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Automated Guideway Transit Technology Development

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16. Abstract

Automated Guideway Transit (AGT) systems offer the promise of meeting many of our present and future urban transportation needs and providing convenient and dependable service. However, many technological problems must be resolved before an AGT system can become a major transit operation. To address these problems, the Federal Government established the AGT Supporting Technology (AGTST) Program. The AGTST program includes many projects aimed at specific problem areas. These include: Systems Operation Studies, Systems Safety and Passenger Security Studies, Vehicle Longitudinal Control and Reliability Studies, Vehicle Lateral Control and Switching Studies, and Guideway and Station Technology Studies. This overview describes the AGTST program and presents results which are available or will be available in the near future. This report was compiled from material provided by the staff of the Office of Technology Development and Deployment, Urban Mass Transportation Administration; the Transportation Systems Center, Research and Special Projects Administration; and The MITRE Corporation.

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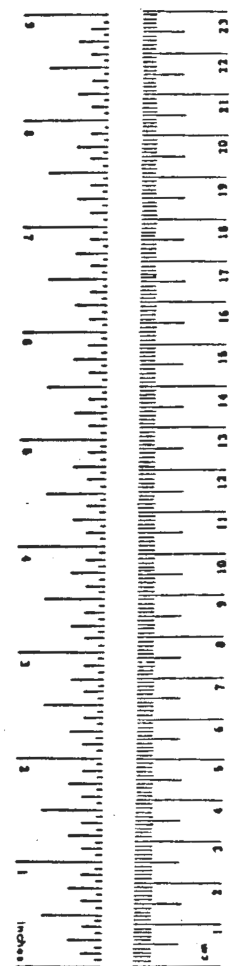
METRIC CONVERSION FACTORS

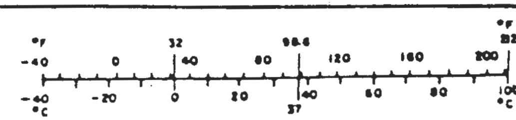
Approximate Conversions to Metric Measures

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



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	35	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



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1. PROGRAM OVERVIEW

1.1 Background

Automated guideway transit (AGT) systems have a high potential for meeting UMTA's goal to improve mass transportation service in a cost effective manner. By adopting automation techniques, the cost of system operation can be substantially reduced through elimination of the vehicle operator. Deployed AGT systems such as those at Tampa and Seattle-Tacoma airports are successfully operated with less than 0.2 man-hours of staff per hour of vehicle operation. Further benefits of automation are gained if vehicle size and operating headways are reduced. Smaller vehicles permit significant reductions in guideway cross-section, thus reducing guideway cost and simplifying system introduction into existing urban sites. Smaller vehicles also allow for the development of extensive urban guideway networks. Flexible routing will also result in improvements in operating efficiency and cost-and-energy effectiveness as a result of improved vehicle load factors. The resulting reductions in access and transfer delays as well as high travel speed should contribute to substantially improved service levels.

The concept of Automated Transit emerged in the early 60's, spurred by the successful application of the concepts of automatic control in the areas of defense and industrial process control. One of the first major developments of an automated urban transit system was the Westinghouse "Transit Expressway" which was developed under Urban Mass Transportation Administration sponsorship in the 1960s. Capable of automatic operation at 60-second headways, the service characteristics of the "Transit Expressway" were similar in many respects to conventional rail rapid transit systems. Towards the end of the 60's, it was recognized that improvements in service and ability to adapt to the diverse trip patterns in modern urban areas could be achieved by operating smaller vehicles at shorter headways with off-line stations. This led to serious studies of short headway operation, the development of system concepts, and the deployment of the "AIRTRANS" and "Morgantown" Automated Guideway Transit (AGT) systems which began revenue service in 1973 and 1975, respectively.

Currently, initial urban deployment of AGT systems is underway as a result of the Downtown People Mover (DPM) Project. This project will result in the deployment of at least three different AGT system technologies in urban cities. Simultaneously, work is progressing on more advanced systems such as the

Advanced Group Rapid Transit (AGRT) system which will be capable of serving the more extensive AGT networks envisioned for the future. These activities increase the need for technical, service, and cost data to assure effective deployment of these new transit technologies.

While technological development continued, the severe operational problems encountered by the deployed systems in the early stages of revenue service eroded confidence in the ability of automated transit to solve urban transportation problems. It was recognized that Government sponsorship of research on solutions to the critical problems of automated transit systems and a complete assessment of existing AGT designs were required to achieve a sound basis for urban deployment.

In response to these demands, the Urban Mass Transportation Administration established the Automated Guideway Transit Supporting Technology (AGTST) program in 1975. This report summarizes the activities currently in progress in the AGTST program.

