag misroutes and swing to B/O and hold tracks)
Track status (lock/unlock, overflow, etc.)
Extra or missing cars.

The yard is currently equipped with WABCO 67 retarders. Two master retarders are used on each of the two hump leads. In addition, a group retarder is located at the head of each of the six track groups. Fifty-two switches are needed to route cars to the 54 classification tracks. Each switch has either a Harmon PD-2500A or RCA-ITT-80 presence detector associated with it.

Additional equipment will be required for the new PC system. A second weigh scale will be required on the second hump lead. Wheel counters or additional presence detectors may be required for increased accuracy in rollability calculation, speed control, and switching. Track circuits are required on each classification track to measure the distance to couple. This measurement will be returned to the PC computer and then passed to the MIS computer.

The detailed specification, prepared during the actual implementation cycle, would also include assumptions on rolling stock characteristics and track type. The specification would also include such computer site specifics as location, space, and environmental conditions, communication distances, and field equipment interface characteristics.

Automatic Routing and Switching--Potomac Yard currently uses a semiautomatic WABCO VR-3 system for car routing and switching. The track numbers of up to four cars are entered at one time. The existing system does not provide distance-to-couple measurement, track circuits, or reporting of misswitches, cornering, catchups, or eventual inventory location.

In the new PC system, a switch list from the MIS computer will be transmitted to and stored in the PC computer. The storage capacity in the PC computer will be sufficient to keep a switch list for every train in the receiving yard. At humping, the switch list will be used to generate a pin-puller's list and to display routing of the upcoming train.

Car identification will be verified by hump personnel and as the car travels to the classification track, its location (as determined by presence detectors and wheel detectors) will be updated in the PC computer. Errors such as cornering, stalls, and catchups will be detected and alarms displayed. When possible, these errors will be corrected by switching. After passing the clearance point, an inventory update message will be sent to the MIS computer. This message will include for each car the new inventory location, its weight or weight class, and a flag of any misswitches or swings made during classification. Additional messages such as track status (lock/unlock) and track occupancy (distance to couple) will also relayed to the MIS computer.

The hump conductor or yardmaster may override any action of the PC computer. From a PC console, changes may be entered to reroute cars, add extra cars or delete missing cars, swing cars to bad order and hold tracks, and set switches for backing cars over the hump. To lock (blue flag) a classification track, the yardmaster need only enter the track number. The PC computer will then automatically move the last switch away from the track, notify the MIS computer of the change, and alert the hump conductor to any required swings that must be made. The MIS computer will return alternative switch lists as required.

The PC computer should be designed for the simultaneous operation of two hump leads. One measure of switching performance is that no more than one misswitch in every thousand cars can occur.

Automatic Speed Control--In the existing speed control system, the retarder operator manually sets car velocity. There are three preset hump exit speeds corresponding to three car weights--light, medium, and heavy.

The use of a PC computer will permit use of a much better rollability and speed control model than exists with the current speed control system. In the automatic speed control algorithm, field information will be used to estimate car rollability. This, in turn, will be used to predict the retarder exit speed required for the proper coupling speed in a designated track. The field inputs will include car velocity and acceleration, car weight, distance to couple, wind and weather conditions, and feedback of actual retarder exit speeds. The rollability computation will also include adjustment for tangent and curve track resistance. A continuous adjustment to speed control algorithm parameters will be made from the distribution of actual car coupling velocities.

One measure of speed control performance is that 95% of the cars must couple at 4 to 6 miles per hour and must not stall before the tangent point of each classification track.

