The Seat Reservation System in Japanese National Railways

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The first reservation system (MARS) for Japanese National Railways (JNR) started its operation in 1960 with a development of MARS 1. The number of reservation seats has rapidly increased from 2,000 to 700,000 seats per day in more than 15 years. To cope with this increase in reservation seats and traffic, many MARS systems were developed since 1960. In 1972 MARS 105 started its operation by replacing all previous MARS systems, and has become one of the largest on-line system in Japan. Since then, MARS 105 has further expanded to handle more than 1,000,000 seats per day for the reservation period of 2 months.

The outlines of applications, system configurations and environment characteristics of MARS 105 are discussed for background information on the railway reservation in Japan.

The paper describes the reliability design of the system with emphasis on avoiding total system crash and reducing down time for high availability. The performance data of central computer system, such as MTBFs, causes of system crash, software failures and etc, are presented from past 5 years. These data are analyzed and compared with the original design for evaluation. The reliability of communication lines, terminals, air conditioning and power supply is briefly discussed.

1. Development of the Seat Reservation System

The history of the seat reservation system (MARS***) in Japanese National Railways (JNR) began in 1960 with the development of MARS 1. This experimental system was able to handle about 2,000 seats per day for the reservation period of one week.

Since the first system, the four major on-line systems, MARS 101 through 104, were successively developed and put into operation from 1964 to 1970 to cope with rapid increase in the number of the reservation seats. The MARS systems were able to handle total of about 500,000 seats per day by 1970.

But by 1972 more limited express trains were expected in operations with the extension of Shinkansen to the west. To meet the demand for further increase of the reservation seats, the development of a large scale reservation system, MARS 105, was started in 1970. MARS 105 began its operation in September 1972, and by January 1973 it had replaced all previous systems, MARS 101 through 104, to handle 700,000 seats per day. Furthermore, in October 1974 MARS 105 was upgraded to handle 1,000,000 seats per day for the reservation period of two months which is the capacity of the system today.

The upgraded system was designed to handle maximum of 1,400,000 seats per day to meet the expected increase of the reservation seats from the future extension of Shinkansen to the northeast. The number of the terminals connected to the system is about 1,800.

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***MARS . . . . Magnetical-electronic Automatic Reservation System.

Besides MARS 105, there are reservation systems for the group and party travel, MARS 202, and the telephone reservation, MARS 150. These systems are in operation with MARS 105 to make up the integrated seat reservation system for JNR. The paper will describe the reliability design and the availability performance data of the main reservation system, MARS 105.

The development of MARS systems is shown in Fig. 1–1. To appreciate the need for the large scale reservation system, the passenger transport share in Japan reservation system, the passenger transport share in Japan should be mentioned. The JNR share of the passenger transport is approximately 30%, while the bus and automobile share is 51%, the privately owned railway share is 15%, and the airline and ferry share is only 4%.

2. Outline of the Application

The functional features of MARS 105 are as follows:

2.1 Sales of the Reservation Seats

(1) Volume and type of seats handled

The system is able to handle the seats and berths of many types for Shinkansen, limited express, and express trains, and is able to make reservation on the ferry, bus, rented-car, and etc. The number of the reservation seats and trains in the system is shown in Fig. 2–1, and the types of the reservation tickets are listed on Table 2–1.

(2) Reservation period

The one week in-advance reservation opens at 10 a.m., while the one month in-advance reservation opens at 2 p.m. daily. The reservation seats for one month in-advance are limited in number. Most of the seats are available for the one week in-advance reservation. The

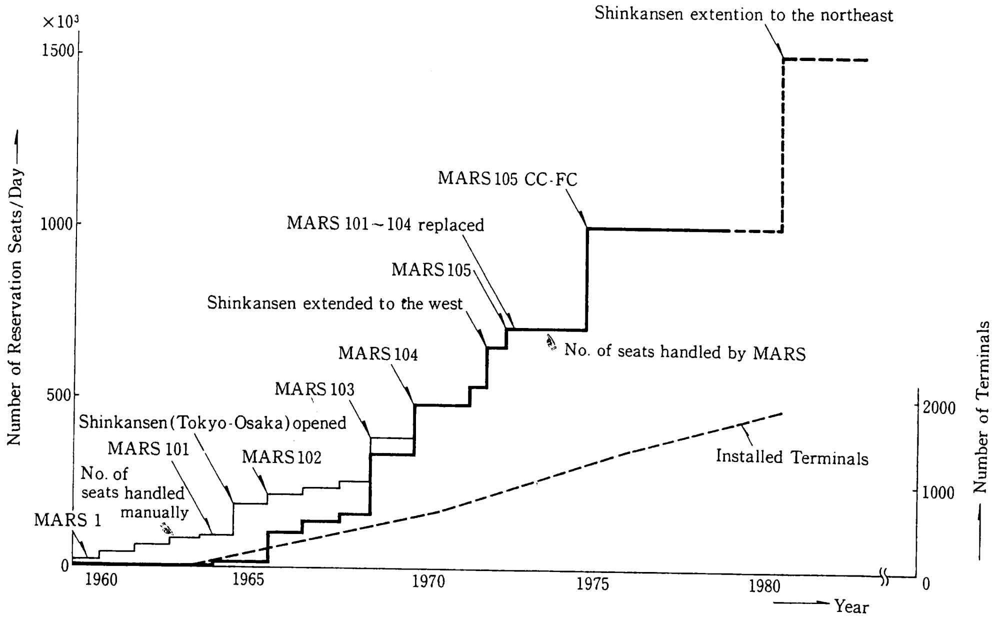


Fig. 1–1 Development of MARS.

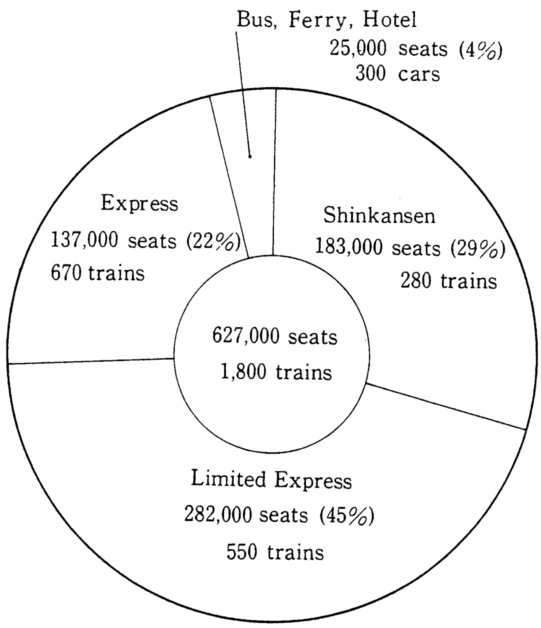


Fig. 2–1 Number of seats in system as of July, 1977.

Table 2–1 Type of reservation tickets.

Type of Reservation Tickets	1st class	Economy class
Shinkansen Limited Express (Hikari/Kodama)	○	○
Limited Express	○	○
Express	○	○
Limited Express (Berth)	○	○
Express (Berth)	○	○
Ferry	○	○
Bus		○
Hotel		

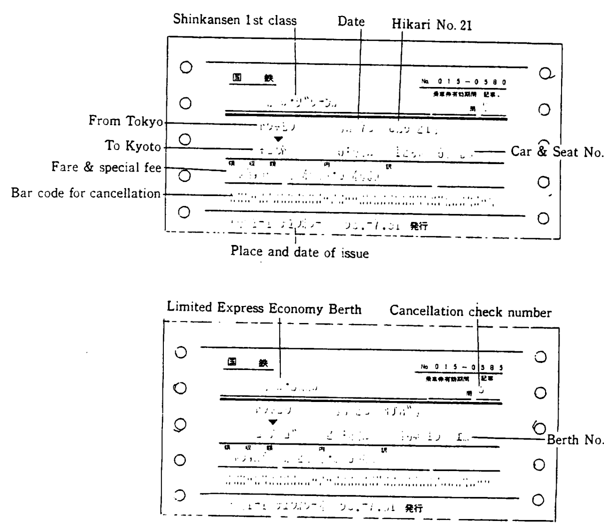


Fig. 2–2 Examples of reservation ticket.

system has the seat file capacity for the two month in-advance reservation.