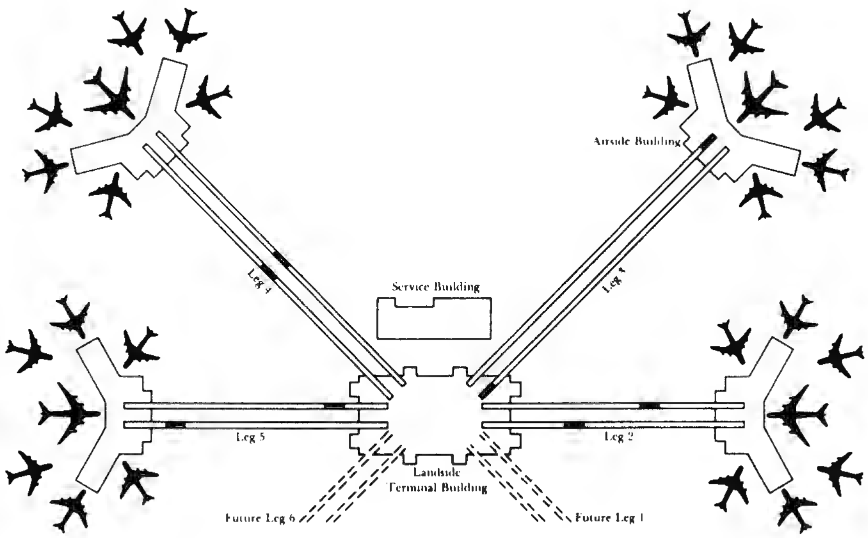
1.2 Definitions

Automated guideway transit systems are types of urban transportation systems and concepts that use automatically controlled, driverless vehicles on fixed, dedicated guideways. The capacity of a vehicle can range from four up to 100 passengers and the vehicles may move at cruise speeds from 25 to 100 kilometers per hour. On the basis of past research, several categories of automated transportation systems have become generally accepted. Three classes of service provide a structure for the study of automated guideway transit technology:

a. Single Line Transit,
b. Group Rapid Transit, and
c. Personal Rapid Transit.

Single Line Transit (SLT) systems generally utilize larger vehicles (carrying mostly standees), which operate in scheduled service on relatively short lengths of dedicated guideway in activity centers, normally without switching. The shuttles accommodate a single vehicle within the dedicated lane. Headways are generally in excess of one minute in loops.

The Tampa International Airport system shown in Figure 1.2.1 is an example of SLT. The terminal central building is connected to four satellites by elevated guideways, each containing two passenger vehicles on separate tracks and a walkway for emergency use. The average trip time, counting waiting time and riding, is 1 and 1/4 minutes.



(a) AGT System Network

(b) AGT System Vehicle on Guideway

FIGURE 1.2.1 THE TAMPA SHUTTLE TRANSIT SYSTEM FEATURES EIGHT VEHICLES OPERATING ON FOUR DUAL SHUTTLES, 238 M AND 305 M IN LENGTH. THE SYSTEM IS CAPABLE OF SCHEDULED OR DEMAND-RESPONSIVE SERVICE.

Group Rapid Transit (GRT) systems generally use fleets of medium sized vehicles (normally 6 to 50 passengers per vehicle, including standees). These vehicles operate independently or are coupled into trains, which travel automatically on dedicated guideways with online and/or offline stations, and provide either scheduled or limited-stop, origin-to-destination demand responsive service. When operated on headways of 3 to 60 seconds, lane capacities ranging from 2,500 to 25,000 seats per lane per hour are obtained.

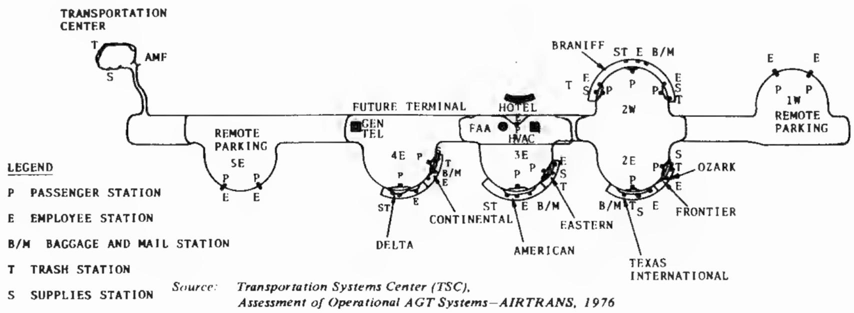
The Dallas/Fort Worth Airport GRT (AIRTRANS) is shown in Figure 1.2.2. The AIRTRANS system links the numerous, widely separated elements of the airport. There are approximately 21 kilometers of one-way guideway carrying 68 vehicles between 55 station stops. Seventeen distinct service loops provide for passenger, airport employee, baggage, and mail transportation.

Personal Rapid Transit (PRT) systems use fleets of small vehicles, transporting 2 to 6 passengers each, that travel automatically in dedicated guideways with off-line stations to provide nonstop origin-to-destination, demand responsive service. High capacities of 30,000 or more seats per lane per hour are achieved by operating the vehicles at short headways (0.2 to 3 seconds); that is, up to 18,000 vehicles per hour per lane.

The Cabinentaxi test track at Hagen, West Germany shown in Figure 1.2.3 is an example of PRT. The small, 3-seat vehicles (no standees) are designed to travel at speeds up to 35 kilometers per hour at headways of one second and less, between off-line stations.

In addition, other automated transit modes which have been defined include Dual Mode Transit (DMT) and Automated Mixed Traffic Vehicle (AMTV) systems. Dual Mode Transit systems feature vehicles which are capable of operation under manual control on conventional road surfaces as well as automatic operation on guideways. Dual Mode concepts are generally envisioned as operational extensions to GRT or PRT networks. Automated Mixed Traffic Vehicle Systems incorporate vehicles which are capable of automatic operation at low speeds in mixed pedestrian/AMTV vehicle environments (e.g., such as pedestrian malls) or at higher speeds on separate guideways and could be applied in SLT and limited GRT applications.

