TRAIN OPERATION CONTROL SYSTEM OF THE NEW TRANSPORT SYSTEM IN YOKOHAMA KANAZAWA SEASIDE LINE

Gembei Kobayashi
Managing Director
Yokohama New Transit Corporation
2-1-1, Sachiura, Kanazawa-ku
Yokohama 236, Japan
Fax No.: 045-787-7019

Masaaki Kuwabara
General Manager
Transportation System Dept.
Chemical Eng. & Const. Division
Niigata Engineering Co., Ltd.
9-3, Kamatahoncho 1-Chome, Ohta-ku,
Tokyo 144, Japan
Fax No.: 03-3737-1168

Hideki Mori
Manager
International Sales Department
Chemical Eng. & Const. Division
Niigata Engineering Co., Ltd.
9-3, Kamatahoncho 1-Chome, Ohta-ku,
Tokyo 144, Japan
Fax No.: 03-3739-8119

abstract:

Kanazawa Seaside Line started its revenue service in July 1989 in Yokohama, Japan.
Total route length is 10.6 km(double track). Number of stations is 14. It has 17 trains with 5-car-consists. The revenue service started using manual operation system, i.e., driver on-board.
In April 1994, Kanazawa Seaside Line started driverless operation after the successful conversion work from manual operation system to fully automated system. This conversion work was done by Niigata Engineering Co., Ltd.
Currently, Kanazawa Seaside Line is providing an excellent service to 40,000 to 55,000 passengers daily.
This paper describes the fully automated train operation system of Kanazawa Seaside Line.

1. INTRODUCTION

Kanazawa Seaside Line was constructed in the reclaimed land in southern part of Yokohama City. This development area provides new housing complex and industrial park. Other major facilities include university hospital and 'Hakkeijima' amusement park. It is providing revenue service for approximately 18 million passengers annually (40,000 to 55,000 passengers per day).

The route extends from JR Keihin Tohoku Line's 'Shin-Sugita Station' to Keihin Electric Express Railway Line's 'Kanazawa Hakkei Station'.

Overview of Kanazawa Seaside Line:

1) Operating company: Yokohama New Transit Co., Ltd.

2) Route:
   Total length : 10.6 km
   Double Track, Elevated

3) History:
   a. Revenue Operation Started (Manual Operation) : July, 1989
   b. Combined Operation (Manual and Automated) : Nov. '93 - Apr. '94
   c. Fully Automated Operation : Apr. '94 - Now

4) Fleet Size:
   Number of cars per train : 5
   Number of trains : 17

5) Car:
   a. Nominal Capacity per Car:
      Type I : 66(21 seated, 45 standing)
      Type II : 75(24 seated, 51 standing)
   b. Car Size : 8.4 m (L) x 2.38 m (W) x 3.28 m (H)
   c. Doors : one/each side of the car
   d. Emergency Exits : Front and rear ends of the train
   e. Max. Speed : 60 km/hour
   f. Guide System : Side Guide, Front and rear 4 wheel steering
   g. Bogie : Unit bogie with parallelogram link with Diaphragm type air suspension
   h. Tire : Tubeless Steel Cord Radial Tire with Inner Safety Wheel

6) Train Control:
   a. Operations:
      Train : Manual / Automated (since April 1994)
      Wayside : Automatic (Route control and Departure timing control)

b. ATC Communication:
Inductive Radio Loop
c. Block Type : Fixed Block Type
d. Train Detector : Non-contact type Check-in/Check-out

7) Guideway:
a. Length : 10.6 km (Dual Track)
b. Guide Rail Gauge : 2.9 m
c. Guidance : Side Guide System
d. Running Surface : Concrete
e. Switches : 12 switches in main line with Fixed and Movable blades

8) Propulsion:
a. Power Distribution System : DC 750V
b. Power Collection : 2 rigid power rails on one side
c. Propulsion Motor : 100 kW, 6 motors/train

9) Stations:
a. Number of stations : 14
b. Platform Doors : Provided

10) System Operation:
a. Minimum Headway:
Current operation : 5 minutes
Capability : 3 minutes
b. Cruse speed : 57 km/h
c. Service speed : Approx. 26 km/h

2. SYSTEM STRUCTURE

Block diagram of central control system and wayside control system is shown in Figure 1. Block diagram of on-board control system is shown in Figure 2.