(3) Selection of seat position

Upon a request the passenger is able to select his preferred seats on the desired train. The request for "the window side" or "seating side by side" on the designated car can be made from the terminal.

(4) Sales of separate fare ticket

When the passenger's boarding and detraining stations are same as the reservation, the fare is calculated and printed on the same reservation ticket. When the boarding and detraining stations are not same as that of the reservation (example, the passenger may board or detrain at the local stations where the limit express train does not stop.), there will be two tickets issued, one for the seat reservation and other for the fare ticket between local stations.

(5) Prevent double booking

To prevent double booking from mishandling during cancellation of the ticket, the cancellation check number is printed on the ticket.

(6) Automatic cancellation

To avoid cancellation errors and to save time for cancellation, the cancellation bar code is optically read from the tickets by the terminal with OMR.

(7) Number of seats reserved in one operation

Upto 14 seats can be reserved in one operation. Fig. 2–2 shows the example of the reservation tickets.

2.2 Display Seat Information

(1) Display alternative trains

When the seat on the requested train is not available, the alternative trains are displayed.

(2) Display available seats

The terminal operator can request the display of available seats on any train.

(3) Information for the train conductor

The seat allocation report for the train conductor is printed at the terminal to be used for selling unreserved seats on the train.

2.3 Sales Report for Management Control

(1) Accounting

The updated sales total, such as the number of tickets and the total amount sold, can be requested from the terminal at any time during the operation. The totals can be requested for a single terminal or a group of terminals in the same station.

(2) Sales report of the passenger transport

From the sales statistics of each train, station, and terminal, the essential reports, such as the boarding efficiency of the train and the passenger flow, are made for the passenger sales control.

(3) Change in the train and car schedule

Updating the computer data for the train and car schedule changes are easily handled.

(4) Change in the charge

The changes in the fare and fee are updated easily.

3. Environment Characteristics

The two main characteristics of the reservation system in JNR are to meet high traffic demand from very large fluctuations in the passenger flow and to meet the requirement of high reliable system.

3.1 Fluctuation of Traffic

There are two types of traffic fluctuations. One is a daily fluctuation, and the other is a seasonal fluctuation.

(1) Daily fluctuation

The operation hours of MARS 105 are from 5: 30 a.m. to 11: 00 p.m. As the sales of the one week in-advance

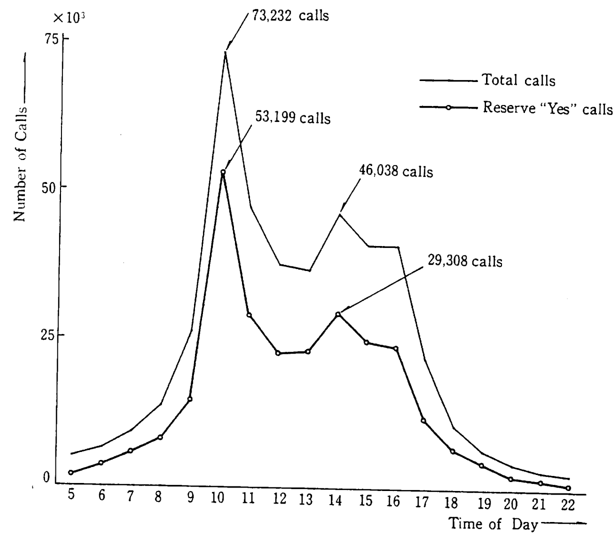


Fig. 3–1 Traffic variations in one day (May, 1978).

reservation at 10: 00 a.m. and the one month in-advance reservation at 2: 00 p.m., the peak of the traffic is concentrated at 10: 00 a.m. and 2: 00 p.m. The traffic fluctuation is shown in Fig. 3–1.

(2) Seasonal fluctuation

The passenger travel varies widely with the season. The passenger travel in Japan reaches its peak at the summer and new year vacations, and the travel also increases in the spring and fall travel seasons. The seasonal traffic variation is shown in Fig. 3–2.

3.2 High Reliability and Performance

There are approximately 1,800 terminals located at 770 sites spread all over Japan. Because many persons are waiting in line at each site to make reservation in-advance every day, the system failure for more than several minutes will have great impact on many people around the country.

The availability of over 99.9% was required from the beginning of the system design. The high reliability requirement and the high volumes of calls, reaching upto 100 calls per second at 10: 00 a.m., are the characteristics of MARS 105.

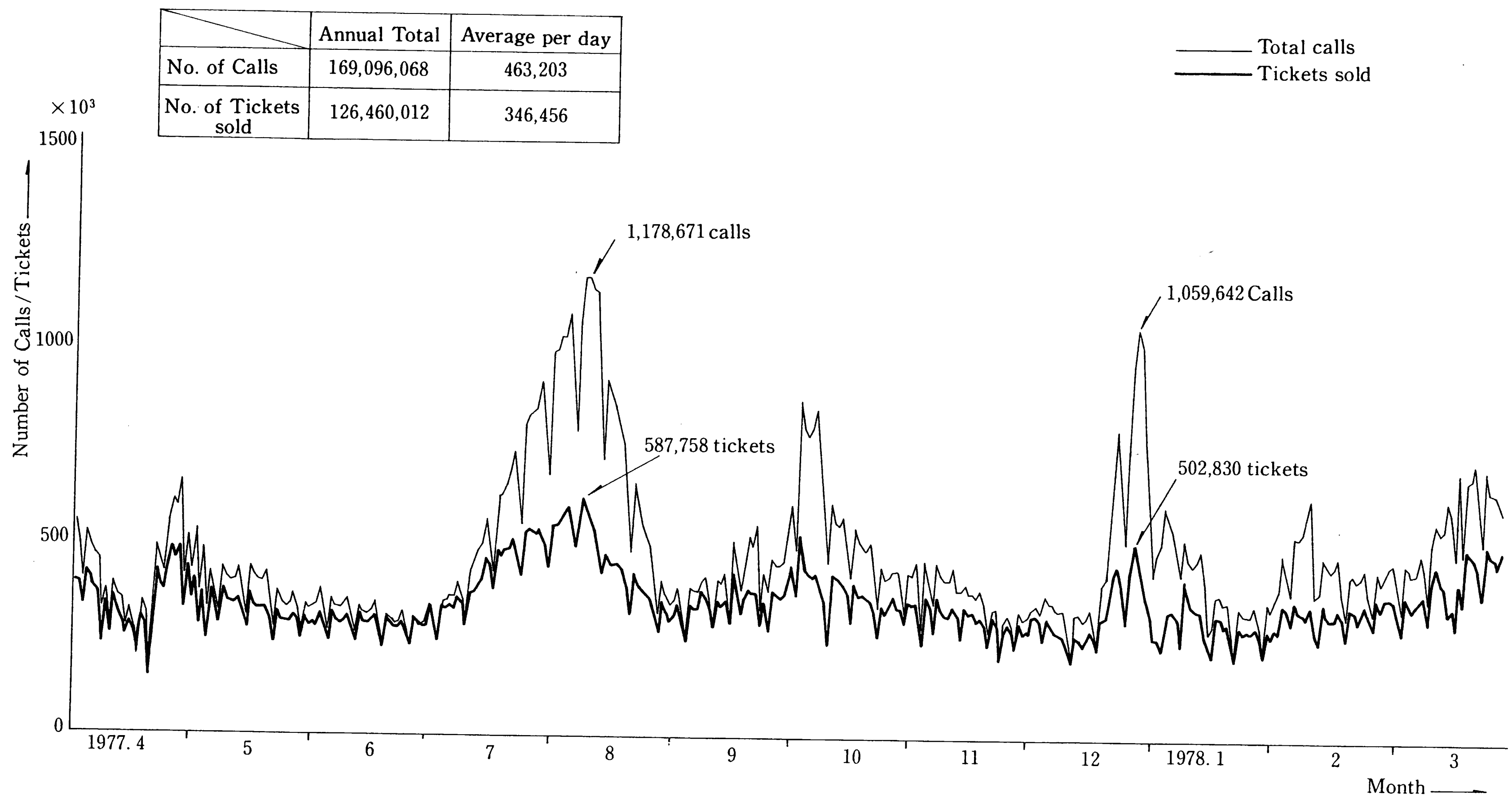
4. Configuration of the System

4.1 Configuration of the Central Processor

The configuration of MARS 105 can be divided largely into two computer subsystems, the Communication Computer subsystem (CC) and the File Computer subsystem (FC). The two computer systems, the telephone reservation system—MARS 150 and the group and party reservation system—MARS 202, are connected to MARS 105 to make up the integrated reservation complex. Some characteristics of the central processor configuration are as follows;

(1) Tandem configuration

To process high volumes of transactions, MARS 105



	Annual Total	Average per day
No. of Calls	169,096,068	463,203
No. of Tickets sold	126,460,012	346,456

Fig. 3–2 Seasonal traffic variations (April, 1977 ~ March, 1978).