Alarms and Reports--The following alarms should be displayed to the yardmaster or hump conductor for a number of conditions, and the following reports and inquiries are also suggested:

- Alarms

  - Misroutes
  - Track overflow
  - Speed errors
  - Equipment failures
  - Catch-up and cornering conflicts
  - Stalled cars
  - Short track circuit
  - Missing, extra, out-of-sequence cars
  - Editing changes to resequence cars
  - Track swing required (overflow or locked track)
  - Hazardous cars.

only review the train consist against waybills and a videotape of the arriving train. Any changes or updates are made directly on a form-formatted CRT. This has not been accomplished for all tenants because some are not yet directly linked to Potomac Yard with computer-to-computer communications. Once these communications have been made, the goal of an up-to-date receiving yard inventory is reasonable and attainable. Consist processing will increase proportionally to the number of tenants in direct communications. As each tenant becomes connected, more processing of consists will be required.

The advance consist is received 2 to 3 hours before train arrival. Thus, an inquiry for empty car disposition can be made and the car destination and classification can be determined before the car arrives in the yard.

Timely humping and inventory updating requires a direct communication link between the MIS computers and the PC computers. Switch lists will provide the PC computer with the humping order and track assignments. As each car clears into the classification track, the PC computer will send an inventory update to the MIS computer. Any misswitches will be flagged. Communications software must be altered to give priority to PC messages.

Other software additions and modifications have been suggested. Although not required for installation of the PC computer on the NB hump, these changes contribute to the overall expected efficiency of the yard. Moreover, these changes are easier to make while other changes are being made for the installation of the PC computer. The most significant improvement is to keep a real-time inventory of all areas of the yard. To do this, any moves other than humping must be promptly reported to the computer operator by telephone or radio or by direct computer input using terminals in the yard. At the SB hump, the eventual track location of cars must be manually reported. This can be done on an exception basis against the switch list generated by the MIS computer. An additional aid to speed the paperwork that slows inventory processing would be the direct input of inspection reports via CRT keyboards; this would require additional CRTs in the yard.

In the departure yard, inventory updates can be made as part of an outbound train preparation monitor. This program would be used to build trains using inventory information and humping and departure schedules. At the ordering time of each departing train, a message would appear on the assistant trainmaster's terminal. He would then call the train. As each move or task were completed in preparation for departure, such as inspection reporting, the assistant trainmaster would record the event using the terminal. The program would be used to "walk through" the departure sequence. Any terminal in the yard could be used to inquire about the current status of any departing train. This detailed record-keeping would require a longer record of car movement history.

The sequence to hump trains from the receiving yard can be automatically created by the MIS computer. The program would follow three operational guidelines: available tracks in the classification yard, connections to outbound trains, and the time resident in the receiving yard.

It has been recommended that software be designed to provide for a fail-soft recovery from the failure of either of the two MIS computers at Potomac Yard. In this plan, if either of the processors fail disk storage and communications equipment would be switched to the remaining computer so that it could carry on critical operations until the system was repaired. Exhibit 2 gives one sequence of priority for programs.

The PC computer will return with each inventory update message the measured weight for each car and a distance-to-couple measurement for each track. Car record and inventory files will have to be modified to store this information.

A number of additional reports can be added to the current MIS programs. A track overflow report will log all tracks unable to take additional cars. The classification table will then be changed to swing cars to available tracks. The distance-to-couple measurements will be received from the PC computer with the inventory update after humping. The inventory program will calculate an expected track occupancy for each track from individual car length records. When the expected track occupancy is less than the difference between track length and the distance-to-couple measurement, the yardmaster can be alerted that the track must be shoved.

When humping has been completed or an inventory change has been made, an inventory update report documenting the inventory change will be printed. This report is used by the general office clerk (GOC) to keep waybills and other car paperwork in a parallel inventory sequence. Another report that can be added to the MIS computer to speed paperwork processing would be computer-assisted production of the consist report.

Hardware

MIS Hardware--The Potomac Yard MIS computer uses two NCR V8455 processors. One performs inventory functions and the other performs communications functions. The NCR-VRX virtual operating system will soon be implemented.