Boxes with weak lines represent originally installed equipment, rounded boxes represent modified equipment, and rounded boxes with thick lines represent the new equipment.

2.1 Control Functions in Manual vs. Automatic Operation

Control Functions	Manual Operation	Automatic Operation
Train Start/Stop/Speed	Driver	ATO
Door Open/Close	Driver	ATO
On-board Announce	Driver	ATO
Station Announce	PTC	PTC
Station Graphics	PTC	PTC
Route Control	PTC	PTC/ARC
Traffic Control	PTC	PTC/ARC

Train Monitoring	-	ATO
Train Remote Control	-	ATO

Abbreviations:

ATO	: Automatic Train Operation equipment
PTC	: Programmed Traffic Control equipment
ARC	: Automatic Route Control equipment;

2.2 Main Design Concept of ATO Modifications

a. Minimize the modification work on PTC, ATP, Door Protection System to keep existing facilities unchanged as much as possible in order not to interrupt the on-going revenue service. Especially, not to make the interface to existing PTC system with Central Computer, which has programs that will be easily damaged if modified.

b. Employ the distributed control system to realize step by step ATO modification for each station and each train because it was essential to complete the conversion work without stopping the revenue service. Distributed control system also prevents the total system shut down. ATO function shall not be modified but some functions were added, i.e. on-board ATO, ATO at Station Control Unit (SCU), Loop Coil, and on-board SCU. On-board ATO and SCU control train-start and train-stop operation at stations. ATO Central Control provides only monitoring and overriding functions only when it is necessary .

c. Utilize a pattern-on-the-car stopping method to reduce the wayside work volume. Wayside signal is based on transponder method using de-energized loop coil. As the result, power cabling work was not necessary.

d. Install ATO test facilities, i.e., ATO inspection area and ATO test track at depot. Train ATO functions at stations, such as train stopping, door opening /closing, and train starting, shall be checked at ATO inspection area. Train ATO functions while running between stations, such as acceleration and deceleration shall be checked at ATO test track within the depot.

Since the on-board ATO modification work required time consuming wiring work, it took 1.5 month to complete the modification work for each train.
After the modification work, the trains were tested at the depot, and also on the revenue service line during the night after the last train of the day returned to the depot. After these tests, ATO upgraded trains were sent for service operation with attendant on-board. During the modification work of whole fleet of trains, the revenue service was carried out in mixture of manual and automatic operation with an attendant on-board.
The fully automated operation, without drivers or attendants, of all trains started in April 1994.

2.3 ATO system structure

a. Train control between stations:
Train control between stations(acceleration, speed control, deceleration, stopping position control)is performed by newly introduced on-board ATO equipment. Target speed is controlled by the speed limit signal from ATP(on-board signal).

b. Programmed stop control:
Programmed stop control is carried out using the stopping pattern of on-board ATO which recognizes the distance to the next station by responses from the loop coil installed at 240 m, 85m, and 10m before the stopping point. The running pattern between stations is shown in Figure 3.

c. Station Control:
Station control includes confirmation of stopping position, door operation, direction change, limitation of stopping interval, and starting control. Sequential signal communication for station control between ATO Station Control Unit and on-board ATO equipment is carried out via loop coil installed on running surface and the on-board ATO antenna installed under the car body.

Communication is also kept between ATO Station Control Unit and ATO Central Control Equipment so that the train status can be monitored at Central Control Room.

d. Train Monitoring and Remote Control:
Train monitoring and remote control systems include Central Control Operator(CCO), wireless train communication telephone, and on-board emergency signal transmission system which requests emergency power shutdown. These systems employ inductive radio transmission with frequency modulation.
By expanding this function, the train control status and trouble signals are transmitted from trains to CCO. Then, CCO send back the reset emergency stop signal, reducing speed signal, etc., to trains.

e. ATO Central Control:
ATO Central Control Equipment, which was newly installed in the Central Control Station, sends station control signal and status data to SCU via SCU Data Transmission. ATO Central Control Equipment also sends train control signal and status data via Train Data Transmission system described in item d. Furthermore, the equipment interfaces with existing ATP and sends train position data, remote control and status, and station graphic indication data, automatic audio announcement data for station area, etc., via Central Traffic Control Data Transmission. The interface with Programmed Traffic Control(PTC) was not provided because modification of software, adjustment and test operation will be difficult without stopping revenue service.
Three new control desks are installed in Central Control Room. Two ATO control desks for main line and one control desk for Depot operation. These desks monitor all train status and provide remote override control if necessary. ATO Central Control Unit performs 1) ATO function in Programmed Traffic Control(PTC) mode, and 2) Automatic Route Control function when PTC is out of order.