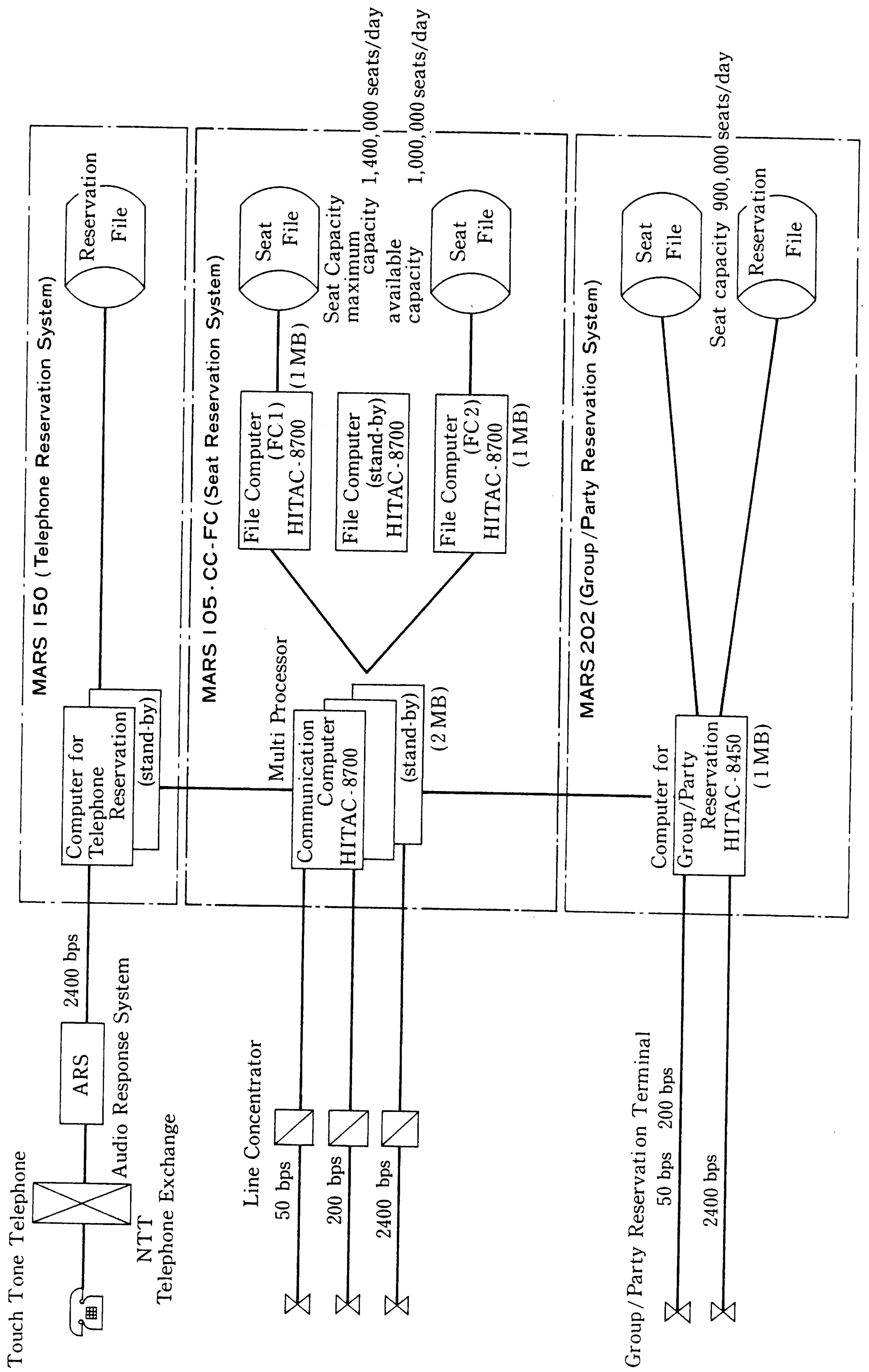
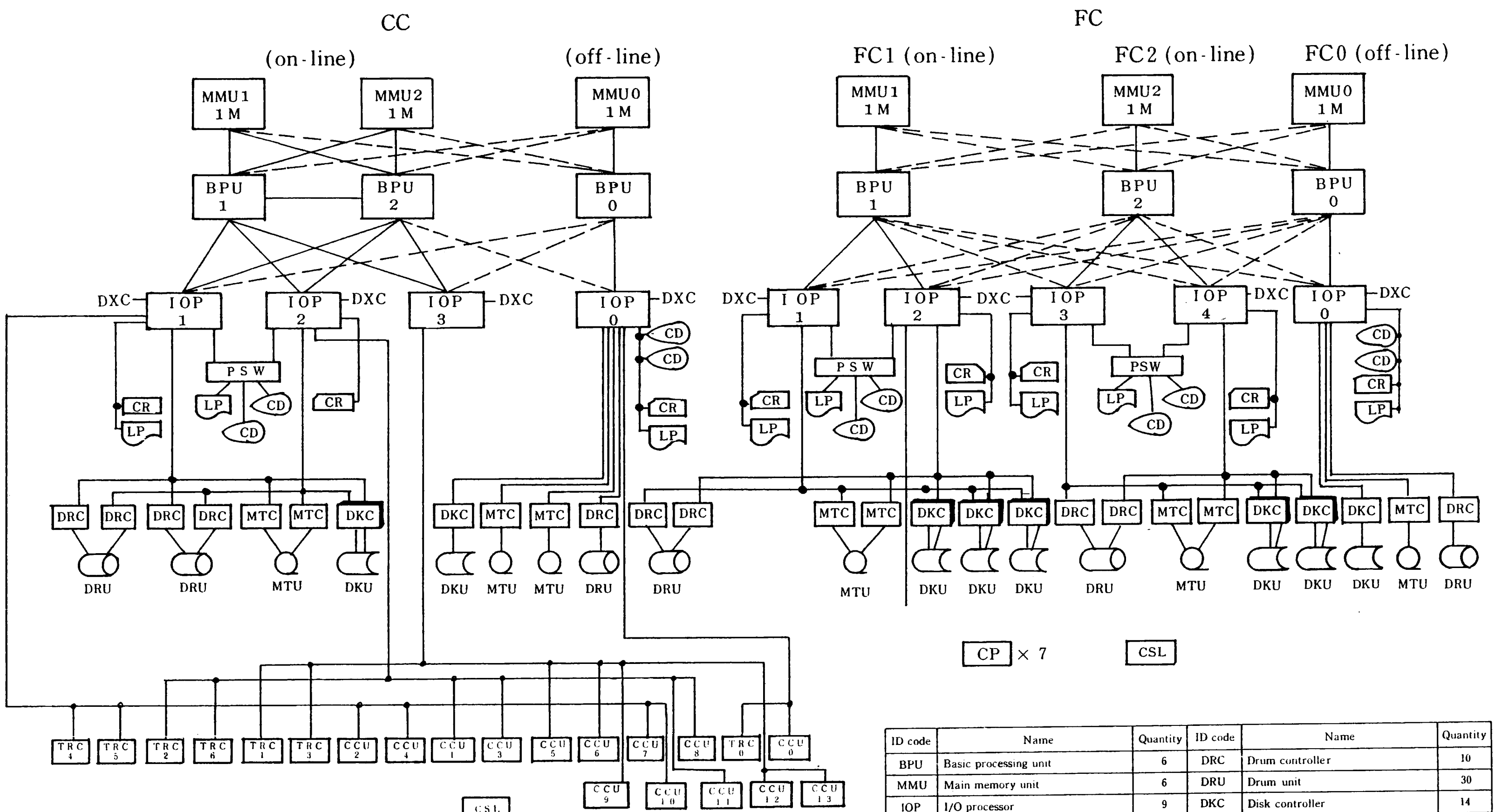
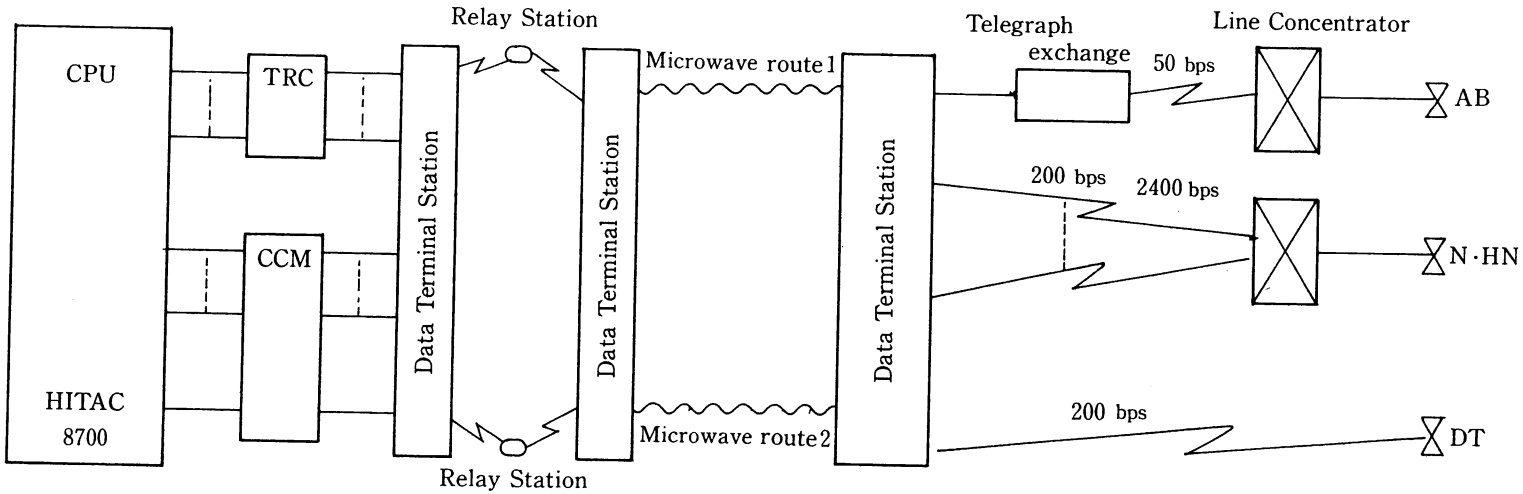