Communications to the NCR processor may be made through an NCR 621 multiplexor and an NCR 695-600 synchronous adapter using a standard RS-232 interface. The specific hardware interface required for the PC computer will be determined by the hardware used by the PC vendor. In addition to terminals for current clerical/GOC, operator console, and inquiry, terminals will be required for the assistant trainmaster, yardmaster, and, in the future, personnel at Radio Control.

Maintenance/Reliability--Of primary importance to the PC system is its reliability, maintainability, and availability. Reliability is the compounded reliability of all required components of the system. For the PC system, the overall reliability should exceed 2,000 hours mean time between failures (MTBF). A backup computer will operate as a cold standby. It will require manual intervention to be started once the operator or other yard personnel have been alerted. A shared disk will provide the data for the backup processor to begin service. A backup power supply will ensure that the PC computer operates when external power has failed.

Maintenance service should be such that the mean time to repair will be 0.5 hour when a technician is available. The system should provide suitable diagnostics and a modular design for ease of service. Specified availability should be high (greater than 99%).

Vendor Responsibility

This section of the specification will detail the extent of the vendor/manufacturer's responsibility to provide goods and services in the implementation of the new PC system.

Potomac Yard/RF&P Responsibility

This section will document in detail Potomac Yard's responsibilities to the vendor/manufacturer for the implementation of the new PC system.

TASK V: SYSTEM IMPLEMENTATION AND INSTALLATION

Common Steps

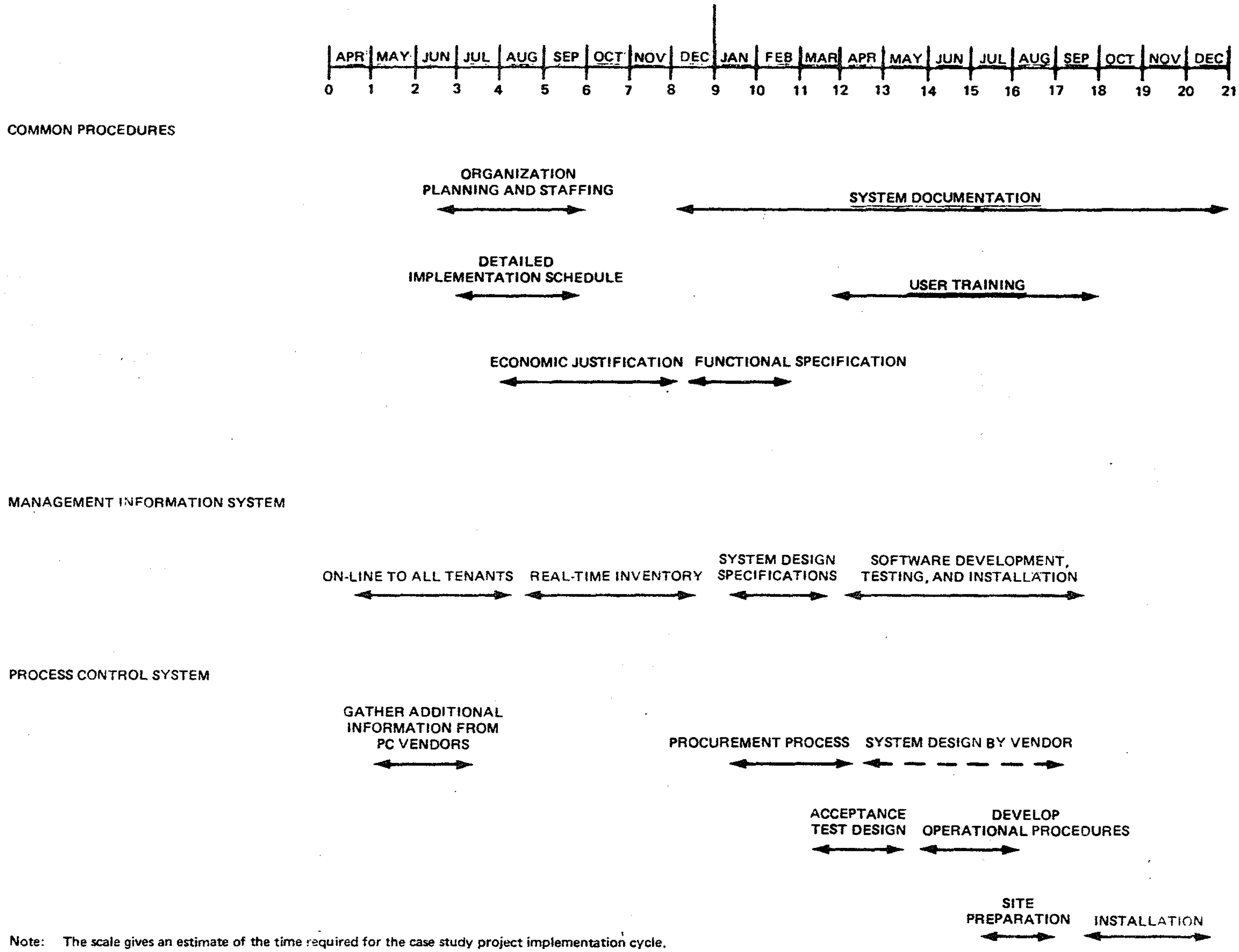
A planning document for system implementation and installation was completed in Task V. As Figure 17 indicates the implementation cycle begins at the completion of this study and concludes with the installation of software changes and PC equipment. The first goal of the project is to complete a feasibility study and detailed project planning. The steps are to:

- Gather additional information from PC vendors
- Design organization planning and staffing
- Develop detailed implementation schedules
- Complete an economic justification study.

The development of functional specifications begins after the completion of the planning stage. System documentation also begins at that point and continues through system conversion and installation. Users must be trained before each MIS software module is installed and the conversion to the new PC computer is completed.

Organization Planning and Staffing--The first step in the development, acquisition, and installation of Potomac Yard's MIS and PC system upgrades is to design the project organization and staffing plan. The project staff will most likely be divided into MIS and PC project teams. The first step in planning and staffing the new organization is to designate the overall project manager. The superintendent of Potomac Yard is the most likely candidate because he oversees both field operations and the computer staff. The project leader for the MIS upgrade project will most likely be chosen from within the data processing department, and the PC project leader may be from the signaling or engineering department.

Task groups responsible for each stage of the project will be formed within each project team. To staff task groups, the project manager will draw on personnel both from the data processing department and from each department affected by system changes. Both project teams must have strong representation from the data processing department because of the close interaction between the MIS and PC computer systems. Project teams will include people who are specialists in systems design, systems software, PC field equipment, and yard operations.



Note: The scale gives an estimate of the time required for the case study project implementation cycle. Other projects will vary significantly.

FIGURE 17 IMPLEMENTATION CYCLE

User representatives will also be members of each project team. In addition, they will assign operating personnel under their jurisdiction to work, as required, with members of the project team or members of task groups.

The entire project team, including user representatives, will change in size and composition during the project cycle. From the development of software specifications to the beginning of software development and testing, the MIS project team will grow and then will remain somewhat stable until the installation of the PC system requires an increase in personnel to work on the interface software and the integration of the PC computer to the MIS computer. The size of the PC project team will grow with the design of specifications and will also remain steady until a large increase is required when installation begins.

Implementation Schedule Checklist and PERT Diagram--The project manager will be responsible for the development of detailed implementation schedules with each project leader. An implementation schedule checklist will be prepared and then, based on the checklist, a PERT diagram will be developed to chart the events that must occur during the project. The purpose is to ensure that all necessary activities are performed in the proper sequence and on time.

An implementation checklist for Potomac Yard would include:

- General
    - Gathering of product and cost data from vendors
    - Organization planning and staffing
    - Development of detailed implementation schedule
    - Economic justification
    - Functional specifications
    - System documentation

- Management Information System
    - System design specifications
    - Software development, test, and installation

- Process Control
    - Procurement process
    - Design of acceptance test specifications
    - Provision of design feedback to the vendor
    - Development of operational procedures
    - Site preparation
    - User training
    - System conversion, acceptance test, and system installation.