As a summary, ATO Central Control Unit has following functions other than normal ATO function;

- Fixed(Variable) Interval Departure Control
- Automatic Route Control
- Station Information Control
- Audio Announcement Control(Station/Onboard)

2.4 Functional Description of ATO

ATO Control Sequence Flowchart is shown in Figure 4.

3. EXECUTION SCHEDULE OF ATO MODIFICATION

ATO modification schedule is shown on Table 1. ATO modification work was carried out in the following steps.

1) Wayside equipment installation
2) Upgrading station ATO equipment
3) Installation of new control desks and modification of original control desk
4) Addition of monitoring function of ATO Central Control Unit
5) Modification of control function of ATO Central Control Unit
6) Trial operation in automatic/manual mix mode
7) Starting fully automatic operation in all stations and trains

The execution schedule was achieved successfully without major problems.

4. CONCLUSION

We believe that our concept of "distributed ATO system structure" realized the step-by-step conversion to fully automated (driver-less) operation system without stopping revenue service. It would be our pleasure if our experience could help the ones who are planning the similar upgrading projects.

ACKNOWLEDGMENTS

We would like to express our sincere gratitude to Yokohama City and manufactures who worked for us during the ATO modification project.

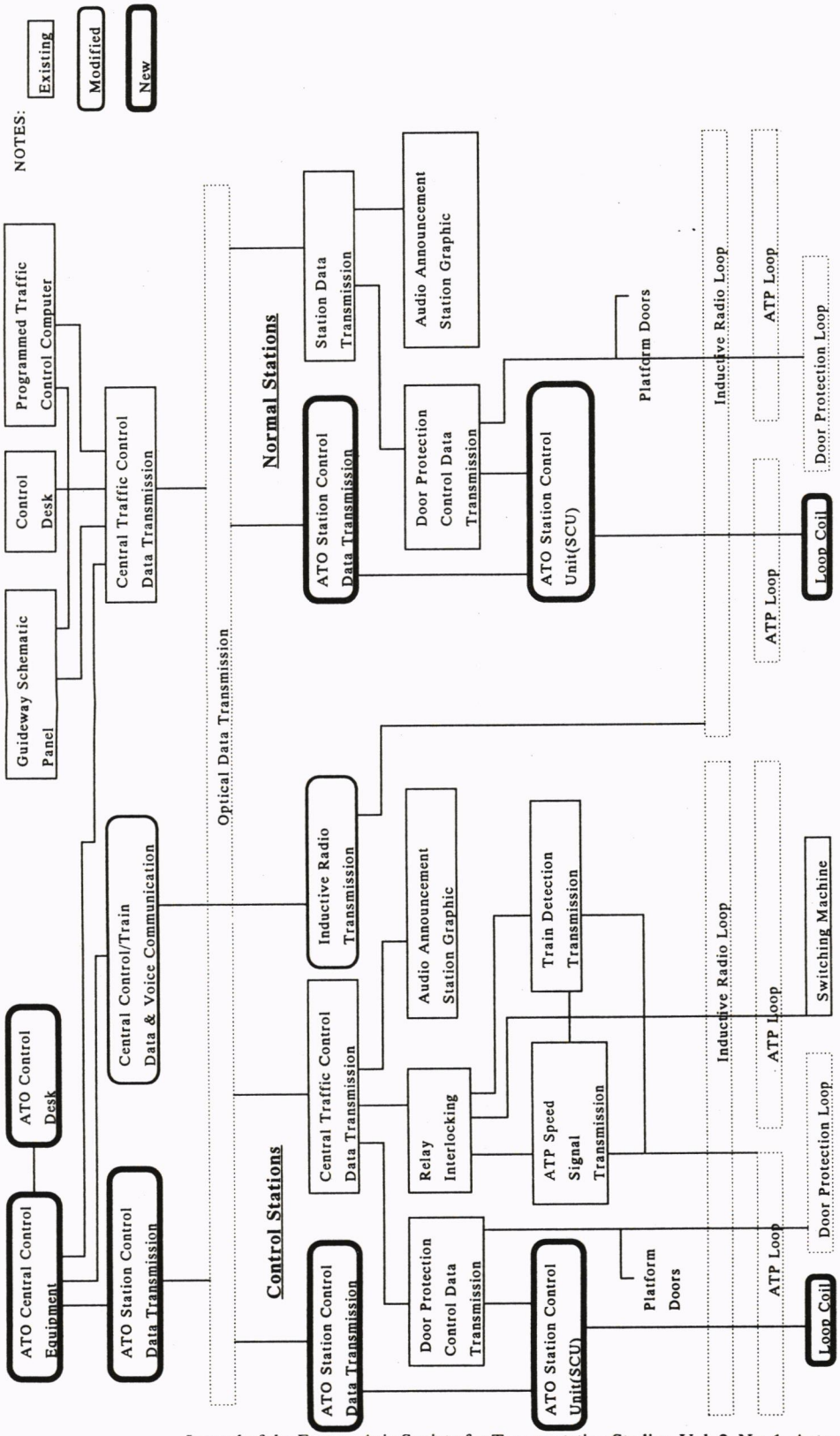


Figure 1. CENTRAL CONTROL & WAYSIDE CONTROL SYSTEM