Fig. 4-1 System diagram of MARS.



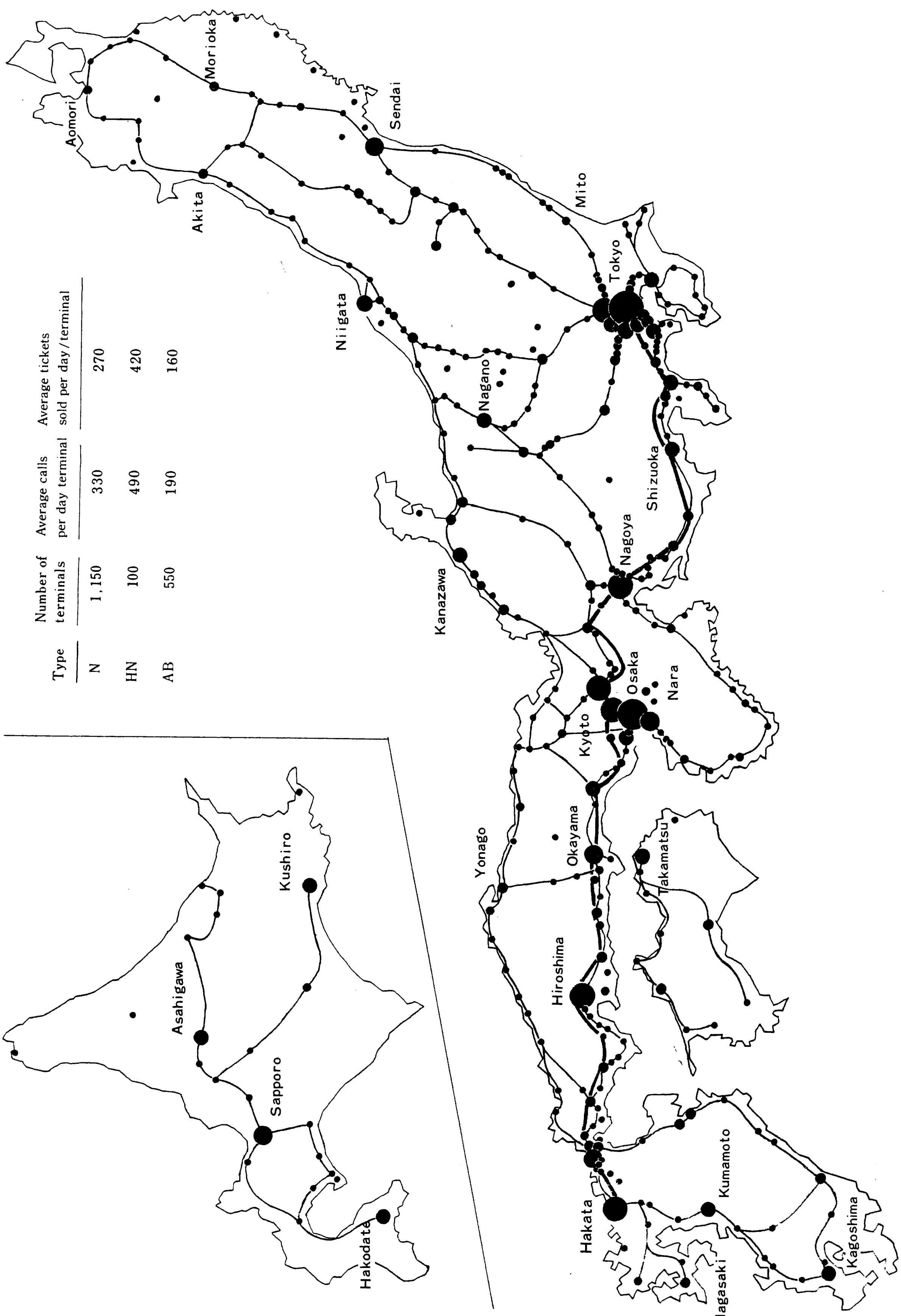
ID code	Name	Quantity	ID code	Name	Quantity
BPU	Basic processing unit	6	DRC	Drum controller	10
MMU	Main memory unit	6	DRU	Drum unit	30
IOP	I/O processor	9	DKC	Disk controller	14
CD	Console display	10	DKU	Disk unit	72
CR	Card reader	10	CCU	Comminucation controller	14
LP	Line printer	15	TRC	Transmitting & Receiving controller	7
MTC	Magnetic tape controller	9	PSW	Peripheral switch controller	8
MTU	Magnetic tape unit	2×30	DXC	Data exchange controller	6
CP	Card punch	7	CSL	System console	2

Fig. 4–2 Hardware configuration of MARS 105.



Type of Terminal (line speed)	Number of Channel	Channel Kilometer
N (200 bps)	850	345,100
HN (2400 bps)	40	12,240
AB (50 bps)	230	130,470
DT (200 bps)	70	39,350
Total	1,190	527,160

Fig. 4–3 Diagram of communication lines.