The final checklist should include not only the prescribed activities, but also an estimation of the time required to perform the activity (both in terms of calendar days and person-days of work), and, finally, the name or title of the person who will have responsibility for the activity.

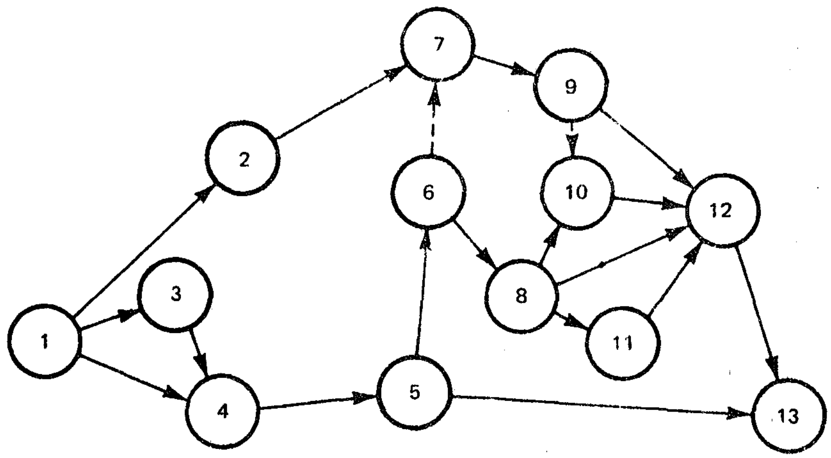
After the checklist has been completed, a preliminary critical path diagram will be prepared, indicating completion dates for all the specified activities. An example is given in Figure 18. After the critical path of total project time has been determined, the chart will probably need to be adjusted by changing schedules or manpower assignments.

Economic Justification--A detailed cost/benefit study must be performed as a justification for the MIS and PC system upgrades. Detailed personnel costs for both systems will be extracted from the organization planning and staffing and MIS and PC implementation schedule tasks. Detailed PC purchase or lease costs and maintenance costs can be obtained in discussions with PC vendors. Costs considerations may limit the scope of the project, as defined in the general-level specifications of Task IV.

Functional Specifications--Preliminary general-level specifications were developed as part of Task IV. Those functional specifications describe system changes for the MIS and define the environment and functions of the expected PC system. More rigorous specifications must be developed as part of system design. Functional specifications include: (1) a statement of preliminary equipment requirements; (2) a listing, as well as samples, of all reports and other output from the system, documentation of the flow of paperwork, frequency of reports, number of copies required, distribution of these copies, and a listing of any special requirements; (3) performance requirements, which serve as source material for subsequent test specifications and acceptance tests; (4) information on each file or data base and its probable contents; (5) processing requirements that discuss topics or functions to be performed by the users and the computer; and (6) proposed organizational changes and changes in clerical procedures. Scripts are developed at this time to specify procedures for terminal users.

Functional specifications should be revised until they best reflect the needs of all users. The functional specifications of the PC system will be used to develop the RFP in the procurement stage. The MIS functional specifications will be used to develop detailed system specifications for programming done at Potomac Yard.

System Documentation--System documentation will be developed at various stages in the system acquisition process and continue during the installation phase. The first formal document produced for the MIS and PC implementation will be the functional specifications. MIS functional specifications, in turn, will be developed into system specifications that give a detailed design for the software programs. MIS software design documents will include flowcharts and program module documentation.