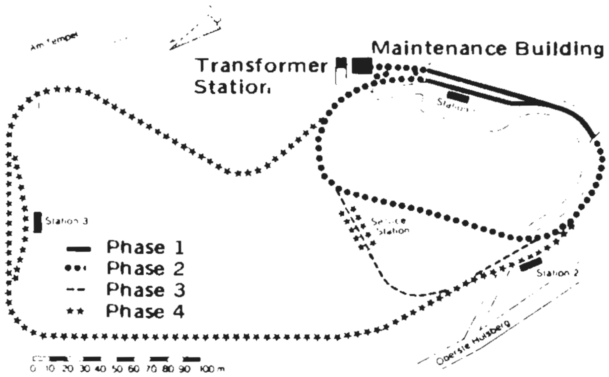
For the purposes of the AGTST program the performance characteristics of the AGT modes have been summarized in Table 1.2.1.



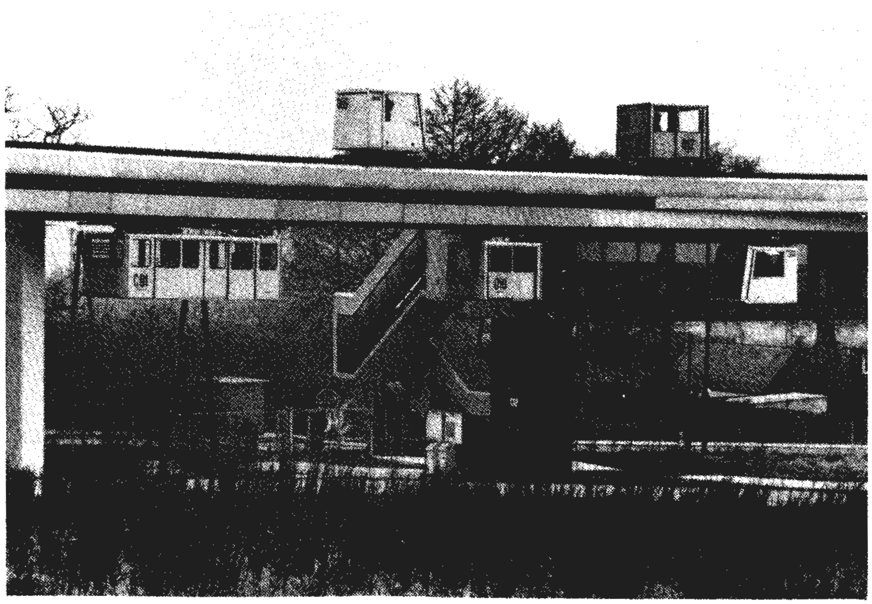
(a) AIRTRANS System Network

(b) AIRTRANS Vehicles on Guideway

FIGURE 1.2.2 **THE AIRTRANS SYSTEM AT DALLAS-FORT WORTH AIRPORT IS THE LARGEST AND MOST COMPLEX AGT SYSTEM DEPLOYMENT IN THE WORLD. THE SYSTEM PROVIDES SCHEDULED SERVICE ON SEVERAL ROUTES.**



(a) Cabinentaxi System Test Facility Network in Hagen



(b) Cabinentaxi Vehicles on Test Track

FIGURE 1.2.3 THE 2 KM CABINENTAXI TEST TRACK IN HAGEN, WEST GERMANY, SHOWING THE THREE PASSENGER PRT VEHICLES IN BOTH A SUPPORTED AND SUSPENDED CONFIGURATION AND A GUIDEWAY COMPATIBLE 12-PASSSENGER SUSPENDED VEHICLE.

TABLE 1.2.1

AUTOMATED GUIDEWAY TRANSIT VEHICLE CATEGORIES

Category	Minimum Headway (secs)	Maximum Line Speed (KM/HR)	Energy Utilization (KW-HR / Veh.KM) [1]	Number of Passengers [2]	Empty Vehicle Weight (Newtons)	Size (Meters)		
						Length	Width	Height
SLT [Nominal]	>60 [90]	25 - 100 [50]	2.0	20 - 120 [80/30]*	45,000 - 135,000 [110,000]	7.5 - 12.0 [11.0]	2.5 - 3.0 [2.75]	3.0 - 3.75 [3.5]
GRT_L [Nominal]	15 - 60 [20]	25 - 100 [65]	1.4	20 - 50 [30/20]*	35,000 - 90,000 [55,000]	4.5 - 7.5 [6.0]	1.8 - 2.2 [2.0]	2.5 - 3.5 [3.0]
GRT_S [Nominal]	3 - 15 [5]	25 - 80 [65]	0.60	6 - 25 [15/10]*	3,000 - 65,000 [45,000]	3.5 - 5.0 [4.3]	1.8 - 2.2 [2.0]	2.4 - 2.8 [2.5]
PRT [Nominal]	<3 [0.5]	30 - 75 [50]	0.15	2 - 6 [3] [4] [3]	4,450 - 13,000 [6,500]	2.2 - 3.0 [2.5]	1.2 - 1.8 [1.5]	1.5 - 1.8 [1.8]

(1) Propulsion Energy

(2) Total Vehicle Capacity, Seated and Standing/Number of Seats

(3) All Seated

1.3 Objectives

The main purpose of the AGTST program is to provide information to system designers, developers, and planners that will assist in the development and deployment of new automated guideway transit technology systems in various application areas.

Objectives of the AGTST program are:

a. Develop a comprehensive AGT network simulation capability, suitable for a wide range of AGT system concepts and applications;

b. Explore the service and operating costs of AGT systems in various applications;

c. Identify, develop and test the critical technology required for the successful operation of AGT systems in urban deployments;

d. Study the technology requirements and the feasibility of advanced AGT systems and develop and test the essential subsystems;

e. Generate the technical and operating data required to make decisions concerning future AGT program activities;

f. Reduce the technical and financial risks involved in the development and deployment of automated systems; and

g. Develop a national data base for use by system designers, developers, local planners, and government officials to assist in selecting and evaluating automated systems and in preparing performance specifications.