Type	Number of terminals	Average calls per day terminal	Average tickets sold per day/terminal
N	1,150	330	270
HN	100	490	420
AB	550	190	160

Fig. 4-4 Location of terminals.

has adopted the tandem system, which connects the front and back-end processors in series, as one of the method in obtaining high performance. The front-end processor, CC controls the communication network, the terminal status, and the traffic flow to the FC subsystems. The back-end processor, FC controls the train and seat files and processes all the on-line application. The CC subsystem is equipped with three H-8700 large scale computers. Normally, the two processors (multiprocessor) are in operation for on-line processing. The other CPU is used for the batch applications and a back-up for the on-line processors. The FC subsystem is also equipped with three H-8700 computers. The two CPUs (each single processor) are used for the on-line applications, and the other CPU is used for the batch applications and testing or a back-up for the on-line CPUs. The CC and FC computers are connected channel-to-channel by the Data Exchange Controllers.

(2) Multiprocessor configuration

The two on-line processors in CC operate in multiprocessor configuration—one operating system controls two processors with one set of programs loaded in a common main memory.

(3) Load-share configuration

The two on-line CPUs in FC operate as two single CPU, FC 1 and FC 2. The transactions to each CPU is separated by CC according to the trains, hence dividing the traffic load between the two CPUs.

Fig. 4–1 shows the system diagram of MARS.

Fig. 4–2 shows the hardware configuration of MARS 105 central processors.

4.2 Network Configuration

The JNR owned communication network is used. Fig. 4–3 shows the dual communication path between major data communication terminals. The installation sites and the number of the terminals are shown in Fig. 4–4.

4.3 Software Structure

The characteristics of software structure in MARS 105 are as follows;

(1) Specially designed operating system

The MARS system has traditionally developed and used specially designed operating system to obtain high performance and reliability. The specially designed operating system, RTCS, was developed to meet the performance and reliability requirement of MARS 105.

(2) Multi-tasking structure

To process high traffic volume by one application program, the multi-tasking was employed which made it possible to process many calls simultaneously. To obtain more efficient processing in the multi-tasking structure, most of the on-line program modules were written in fully re-entrant code.

Fig. 4–5 shows the software diagram of MARS 105. The total amount of program in MARS 105 is listed on Table 5–5. The assembly language was used to obtain high performance.

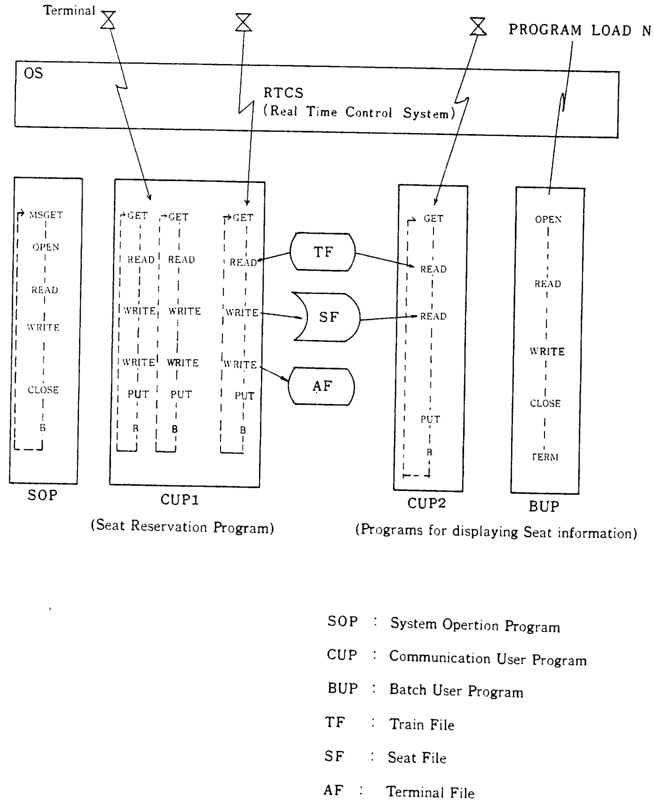


Fig. 4–5 Software diagram.

5. Reliability Design and Availability Performance

5.1 Reliability of the Central Hardware System

(1) Reliability in hardware configuration

The specially designed operating system was developed to fully support the multiprocessor and the configuration control features of H-8700. Utilization of these features helps further in obtaining high reliability of the system. To improve the reliability through the hardware configuration, the main equipments are duplicated.

(a) Reliability of the central processor

The CPU components of H-8700 can be separated into the basic processing unit (BPU), the main memory unit (MMU), and the input-output processor (IOP). These components can be reconfigured automatically by the configuration control features of H-8700.

When the hardware malfunction is detected in the BPU or MMU, the system is able to continue normal operation by reconfiguring the BPU or MMU of the back-up CPU. When the IOP malfunction is detected, it is cut-off from the system automatically, and the system continues to operate in the fall-back mode. Access to all the files is possible through other IOP because the file access routes are all duplicated.

When the fault is detected in two BPUs in the CC subsystem, the system is able to continue operation with single processor by using remaining BPU in the fall-back mode. In the FC subsystem, FC1 or FC2 can be backed-up by the remaining CPU to continue normal on-line operation.

(b) Dual access route

(i) Dual channel

There are three types of files in the system, the disk (DKU), the drum (DRU), and the magnetic tape (MTU).

Access routes for all files are duplexed through the dual channel. Therefore, when the fault is detected in the IOP or device controller (CE), other access route through the normal IOP or CE is open for fall-back mode.

(ii) Distributed configuration of the communication controllers

The communication lines are concentrated at the line concentrators located throughout the country. The concentrated lines from the same line concentrator are distributed to more than one communication controller (CCU), and there are more than 15 CCUs in the system. Therefore, the malfunction of the IOP or CCU does not stop the data communication between the terminals and the central processor. Again, the alternate route is used in the fall-back mode.

(c) File protection

The files of MARS 105 are all duplicated to avoid data destruction from the single file crash and to reconstruct data in short time. For instance, when one of the duplicated files (the train or seat data files) is unavailable for some reason, the data is recovered by copying from the duplicated file very quickly.

The duplicated files are used in normal operation, but in case of emergency, the operator can direct the system to operate partially in single file mode. When both duplicated seat files are lost, the file can be reconstructed by following procedure;

Since the file data are recorded on the magnetic tape at the end of operation each day, it is possible to reconstruct the data file of the start-of-a-day by using this file copies. To this start-of-a-day file, the transaction to this particular volume file is selected and processed from the today's transaction tapes. The system is in normal operation during this recovery procedure. Of course, access to the out-of-order volume file will not be made until it is recovered completely.

(2) Reducing down time

The system was designed to avoid total system crash, and the effort was made to operate in fall-back mode as much as possible. The fall-back operation was made possible by the redundancy of the hardware configuration and the elaborate error recovery support by the specially designed operating system.

In case the system stops completely, following means are employed to reduce down time operation.

(a) Automatic system recovery

When the hardware or software failure occurs during the on-line operation, the on-line system is automatically restarted by reloading the on-line programs in the same hardware configuration. The recovery programs are started automatically after detecting system failure. The time to restart the system from the detection of failure takes approximately one minute.

(b) System console

The system console was developed to reduce operation time and to display abnormal system status.

(i) Reduce operation time

The system console panels (SCP) are installed in both CC and FC subsystems for quick system recovery. The operator at the SCP is able to start, restart, and end the operations of MARS 105 by simple one-touch operation. In other word, the on-line program loading, file recovery, and on-line start are processed automatically by the single instruction from the SCP.

By operating through the SCP, the three processors configuration can be changed easily by pushing the buttons on the panel.

(ii) Error display

When the program error or the hardware fault is detected, the system will display the alarm lamp on the panel and sound buzzer to warn the operator. Also, the cause of the alarm is displayed on the console display or printed on the line printer to be used for further investigation by the maintenance personnel.