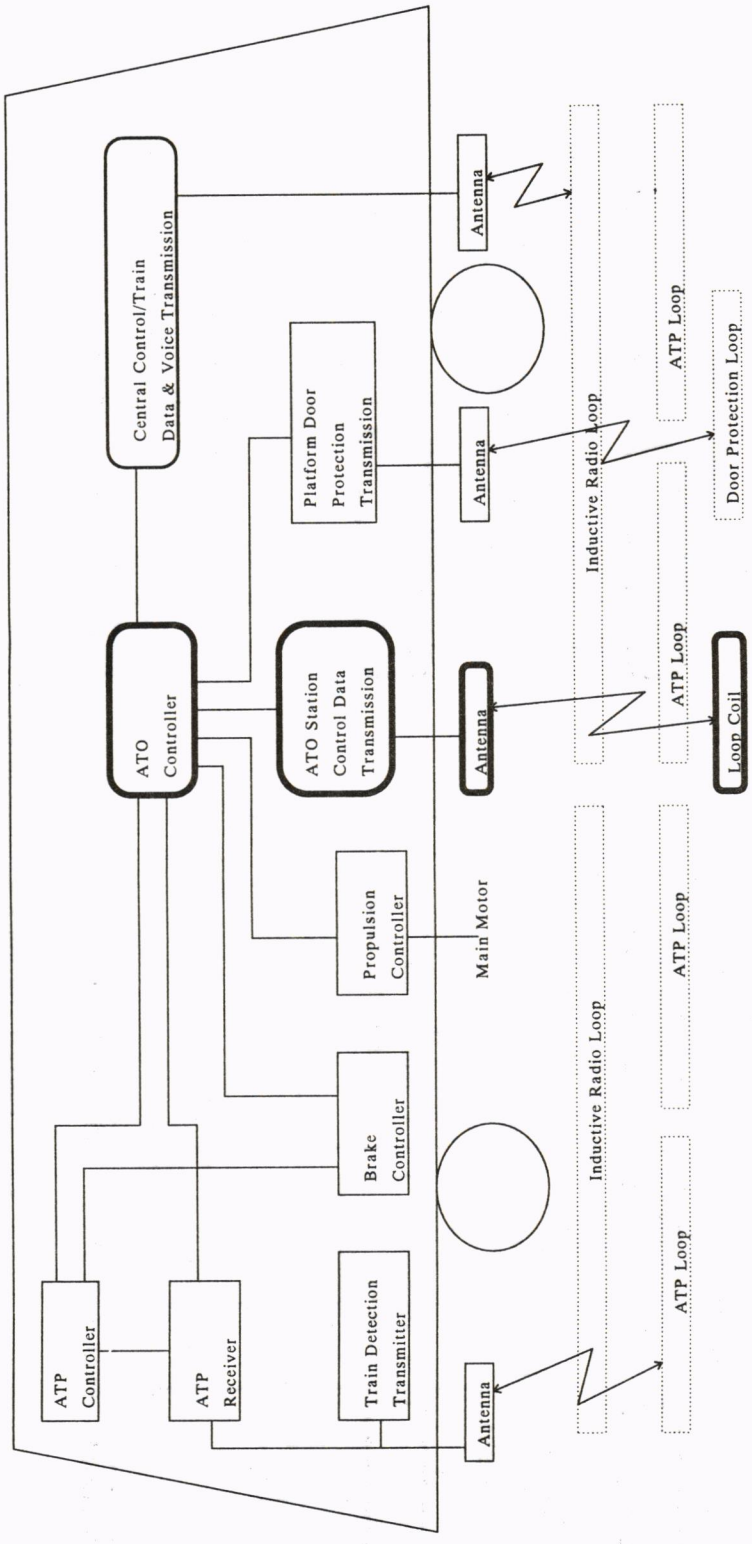


Figure 2. ON-BOARD CONTROL SYSTEM

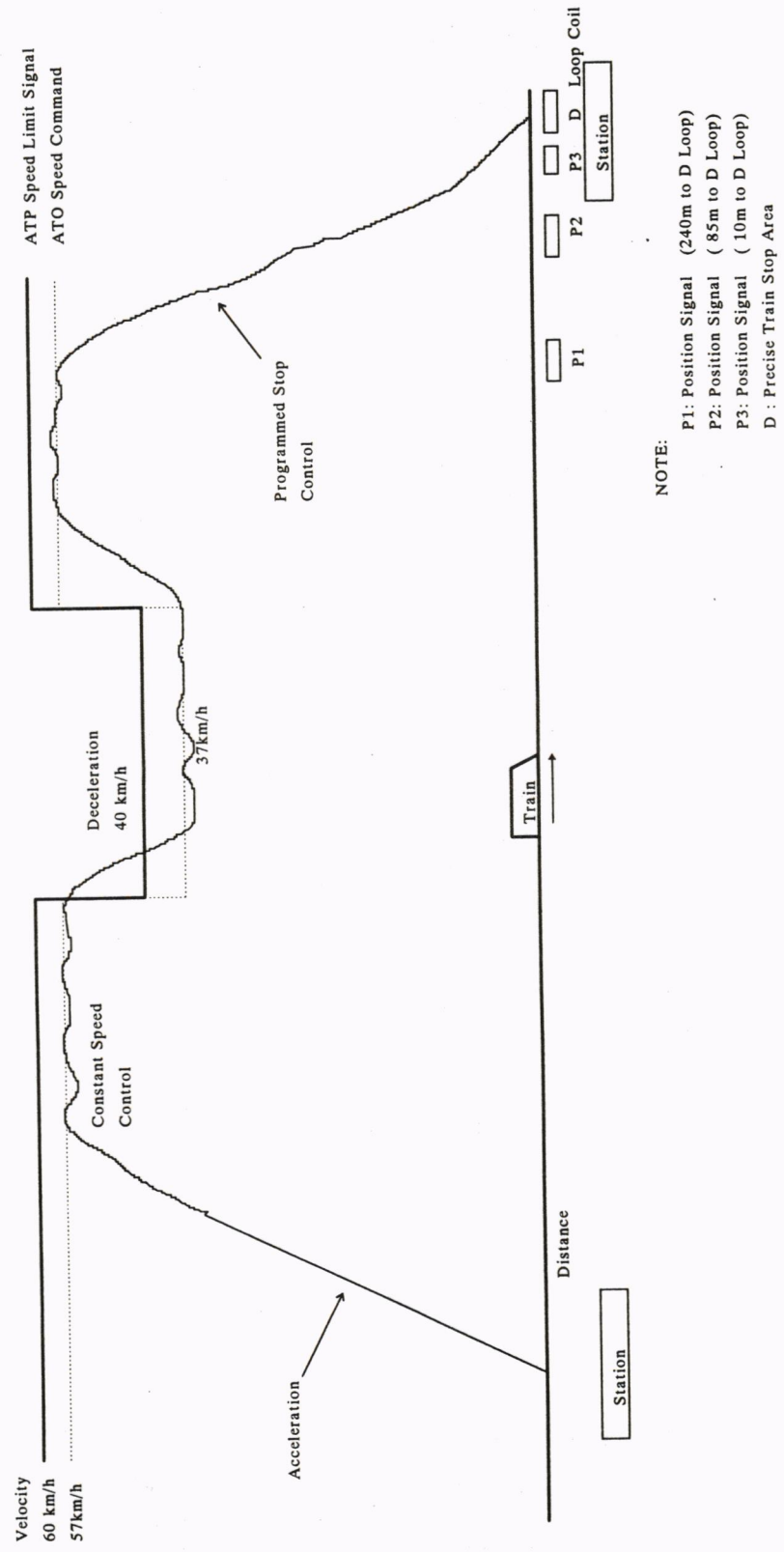


Figure 3. ATO SPEED CONTROL PATTERN

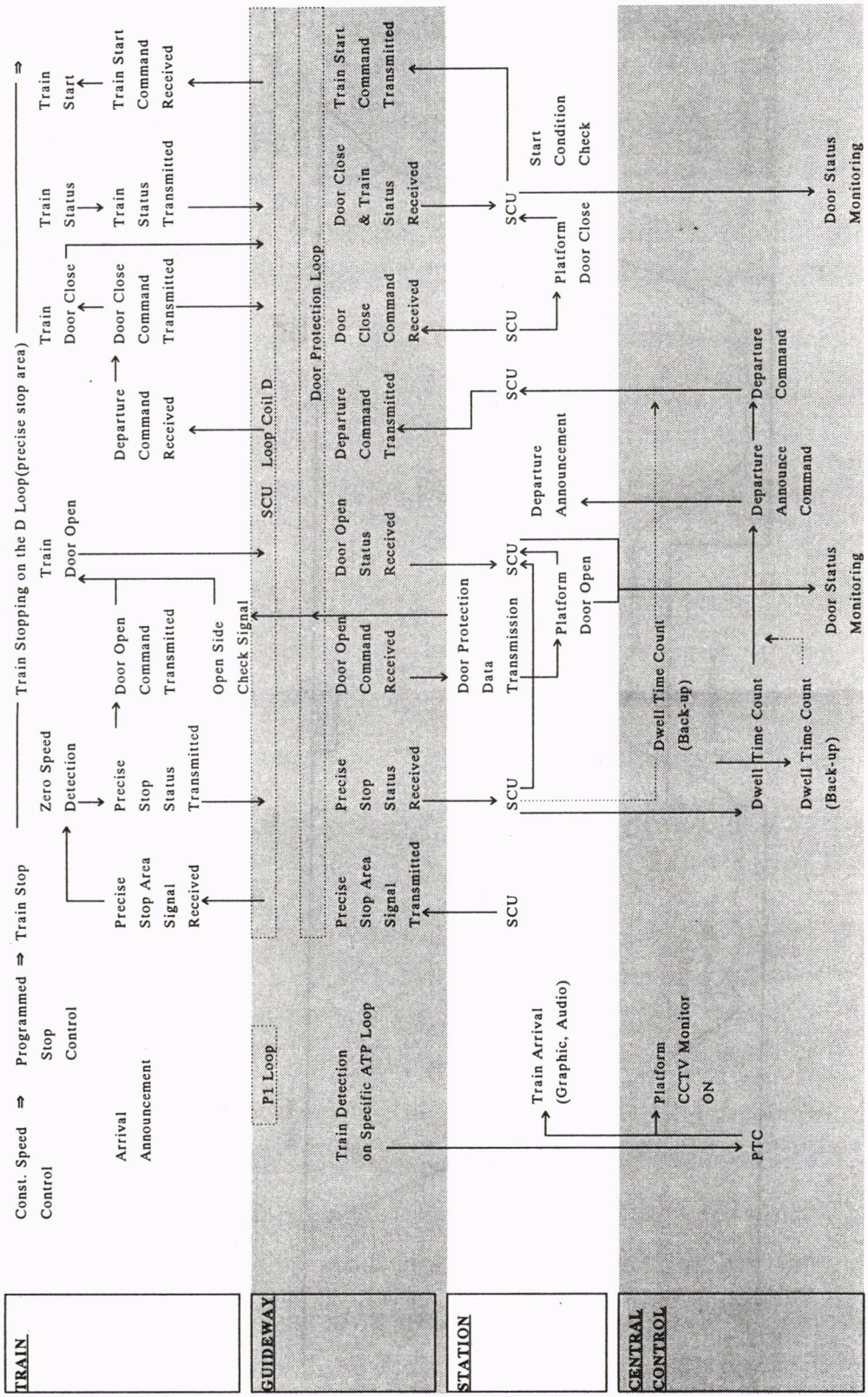
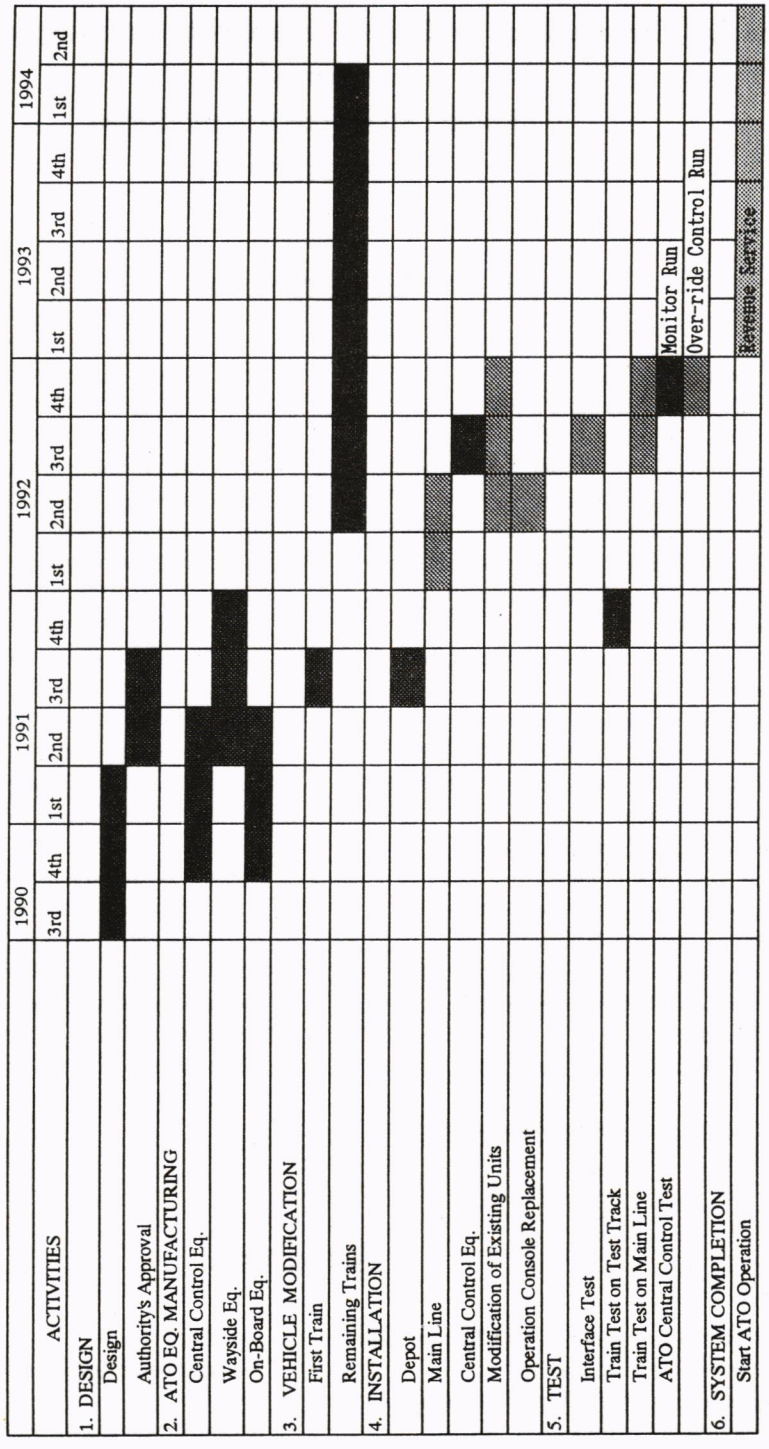


Figure 4. ATO CONTROL SEQUENCE FLOWCHART

Table 1. ATO MODIFICATION SCHEDULE



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