The major benefit of the AGTST program is that program resources can be directed towards the solution of generic problems such as system operation and passenger processing, thus saving unnecessary duplication in each system development.

1.4 Activities

The AGTST program is being performed in two phases. Phase I, approved by TSARC* on 27 August 1975 involved the expenditure of $12.525M on a variety of critical problems in three areas:

1. System Technology addressing total system problems such as overall system control (vehicle routing and scheduling), and passenger safety and security;

2. Subsystem and Component Technology which treats vehicle control and reliability;

3. Wayside Technology which addresses guideway and station technology; and

4. Independent Analyses covering a variety of topics.

The corresponding Phase I projects were:

System Technology

- System Operation Studies (General Motors)**
- System Safety and Passenger Security (Dunlap and Associates)
- System Service Availability (Battelle)

Subsystem and Component Technology

- Automated Mixed Traffic Transit Technology (Jet Propulsion Laboratory)
- Hydrostatic Drive Evaluation (Mobility Systems)
- Vehicle Data Acquisiton (Port of Seattle)
- Vehicle Lateral Control and Switching (Otis)**
- Vehicle Longitudinal Control and Reliability (Otis)**

Wayside Technology

- Guideway and Station Technology (De Leuw, Cather)

*Transportation Systems Acquisition Review Council
**Major Projects

Independent Analyses

- Independent Control Studies (Applied Physics Laboratory)
- Independent Studies (MITRE)
- Industry Requirements (American Public Transit Association)
- Small Vehicle AGT Study (Aerospace)
- Training and Platooning Studies (Massachusetts Institute of Technology)

The Phase I projects are essentially complete. Phase II of the AGTST program was approved by TSARC on 2 April 1979. Phase II will involve an expenditure of $3.87M in four areas:

1. Operation Studies which will continue the examination of overall system control,

2. Passenger Interface which will study AGT station operation,

3. Innovative transit concepts developing technology for new system concepts, and

4. Independent Analyses addressing a variety of topics.

The Phase II activities are just beginning.

1.5 Accomplishments

The outputs of the major Phase I projects fall into five areas:

a. AGT simulation models and case studies (General Motors)

A complete set of AGT system planning models has been developed which permit the user to develop detailed cost and service information for a proposed AGT deployment starting from zone-zone trip demand data, feeder characteristics, station locations and configurations, and network geometry. Analysis fidelity ranges from average traffic flow through detailed representation of individual passengers and vehicles. Models are applicable to all classes of AGT technology.

b. Passenger security and safety enhancement techniques (Dunlap and Associates)

Security and safety enhancement techniques currently employed by transit authorities were identified and evaluated. Areas studied included architectural design, police methods, surveillance techniques, evacuation, rescue and passenger attitude values placed on safety features. A highlight of this project is evaluation of a television surveillance experiment in an at grade station on a New York subway line. In addition, experiments were conducted to establish relations between seat design and permissible emergency braking levels.

c. Improved longitudinal control system designs and reliability enhancement techniques (Otis)

An extensive program to design and test experimental longitudinal control systems is currently underway. Particular attention is being focussed on the development of a fail operational microprocessor-based longitudinal control system which promises to substantially improve reliability by increasing the mean time between failures which result in vehicle stoppage on the guideway. This project complements extensive analytical studies sponsored previously at APL, MIT, etc.

d. Lateral control and switching system designs featuring improved ride comfort (Otis)

The lateral control project will provide extensive analysis and test results on wall and wire-following Ackerman steering systems. The analytical and experimental data will provide a complete picture of the performance capabilities of this type of steering system in both passive and power assisted versions for AGT vehicles. An AGT vehicle chassis has been developed for testing at the Otis test track and at Lowry AFB.

e. Less costly, rapidly deployable guideway and station design concepts (De Leuw, Cather)

A comprehensive survey of existing design concepts has been completed. Detailed analysis of existing designs has indicated a number of areas where cost and implementation time can be reduced (use of double-T beams, prefabrication, etc). A detailed analysis is developing improved guideway and station designs for AGT vehicles ranging from small to large sizes.

The major accomplishments of the project to date are summarized in Table 1.5.1. In addition the projects are providing key inputs for other programs such as the Advanced Group Rapid Transit and Downtown People Mover programs.*

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*Described in Appendix B

TABLE 1.5.1 - AGTST PROGRAM ACCOMPLISHMENTS TO DATE

MAJOR PROJECTS

System Operation Studies

- seven planning tools (4 coarse, 3 detailed) developed and under evaluation
- special planning tool developed for DPM cities
- exhaustive analysis of 11 SLT case studies completed
- analysis of one AGT case study completed
- two GRT case studies completed

System Safety and Passenger Security

- security effectiveness evaluation techniques developed and evaluated
- passenger safety and security value structure model developed
- recommendations developed for safety and convenience services and passenger evacuation
- NYCTA closed circuit televison security enhancement experiment performed with 8 TV cameras, monitors, a video recorder, and noise alarms
- survey of NYCTA indicates security is a major factor in decision to ride transit

Vehicle Longitudinal Control and Reliability

- generic baseline vehicle designs developed for four classes of AGT (SLT, large GRT, small GRT, PRT)
- comprehensive AGT vehicle weight, cost, reliability models completed

TABLE 1.5.1 (Continued)