EVENT NUMBERS	ACTIVITY
1 – 2	Direct communications to each tenant railroad
1 – 3	Organization planning and staffing
1 – 4	Gather additional information from PC vendors
2 – 7	MIS real-time inventory
3 – 4	Detailed implementation schedule
4 – 5	Economic justification study
5 – 6	Functional specifications
5 – 13	System documentation
6 – 8	PC procurement process
7 – 9	MIS system design specifications
8 – 10	Develop PC operational procedures
8 – 11	PC system design by vendor
8 – 12	PC acceptance test design
9 – 12	MIS software development, testing, and installation
10 – 12	MIS and PC user training
11 – 12	PC site preparation
12 – 13	PC installation

FIGURE 18 CRITICAL PATH DIAGRAM

The final two documents to be developed will be manuals--one for PC operations and one for MIS users. Ideally, the PC operations manual should be prepared before system testing and installation. User manuals for each MIS software change should be completed before user training begins and the software change is put on-line. A review of vendor documentation requirements should be included in PC acceptance tests.

As the system development cycle proceeds, documentation in the later stages will be based to a great extent on documents developed in the earlier stages. For example, if functional specifications are well prepared, they should provide the structure for the user manual.

User Training--Part of the process of installing the new PC system and modifying the existing MIS system is the training or retraining of the users. Some of the user training can come about as a by-product of the acquisition process. For example, the functional specifications are promulgated to advise the users about how the new system will affect them and, as recommended in the section on organization planning and staffing, how staff and supervisors are expected to work with the project team.

For each MIS modification, each employee who may be required to use the new MIS function should be provided with training as well as with documentation of user procedures. This training must be provided by Potomac Yard staff. Materials to be used can be obtained by modifying system documentation.

Training for the PC system should be purchased from the vendor, if cost-effective, for a limited number of personnel. The training documentation provided by the vendor can then be used for internal training of others in the yard.

An internal training plan should be carefully documented, indicating those users who require training, the content of the training, and the time required for the training so that the training can be completed by the time each new MIS modification or the new PC system begins operation.

Management Information System

The MIS project team will be responsibile for the in-house development of additional software functions (Exhibit 4). Each function will be developed as an independent software module and installed separately. The first step is to develop detailed software system design specifications using the MIS functional specifications as a guideline. The completed design specification will be used as a guide for coding, test, installation, and the conversion to each module.

System Design Specifications--After the functional specifications have been completed, system specifications for MIS software are to be developed. Detailed system specifications for software include the basic design for the programming system and subsystems. Before programmers begin working, they must understand the system objectives and specific responsibilities that they will have in developing the software. To provide this information, the project team must prepare a written narrative describing the new system. This narrative should contain a brief statement of the purpose of each program, a description of the type and extent of the system, and an explanation of the general design concept.

After the system narrative has been completed, specifications for individual programs should be written that state what the programmers must accomplish. First, the functional specifications are broken down into their component parts so that the detailed systems modules are defined. All the functions, logical control, and sequences to execute each function are then identified, and data names, formulas or specific logic for complex routines, and record layouts are specified. All conditions should be covered, and charts and decision tables may be helpful. Final system specifications should be approved before programming begins. At the same time, a procedure for modifying the final specifications should be prepared to include review by the affected users as well as by management.

MIS Software Development, Testing, and Installation--After the final specifications for software have been approved, the design stage is addressed. This stage varies according to the completeness of the specifications but may include the production of module hierarchy charts that show control flow among segments, descriptions of the functions performed by each segment as well as definition of all data inputs and outputs from each segment, and plans for testing the operation of each module. Only after the design stage has been completed, reviewed, and approved is it wise to begin coding.

With detailed specifications and design, segments within each functional module can be coded in parallel. Code reading, where the logic and format are checked by another programmer, is a reasonable and effective way to detect most errors--particularly when combined with a review by programmers whose work interfaces with the module and by the chief programmer. Remaining errors are expected to be uncovered by a series of machine tests beginning with individual segment and module testing and then proceeding to integration testing, and system testing.

The first step to implement each MIS program is to gather the input data required to run the new program in a test mode. The results of the program are then compared with results of the present method. The next step is to run the new program in parallel with the manual task before cutover. For example, while the classification program is being phased in, it will be run concurrently with the present clerical classification procedures. For a short period of time, classification clerks will be required to do both tasks. The parallel operation acts as final check of the new program.