(3) Reliability design in software

Support of the automatic system recovery and the one-

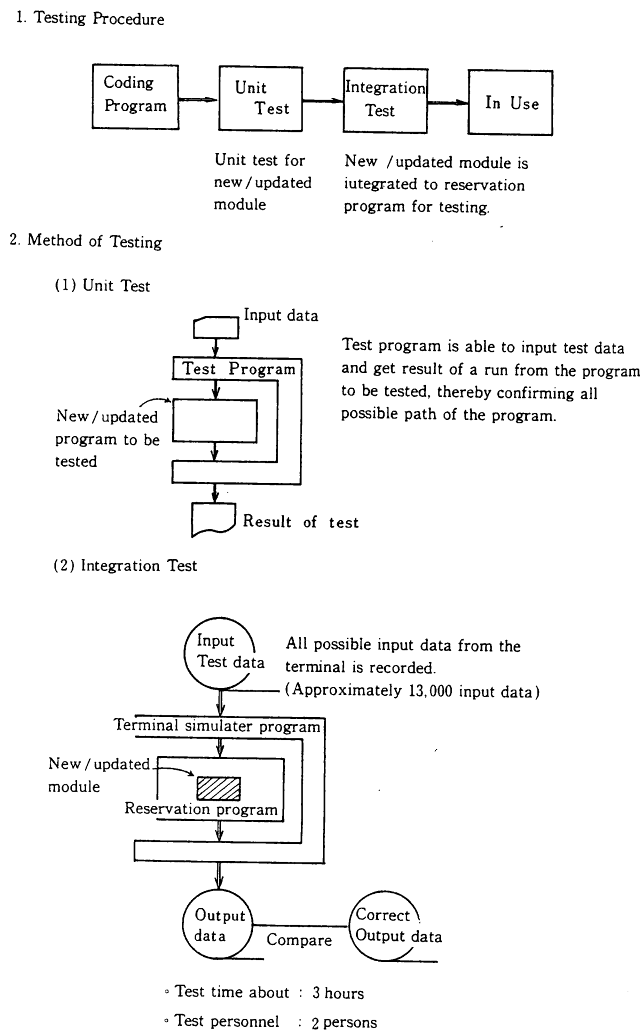


Fig. 5–1 Outline of program testing.

touch operation contributed greatly to the improvement of the system reliability by the software.

Following additional software support contributed to the higher reliability of the system.

(a) I/O patrol by software

To quickly detect the malfunction in the peripheral devices and the communication equipments, the I/O patrol feature is supported by the specially designed operating system.

(b) Isolation of abnormal program

The system crash is avoided as much as possible, even when the errors are detected in the application programs. If the program error does not greatly affect the total system performance, the operating system will isolate the abnormal program. The on-line operation will continue in the fall-back mode.

(c) Considerations in program testing

As program maintenances are frequently made, the updated or newly written programs are tested in following way.

First, the updated or new program modeles are unit tested intensely. Next, the programs are tested in the on-line environment by the terminal simulator program. The input data from the terminals are generated and processed through the simulator. The result of the test are compared with the correct data to assure quality of the tested programs.

Fig. 5–1 shows the outline of the program testing.

(4) Maintenability

To improve maintenability of the system, following program structure and functional features are employed in the system.

(a) Program modularity for easy maintenance

For simple program maintenance, following program structure was considered.

(i) Modular structure

The program module structure was designed to separate major functions in the application programs. So that, the modification in the number of the modules is limited when changing application. Examples of the modules in the reservation program are the input data checking, the train file search, the seat file search, the fare and fee calculations, and the ticket editing.

(ii) Separation of the parameter data

The system parameters, such as the fare, fee, and discount rates are separated from the program and independently stored in the system table file. By changing the system table, these rates can be easily changed without modifying the program.

(b) Fault recording

(i) Preventative maintenance of hardware

For preventative maintenance, every hardware faults and its data from the machine check errors and the peripheral device errors are recorded. From these recording, the transient faults are detected and corrected in advance.

(ii) Analyzing cause of the system crash

To analyze the cause of the system crash, the data fields and programs are recorded from the main memory during the system recovery.

(5) Availability performance data

(a) Availability of the system

The availability of the system is shown in Table 5–1. In Table 5–2, the MTBF, MDT, system crash, and automatic recovery data are listed for CC and FC. The availability data show that well over 99.9%, a design target, was achieved. Such a high availability can be attributed to the short MDT. The main factors are analyzed as follows:

(i) Successful automatic system recovery

The high percentage of the successful automatic recovery has contributed greatly toward reducing the MDT. The effort from this feature is more than what was expected at the beginning of the design.

The percentages of the successful automatic recovery in the total system crashes are about 13% for FC and about 30% for CC.

(ii) Operation by the system console

The system recovery time of the operator was reduced to about four minutes on the average. The time includes the configuration changes by the operator in 20% of the system crashes.

(b) Cause of the system crash

Table 5–3 shows the causes of the system crash. The principle causes of the system crashes are connected to the hardware faults rather than to the software errors.

About 50% of all hardware faults connected to the system crashes are caused by the central processor (BPU, MMU, IOP).

(c) Effectiveness of the fall-back mode

Table 5–4 shows the hardware faults not directly connected to the system crash. Even though the number of disks faults are great, the disk faults had very little effect upon the total system crashes. The reasons can be attributed to the duplicated files and dual access routes. The malfunctions in the disk, channel, and disk controller can be backed up by the duplicated files and another

Table 5–1 Availability of MARS 105.

Year	Expected Availability	Actual Availability	Availability of System		
			A_{CC}	A_{F1}	A_{F2}
1974 (5 months)	99.90	99.96	99.96	99.97	99.99
1975	99.90	99.95	99.95	99.99	99.98
1976	99.90	99.97	99.97	99.97	99.98
1977	99.90	99.97	99.97	99.99	99.98
1974–1977 (3years and 5 months)	99.90	99.96	99.96	99.98	99.98

※ $A = A_{CC} \cdot [(A_{F1} + A_{F2}) - A_{F1} \cdot A_{F2}]$ (%)

A_{CC} : Availability of CC
A_{F1} : Availability of FC1
A_{F2} : Availability of FC2

※ Availability of a subsystem is obtained from the following equation using MTBF and MDT of the subsystem.

$$\frac{MTBF}{MTBF + MDT}$$

※ System crash is defined as either CC failure or simultaneous failure of FC1 and FC2.

※ 1974 data is based on 5 months operation

MARS—105

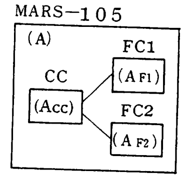


Table 5–2 Availability performance.

System	Year	Operation time (h)	Downtime (h)	Number of down				M D T (h)	M T B F (h)	Availability (%)	Number of Automatic Recovery
				Hardware	Software	Others	Total				
CC	1974 (5 months)	2773.3	1.08	1 1	3	1	1 5	0.07	184.9	99.96	1 2
	1975	6344.0	3.32	1 7	8	6	3 1	0.11	204.6	99.95	1 1
	1976	6326.7	1.63	1 8	0	6	2 4	0.07	263.6	99.97	9
	1977	6326.7	1.98	1 4	0	1 1	2 5	0.08	253.1	99.97	1 3
	1974 ~1977	21770.7	8.01	6 0	1 1	2 4	9 5	0.08	229.2	99.96	4 0
FC1	1974 (5 months)	2773.3	0.73	2	4	7	1 3	0.06	213.3	99.97	0
	1975	6344.0	0.50	3	4	1	8	0.06	793.0	99.99	3
	1976	6326.7	1.55	1 0	0	3	1 3	0.12	486.7	99.97	1
	1977	6326.7	0.35	5	0	1	6	0.06	1054.5	99.99	2
	1974 ~1977	21770.7	3.13	2 0	8	1 2	4 0	0.08	544.3	99.98	6
FC2	1974 (5 months)	2773.3	0.35	5	0	1	6	0.06	462.2	99.99	0
	1975	6344.0	1.08	1 8	1	2	2 1	0.05	302.1	99.98	2
	1976	6326.7	1.23	1 0	0	5	1 5	0.08	421.8	99.98	1
	1977	6326. 7	1.13	1 6	1	1	1 8	0.06	351.5	99.98	4
	1974 ~1977	21770.7	3.79	4 9	2	9	6 0	0.06	362.8	99.98	7

※1 Operation time =(Available time + Downtime) =17.3(h/day)

※2 Availability $= \frac{\text{MTBF}}{\text{MTBF} + \text{MDT}} \times 100(\%)$

※3 1974 data is based on 5 months operation

Table 5–3 Cause of system crash.