- comprehensive survey of automatic couplers used in transit completed covering experience, problems, etc.
- new buffing gear for automatic coupler designed and basic coupler specification prepared covering mounting requirements, electrical connections, etc.
- new approaches to short headway longitudinal control developed at APL and Draper Laboratory
- checked fail-operational redundancy approach shown to potentially increase mean time between failures by several orders of magnitude
- experimental control system design for operation at variable headways (5.0 to 90 seconds) completed and demonstrated

<u>Vehicle Lateral Control and Switching</u>

- five and 12 degree-of-freedom models developed for lateral control studies
- fifteen domestic and foreign AGT vehicle lateral control and switching system designs surveyed
- experimental test vehicle for steering studies designed, built, and tested
- laboratory tests of subsystems completed
- wire-and wall-follower steering controllers developed for experimental program and wire-and wall-follower tests completed

<u>Guideway and Station Technology</u>

- Sixteen all-weather operation protection concepts identified
- weather protection concepts to reduce guideway heating energy requirements by 80 percent identified

TABLE 1.5.1 (Continued)

- twenty-three AGT guideway and 99 AGT stations designs surveyed and documented
- design improvement analyses completed on existing guideway designs
- double-T supported guideway identified as low cost choice

OTHER PROJECTS

Automated Mixed Traffic Vehicle

- experimental AMTV vehicle developed and evaluated on 600m test loop
- comprehensive AMTV failure-mode effects analysis completed
- AMTV market study identifies a large number of potential applications
- MITRE and SRI work indicates desirability of minimally-protected guideway to increase average AMTV speed

System Reliability and Service Availability

- eleven different service availability measures documented and evaluated
- four different service availability analysis techniques evaluated for accuracy, versatility, and computation cost

Vehicle Data Acquisition System

- vehicle data acquisiton system developed and tested at Seatac Airport--reduces maintenance costs by providing a record of 35 AGT vehicle parameters prior to failures

TABLE 1.5.1 (Concluded)

Aerospace Research

- Aerospace small vehicle AGT research fully documented and Los Angeles application study completed

Hydrostatic Drive Noise Evaluation

- hydrostatic drive noise measured and solutions proposed

Independent Studies at APL and MITRE

- improved vehicle-follower control system developed for 0.5 to 3.0 second headways
- hardware implementation considerations established (sampling rate, quantization, filtering, wayside-onboard allocation)
- mixed online/offline station operation evaluated
- cost-benefit studies completed for AMTV and Accelerating Walkway applications

Industry Liaison

- APTA AGT Task Force review of five reports completed
- results of major programs presented to APTA AGT Task Force on 17/18 August 1978

2. PROJECT DESCRIPTIONS

2.1 Major Projects

The five major projects in the AGTST program are addressing:

a. System Operation Studies,
b. System Safety and Passenger Security,
c. Vehicle Longitudinal Control and Reliability,
d. Vehicle Lateral Control and Switching, and
e. Guideway and Station Technology.

The major projects account for 62 percent of the total amount approved for the AGTST program.

The lack of adequate data on the operating characteristics of various AGT systems in different applications has often thwarted adequate planning for AGT system deployment. One object of a System Operation Studies program in progress at General Motors is to develop computer tools which can be used to accurately model the behavior of AGT systems in urban deployments. The models and their application are indicated in the Deployment Analysis Flow diagram shown in Figure 2.1.1. The basic analysis inputs are zone to zone trip demand (Z/Z Demand), the transit network geometry (Network) and the system characteristics (System). A subprogram in the Discrete Event Simulation Model (DESM) and the Feeder System Model (FSM) map the zone to zone trips onto the transit network using the designated technology to produce station to station (S/S) trip demand and travel time (Impedance) data. The station to station demand data together with the network and system characteristics provide the necessary data for coarse passenger and vehicle flow-based analysis using the System Planning Model (SPM) or detailed analysis using the Discrete Event Simulation Model (DESM). The DESM provides data on individual passenger and vehicle behavior permitting accurate evaluation of system performance. The DESM together with system failure data also permits an evaluation of service reliability as perceived by the passenger or operator using the Service Availability Model (SAM). An analysis of capital, operating and life-cycle costs may also be performed by using the System Cost Model (SCM). All of the models interface with the AGT/SOS Data Base as shown in Figure 2.1.2, permitting information exchange between various models and systematic accumulation of results.

Currently the models are being tested and evaluated prior to general distribution to planners, system developers, government agencies and other interested users. A simplified version of the DESM model has already been developed specifically for studying the performance of the Downtown People Mover (DPM) systems and is being implemented at a number of DPM sites including Detroit and Los Angeles.