Documentation and user training must be included in the installation of each software change implemented.

Potomac Yard is now in the process of connecting all tenant railroad computers directly to its MIS computer. This phase of system upgrade will accelerate the input of advance consist information. These records must be up to date before they can be used to keep a real-time inventory. These tasks are best completed before the design of functional specifications because experience with a real-time inventory may affect systems design.

Process Control

The PC project team will be responsible for selecting the PC system vendor, monitoring the progress of system development, designing and completing acceptance tests and assuring the correction of any discrepancies, and planning and overseeing installation. Installation includes the development of operational procedures, training users, preparation of the site, and conversion to the new PC system.

Gathering Vendor Data--Additional information is required from PC system vendors. Informal conversations should be held with qualified vendors to acquaint them with the needs of Potomac Yard. In return, such information as details on available PC functions, system capabilities and limitations, and requirements for an MIS computer interface can be gathered on prepackaged and customized turnkey PC systems. A cost estimate for different systems is necessary for preparation of the economic justification study.

Procurement Process--After the PC functional specification has been reviewed by all affected staff and management, RFPs should be issued to potential vendors. The RFP should cover the following areas:

- Yard layout and design parameters
- Assumptions about track type and rolling stock
- Existing field and PC equipment
- Functional specifications
- Performance requirements
- Hardware interfaces
- Data storage requirements
- Workload expansion capability
- Location and site preparation
- Security
- Maintenance and availability
- System backup/redundancy
- Support by vendor, vendor responsibilities
- Potomac Yard and RF&P responsibilities.

After proposals have been received from vendors, they must be evaluated. Although benchmark tests are usually part of a general hardware systems procurement, the selection of a PC system vendor will not weigh heavily on the direct comparison of computer hardware. Little consideration for hardware will be given once a computer has been demonstrated as adequate. Total systems cost, available applications software, and the installation record of each vendor will be of greater influence. Therefore, hardware benchmark tests most likely will not be required.

A negotiations team should be formed that consists, at least, of the project manager, the data processing manger, and an RF&P company lawyer (or counsel). Vendors have standard cost contracts that can be modified to cover a specific situation. Modifications are often specified by the project manager and reviewed by the company lawyer or counsel. The contract should stipulate in general terms the requirements for hardware and software, the details of site requirements, delivery and installation, the documentation and maintenance to be supplied, the guarantees and limitations on the manufacturer's liability, the problems of risk loss, the cost, and the method of payment. Ordinarily, the specification in the RFP become part of the final contract. In addition, acceptance tests should be specified, as should the monetary penalty or deposit that will be held in lieu of satisfactory hardware and software delivery and installation.

Development of Acceptance Test Plan and Test Data--Acceptance testing is used to judge satisfaction with the vendor-installed system. Major problems should be resolved or steps to the solutions agreed on in writing before the PC system is accepted from the vendor. Recourse from the vendor is much more difficult to obtain after the system has been accepted.

Acceptance testing for the PC computer will be divided into functional components. A test plan specifying the tests in detail must be prepared. The test plan will include the number of tests, the sample size, and test measurement methods. Standards from the specification state acceptable system performance.

Feedback for PC System Design--Periodic communication must be maintained between the Potomac yard PC project team and the design, engineering, and installation staff of the system vendor. Feedback to the system vendor will ensure that the delivered system complies with functional specifications. Any changes that are required, when agreed on in advance, can be made more smoothly.

Develop Operational Procedures--Operating procedures must be developed and documented for the new PC computer system. Because the PC computer is a real-time system for operational personnel, operating procedures will be limited to this use and the maintenance procedures. The user interface must be simple, and user documentation must be informative and easy to follow. Access to terminals should be closely supervised because of the potential safety violations and inventory errors that can occur if the PC computer is used incorrectly.