Type		CC 1974	CC 1975	CC 1976	CC 1977	CC 1974~1977	FC1 1974	FC1 1975	FC1 1976	FC1 1977	FC1 1974~1977	FC2 1974	FC2 1975	FC2 1976	FC2 1977	FC2 1974~1977
Central Processor	BPU		2	4	3	9	1		2	4	7		2	1	6	9
	MMU	7	3	5	3	1 8		1	7		8	3	8	8	9	2 8
	IOP	2	3	5	5	1 5		1	1		2	1	2		1	4
	Sub-total	9	8	1 4	1 1	4 2	1	2	1 0	4	1 7	4	1 2	9	1 6	4 1
Peripheral Device	MTC/MTS									1	1					
	DKC/DKU		4			4	1	1			2	1	4	1		6
	DRC/DRU			3	3	6							1			1
	DXC	2				2							1			1
	Otber device		5	1		6										
	Sub-total	2	9	4	3	1 8	1	1		1	3	1	6	1		8
Software	Program	2	8			1 0	3	4			7		1		1	2
	Data	1				1	1				1					
	Sub-total	3	8			1 1	4	4			8		1		1	2
Others	Operation	1			4	5	2				2		1	2		3
	Power, Air Conditioner etc		6	6	7	1 9	5	1	3	1	1 0	1	1	3	1	6
	Sub total	1	6	6	1 1	2 4	7	1	3	1	1 2	1	2	5	1	9
Total		1 5	3 1	2 4	2 5	9 5	1 3	8	1 3	6	4 0	6	2 1	1 5	1 8	6 0

※ 1974 data is based on 5 months operation

Table 5–4 Failures not linked to system crash.

Type	Systm / Year	CC					FC1					FC2				
		1974	1975	1976	1977	1974~1977	1974	1975	1976	1977	1974~1977	1974	1975	1976	1977	1974~1977
Central Processor	BPU															
	MMU															
	IOP						8	3			11	1	1	2		3
	Sub total						8	3			11	1	1	2		3
Peripheral Device	MTC/MTS		1			1										
	DKC/DKU				1	1	16	8	7	17	48	19	29	18	20	86
	DRC/DRU		4	1	5	10						2			1	3
	DXC															
	Other Device		4	4	3	11	1	2			3					
	Sub total		9	5	9	23	17	10	7	17	51	21	29	18	21	89
Software	Program							2			2					
	Data	1				1	2	1		1	4	1			1	2
	Sub total	1				1	2	3		1	6	1			1	2
Others	Operation, etc.	1				1	3		1		4	1				1
Total		2	9	5	9	25	30	16	8	18	72	24	31	18	22	95

※ 1974 data is based on 5months operation

Table 5–5 Amount of program.

ON LINE(RTCS, CUP, SOP)

Item / Year	1974※	1975	1976	1977
Number of Program Updates	49	59	115	75
Amount of Updated Steps	7,830	1,730	18,640	16,120
Number of Program Failurs	17	23	12	13
Amount of On-line Program (Steps)	196,540	198,270	214,920	231,040
Percent of Updated Program	4.0	0.9	7.7	7.0

BATCH (File maintenance, Statistical prog, Test prog)

Item / Year	1974	1975	1976	1977
Number ot Program Updates	133	163	284	311
Amount of Updated Steps	14,450	37,610	35,370	67,140
Number of Program Failurs	44	38	41	54
Amount of Batch Program(Steps)	357,770	395,390	430,760	497,910
Percent of Updated Program	4.0	9.5	8.2	13.4

1974 data is based on 5months operation

channel or disk controller. The system has never experienced the simultaneous failure of the duplicated file since the start of MARS 105 operation.

(d) Software reliability

The number of software changes and the program bugs are listed on Table 5–5. Even with such large software changes, the system crashes caused by the software bugs were very few. Although there were few system crashes at the beginning of the operation, not one system crash has occurred in past three years. It can be concluded that the testing procedure in Fig. 5–1 has been effective in reducing the software bugs.

5.2 Reliability of Communication Network

(1) Number of the communication lines

The number of the communication lines connected to the system is shown in Fig. 4–3.

(2) Performance data

(a) Availability of the communication lines

The private communication lines owned by JNR are used to obtain the availability of 99.93% which can be considered satisfactory in this type of application.

(b) Quality of the communication lines

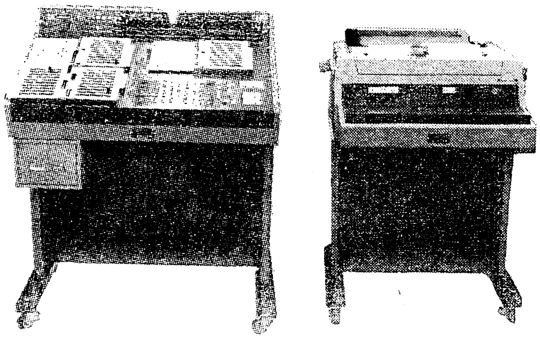
The quality of the communication lines are checked by the four pilot lines in representative directions from Tokyo. The bit error rates (200 bps) are measured in parallel with the on-line operation. The result of the measurement shows 3.7×10^{-6} bit error rates on the average.

5.3 Terminal

(1) Types of terminals

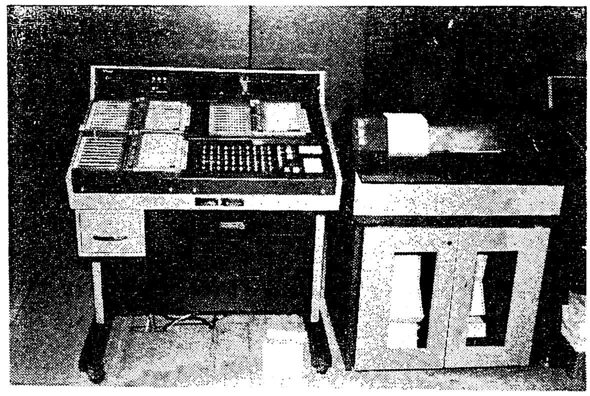
The types of terminals used by MARS 105 system are shown in Fig. 5–2.

N-type (200bps)



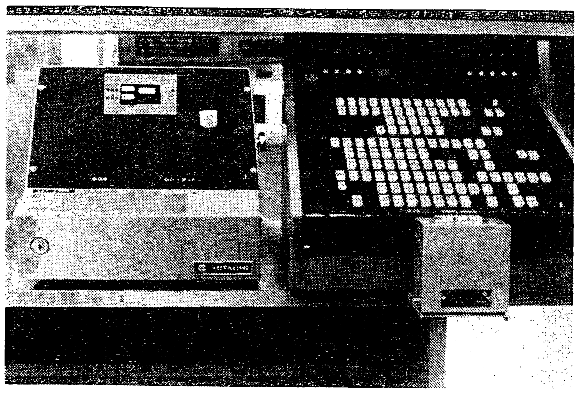
The terminal was especially designed for MARS 105. Train names and station names are selected by the pins on the paged matrix plates. Special purpose keys perform all the other desired functions.

HN-type (2400bps)



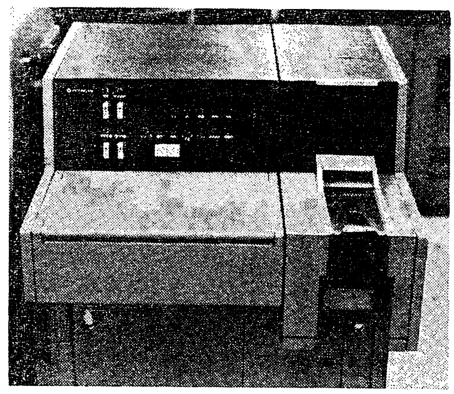
A fast line printer enables speedier tickets printing. Its functions and operations are the same as that of N-type terminal. It is installed primarily in principal stations such as Tokyo and Osaka.

AB-type (50bps)



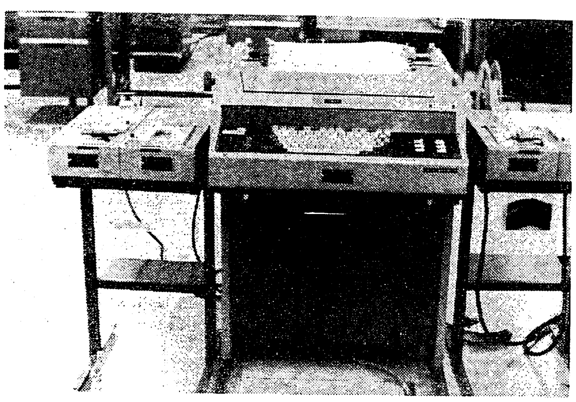
Special type-bars with Japanese character are inserted to input the train and station codes as well as to print these names on the ticket. The terminals are soon to be replaced by more advanced N-type terminals.