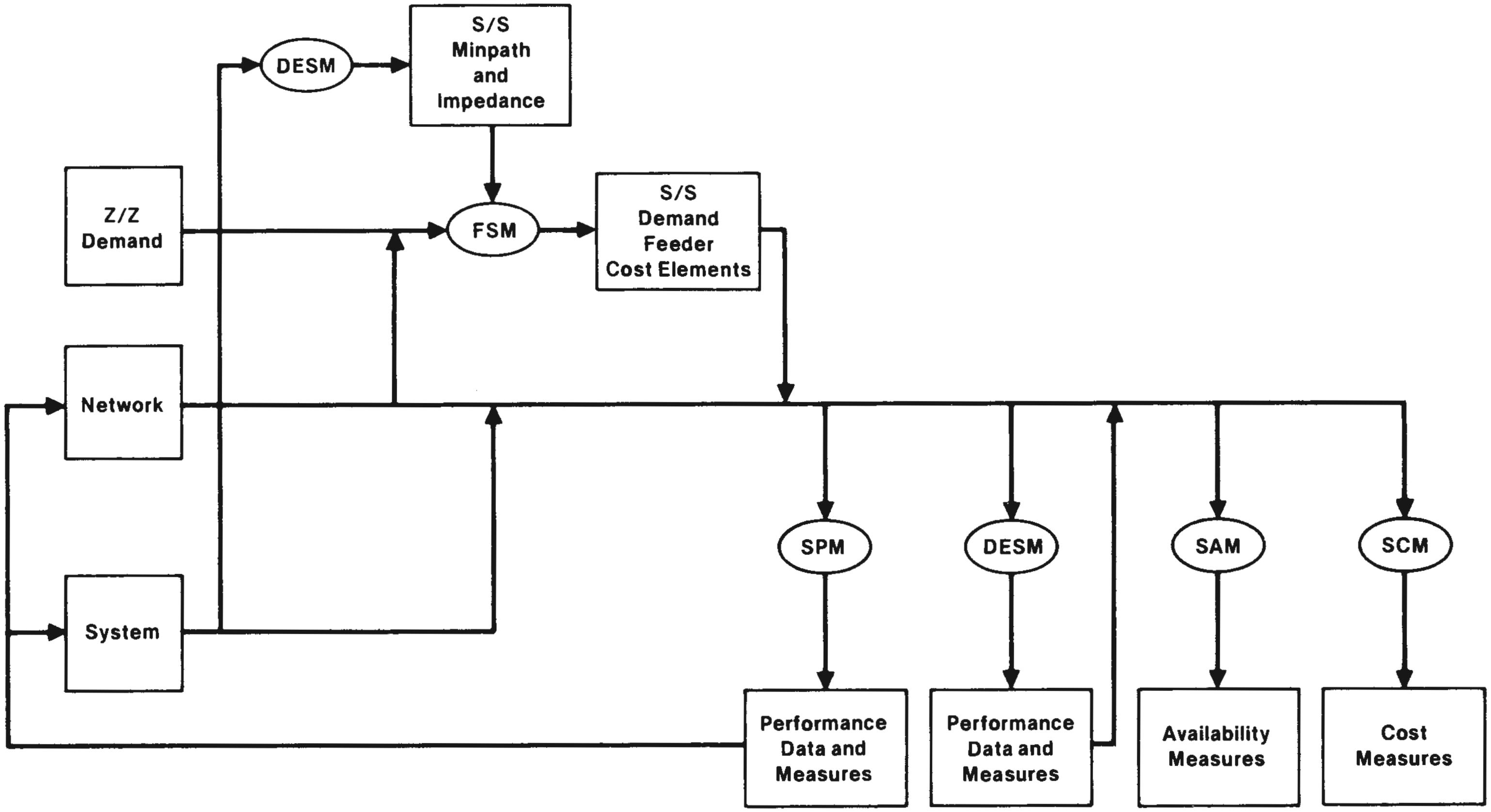


FIGURE 2.1.1. AGT SYSTEM OPERATIONS ANALYSIS FLOW DIAGRAM SHOWING THE PHASING OF MODEL APPLICATIONS TYPICAL AGT DEPLOYMENT ANALYSIS PROBLEMS.