The operating system must be such that no operator is needed for the PC computer. Periodic hardware and software maintenance will be the only responsibility of the vendor or of the data processing department. The data processing department's access to the computer will be limited to specific scheduled periods when yard activities will not be seriously interrupted. Although backup disks of system software should be retained, in case of destruction of the primary set of programs and files, periodic file retention and backup procedures are not required because no critical information need be stored in the PC computer.

Site Preparation--Site requirements from the vendor will include mechanical and electrical requirements and information on such items as dimensions of the units and the interface to field equipment and to the MIS computer. Written environmental specifications (including temperature and humidity control, for example) for optimum operation should also be obtained from the vendor.

Vendors can also be helpful in providing assistance during the site selection, design, and preparation phases. The PC equipment may be divided between the present data processing center and the signal department building, where the present PC equipment and the convergence of field equipment signal input are located. The optimal location for the computer may be with the current NCR computers. The PC computer will require a minimum of floor space; the present computer room meets required environmental standards and the communication distance to the signal building is relatively short. Field equipment now connects to a relay-based PC system located in the signal building. If this equipment is replaced by analog-to-digital and digital-to-analog converters and signal transmission equipment, the signals between the PC computer and field equipment can be efficiently transmitted over the 100-yard distance. Because the installation of the new PC system can involve new communications lines and renovations to buildings and equipment rooms, detailed planning and scheduling is mandatory. Ordering and delivery of supplies clearly can be a crucial element in effecting an orderly transition and on-time project performance.

If in-house expertise is not available or expertise additional to that of the PC vendor is warranted in site design and preparation, contracting for the services of an outside consultant or engineering firm might assist in this important phase in system development.

System Conversion--Several methods are used to effect system conversion. One method is to use a parallel operation, whereby both the new and the old system are run concurrently until it is certain that the new system is performing as well as the old one. Another method is to completely cut over, without the possibility of returning to the old system. This method is risky, but can be the least expensive of the available alternatives if well managed. A combination of these two methods, called "phased" cutover, converts only parts of the system at a time. Some parts may be converted in a parallel mode, while others may be converted without recourse, depending on the complexity and other factors that affect the individual components. At times, emulation or simulation may be used to assist in converting from one system to another. These processes enable the cutover to proceed at a slower pace than would otherwise be possible.

The PC system will require additional field equipment. Presence detectors and/or wheel counters will be required for car tracking and counting and rollability estimation. Distance-to-couple track circuits must be installed in classification tracks to return distance-to-couple information to the speed control function, the track overflow alarm routine, and MIS inventory records. An additional scale may be needed for the second hump lead. This equipment can be installed track by track in phases by track group. This will ensure that a minimum of cars are affected by the closure of classification tracks. Each new device will in turn be connected to the PC computer.

To safely and efficiently convert the existing PC system to a PC computer, parallel operations are suggested. In turn, the speed control function and automatic switching and routing function must be installed. Incoming signals would be taped off from the input junction of the existing relay PC system and passed through an analog-to-digital converter to the PC computer. In each case, the PC computer would be connected in parallel with incoming field sensors and equipment signals. These signals would be used to drive simulated output from the computer. The simulated output signals would be compared with actual and expected output signals as a test of the new system. Once the simulation showed that the PC computer works correctly for a particular part of the yard, actual tests could be run. The existing relay PC system would be used as a safety backup while testing the new computer system. Once parallel simulation and actual tests were completed, the existing relay-based PC system could be phased out by disconnecting the field communications.

<u>Acceptance Test and System Installation</u>--PC software and equipment should be thoroughly tested for acceptance before they are used for actual full-time operation. Tests should be performed in accordance with the specifications developed and stated in the contract.

It is likely to be infeasible to satisfactorily test PC software before system installation. A gradual phased conversion could act as the acceptance test. As each function of the system were tested and successfully cut over, acceptance would be acknowledged by Potomac Yard.