C-type (200bps, 2400bps)



The terminal is attached to N-type, HN-type terminals as option, and is used to cancel a reserved seat by optically reading cancellation codes on the ticket.

DT-type (200bps)



A 'general purpose' terminal used to output manifests and other sales information.

Fig. 5–2 Terminals of MARS 105.

(2) Performance data

(a) Terminal utilization

The normal utilization of each type of terminal is listed in Fig. 4–4. During the peak traffic seasons the terminal utilization increases to 2.5 times as compared with the off-peak period.

(b) Terminal failure rate

The failure rate of the N-type terminals, which is used most frequently, is about 0.5 failures per month per terminal. The mechanical part of the printer contributes 80% of the terminal failures. To improve terminal reliability, the development of new printer is under consideration.

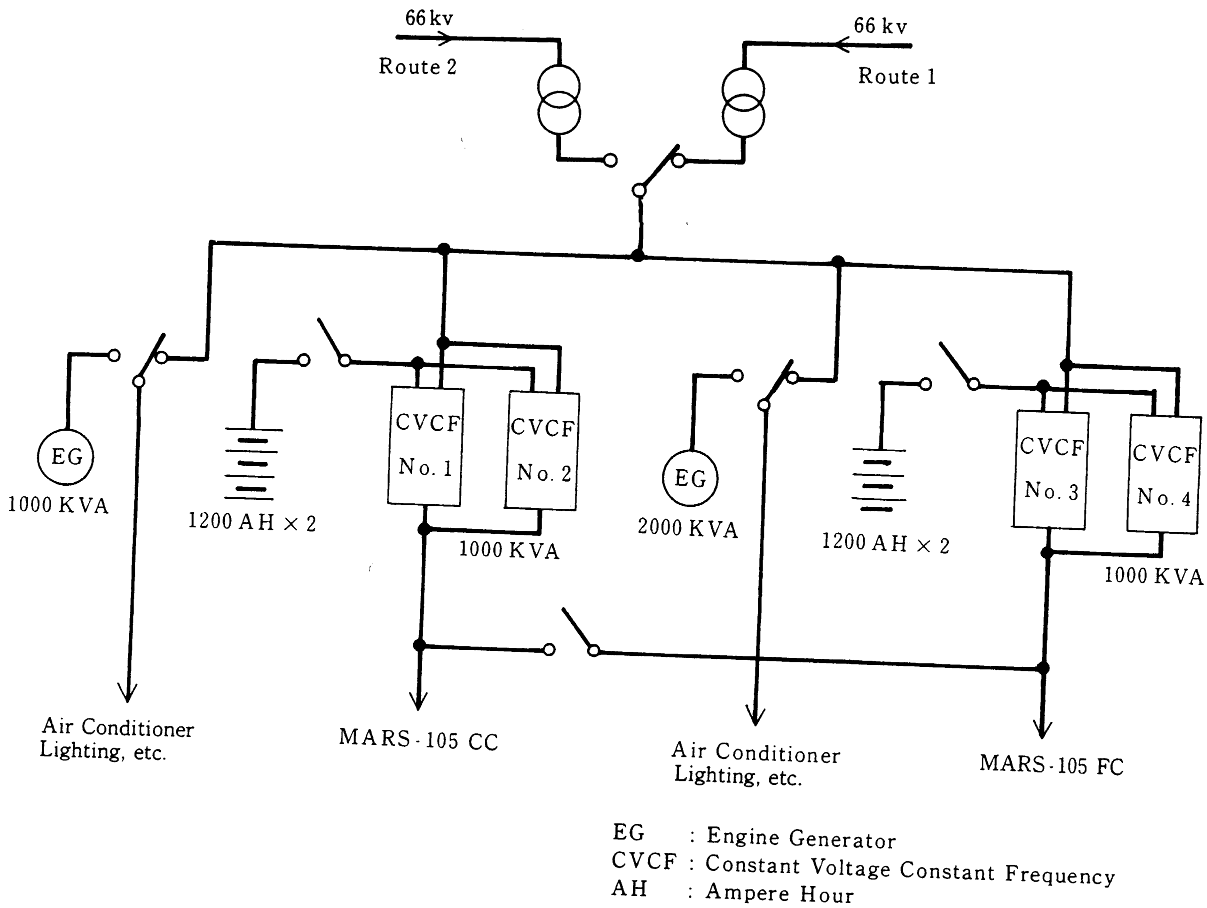


Fig. 5–3 Power supply equipments.

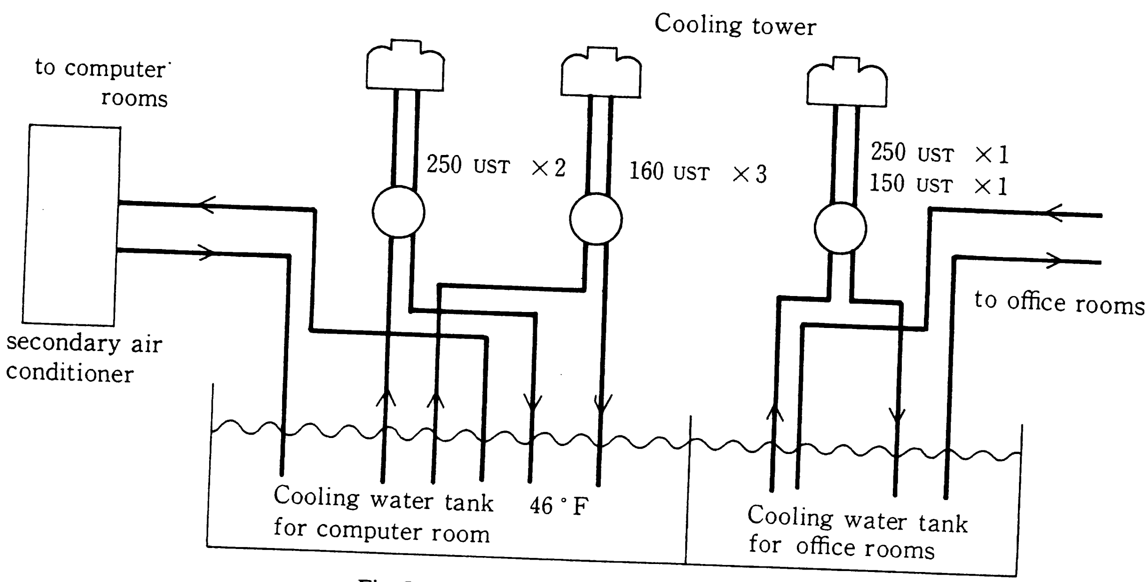


Fig. 5–4 Air conditioning equipments.

5.4 Power Supply and Air Conditioning Equipments

(1) Power supply

The electrical power to the computers are supplied through the CVCF (Constant Voltage Constant Frequency). The battery is installed to supply power to the CVCF for approximately 30 minutes in case of complete power failure.

The outline of the power supply equipments is shown in Fig. 5–3.

(2) Air conditioning

The waters in the cooling tank is cooled by the refrigerator, and by using this cooled water, the secondary air conditioning equipments at each floor distributes the cooled air to the computers. When the power fails or the refrigerators fails, it is possible to cool the computers for 30 minutes by using this cooling water tank.

Fig. 5–4 shows the outline of the air conditioning equipments.

6. Conclusion

From the four years performance data as presented in the paper, it can be concluded that the availability performance has surpassed the design target. Such high availability was achieved primarily through the support of the multiprocessor and the automatic system recovery.

The system is operating very satisfactorily, but the system was designed 8 years ago. Since then, the technology in the computer has advanced greatly.

In the next phase of the MARS system, the advanced technology should be fully adopted to obtain high reliable system.

Also, the advancement in the software technology should be fully utilized for simple program maintenance. The productivity of the software will increase through the usage of the high-level language instead of the assembly language.

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