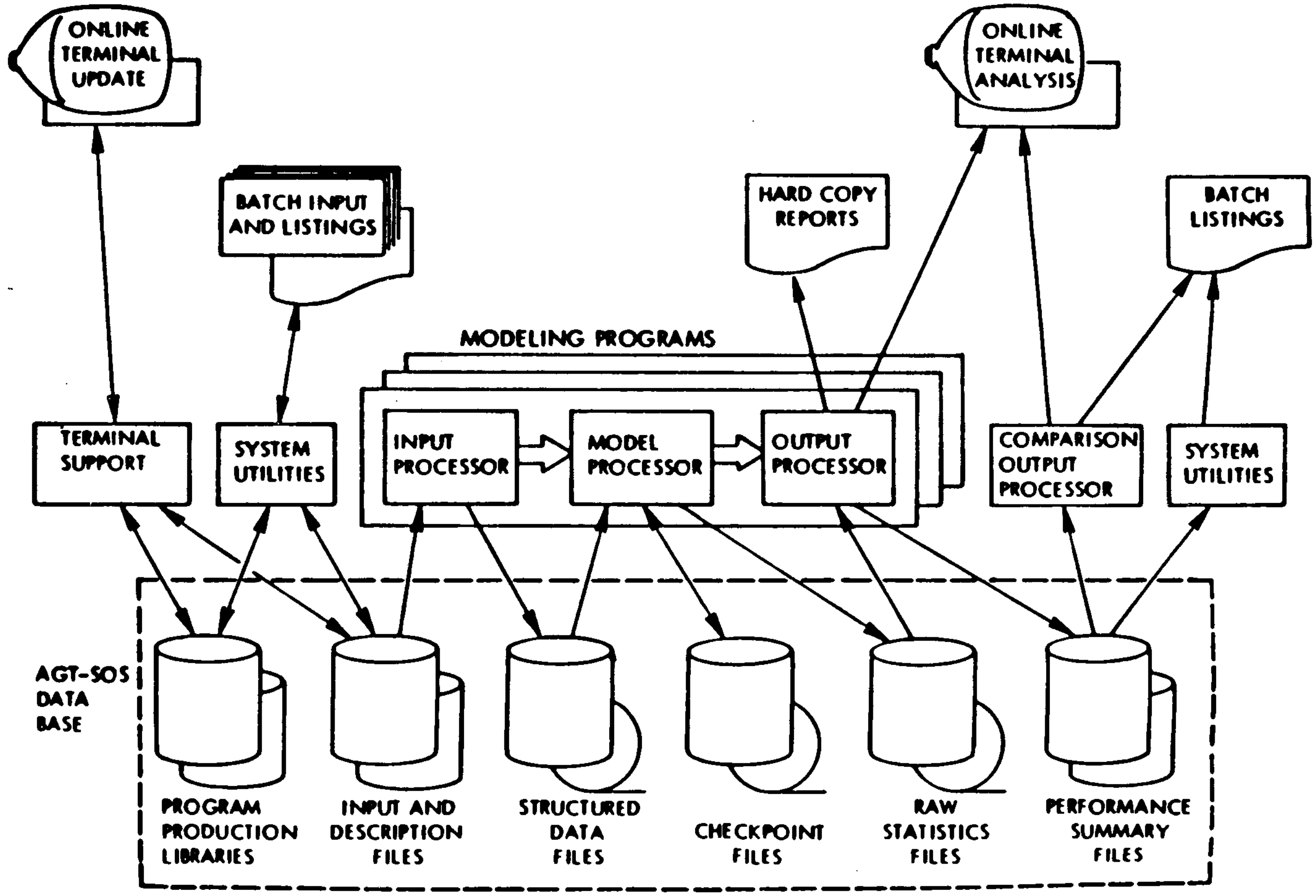


FIGURE 2.1.2. SYSTEM OPERATION STUDIES ANALYSIS MODELS AND DATA BASE ORGANIZATION ILLUSTRATING THE COUPLING BETWEEN THE MODELS AND A COMMON STRUCTURED DATA BASE.

The second object of the System Operation Studies program is the development of guideline standards and requirements for design and use of AGT systems. The performance of different classes of AGT systems has been analyzed in various deployments with the aid of these models. The systems studied have ranged from Single Line Transit (SLT) to Group Rapid Transit (GRT) and Automated Rail Transit (ART). The application areas included circulation and line haul activity centers and CBD's and area-wide line haul deployments. The systems analyses determined efficient systems within a given class for a specification application, while the comparative analyses looked across system classes. Studies were also done of alternative AGT operational control strategies.

Eleven nominal SLT deployments were specified as a result of trade-off analyses so that each one satisfies a set of performance goals at minimum life cycle cost. A set of design guidelines were then developed. The systems were required to have an average wait time of no more than four minutes, a maximum wait time of no more than nine minutes, a passenger availability of .996 and an average travel speed in the CBD cases of at least 3.5 m/sec. A summary of the nominal SLT deployment characteristic is given in Table 2.1.1. The guideway layout of one of the analyzed networks is shown in Figure 2.1.3, along with the network configuration required to model it on the computer. The more detailed computer network model was required to preserve the directionality of the guideways (indicated by the solid and broken lines) and the shared nature of stations on the dual-lane loop.

Wait time goals should be specified for a selected set of stations for time periods in which queuing is expected to occur and not averaged over the entire system for an extended period of time, or else congestion problems may be masked. A linear relationship between the average wait time and system capacity can be established for SLT systems through the use of system simulation whenever system performance is limited by a relatively large wait time at one particular station in the network. An example of this relationship is given in Figure 2.1.4.

Additionally, systems designed to just satisfy maximum expected demands are very sensitive to minor demand increases above the design point. Thus a 10-20 percent design margin appears necessary to assure satisfactory operation. Lastly, passenger availability is a much more sensitive measure of system operation under failure conditions than vehicle availability.

In the ART analysis, many results were similar to those in the SLT analysis. However, the linear relationship between average wait time and system flow capacity had limited applicability. The sharing of segments of the guideway by two or more of the

TABLE 2.1.1 - SUMMARY OF NOMINAL SLT DEPLOYMENT CHARACTERISTICS (1 of 2)

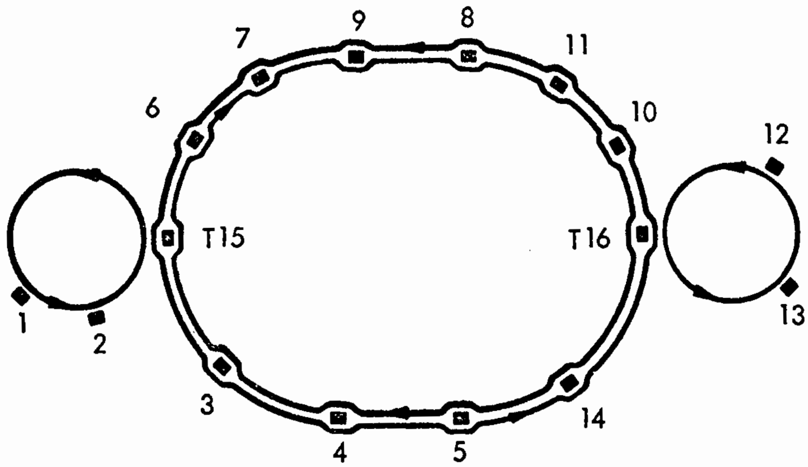
Deployment Description			System Description				Performance Measures	
Deployment	Network Type	Daily Demand	No. of Stations	Guideway Lane Km	Vehicle Capacity	Total Fleet Size	Average Wait Time (s)	Average Travel Speed (m/s)
CBD Circulation								
SLT 3	Loop	52,133	11	3.7	58	20	85	4.6
SLT 4	D/L Loop	68,797	11	7.4	62	26	117	4.0
SLT 5	Loop	65,252	11	3.7	58	24	83	4.7
SLT 6	Loop	65,252	11	3.7	109	12	72	5.0
SLT 7	Shuttle	39,036	11	3.8	55	14	210	4.2
CBD Line-Haul								
SLT 8	Mu/Loop	24,235	10	3.6	109	8	184	5.2
SLT 9	Loop	25,580	8	3.6	100	9	147	5.4
SLT 10	Loop	25,580	8	3.6	24	35	94	5.7
SLT 11	Loop	51,160	8	3.6	100	17	140	5.4

TABLE 2.1.1 (Concluded)

Deployment Description				Performance Measures			Availability Measures	
Deployment	Network Type	Land Utilization (m^2)	Noise Impacted Area (m^2)	Annual Energy Consumption	Maximum Average Percent Standing	Maximum Average Wait Time	Vehicle Availability	Pass. Availability
CBD Circulation								
SLT 3	Loop	10,066	7,180	10.1	37	484	99.9	99.2
SLT 4	DL Loop	18,394	11,366	16.3	27	500	99.9	99.6
SLT 5	Loop	10,471	11,000	11.5	39	514	99.9	99.2
SLT 6	Loop	12,780	45,000	11.6	85	491	99.9	99.4
SLT 7	Shuttle	10,858	5,708	11.4	38	313	100.0	99.8
CBD Line-Haul								
SLT 8	Mu/Loop	12,146	61,000	4.8	81	386	100.0	99.8
SLT 9	Loop	11,793	54,000	4.0	76	374	99.9	99.5
SLT 10	Loop	9,676	11,567	4.8	25	321	99.8	99.0
SLT 11	Loop	12,790	77,000	6.5	77	375	99.9	99.3

*Passenger availability is based on a passenger dely threshold of five minutes.

**In addition, other measures available from the simulation include Cost Measures and Normalized Cost Measures.



SLT 2 - ACTIVITY CENTER CIRCULATION APPLICATION
USING A LOW-SPEED LGRT

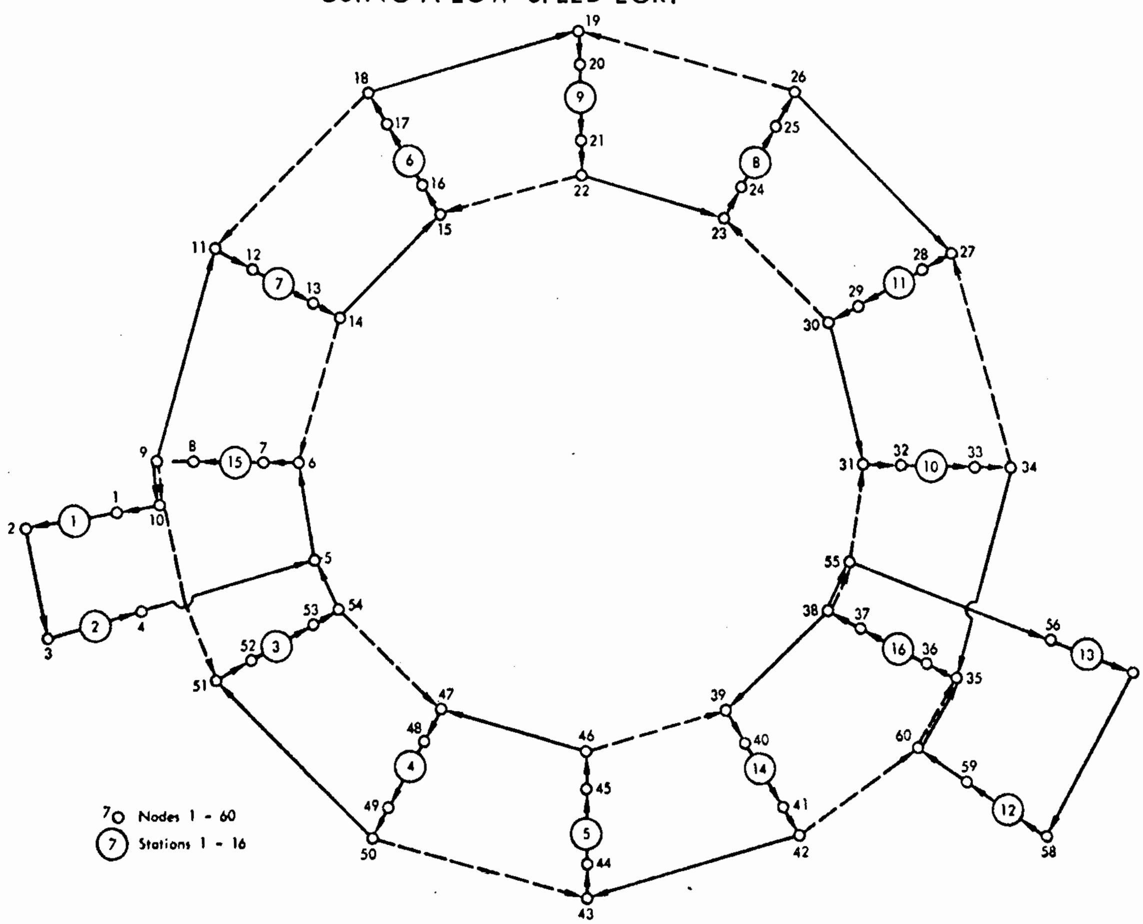


FIGURE 2.1.3. SLT 2 NETWORK MODEL

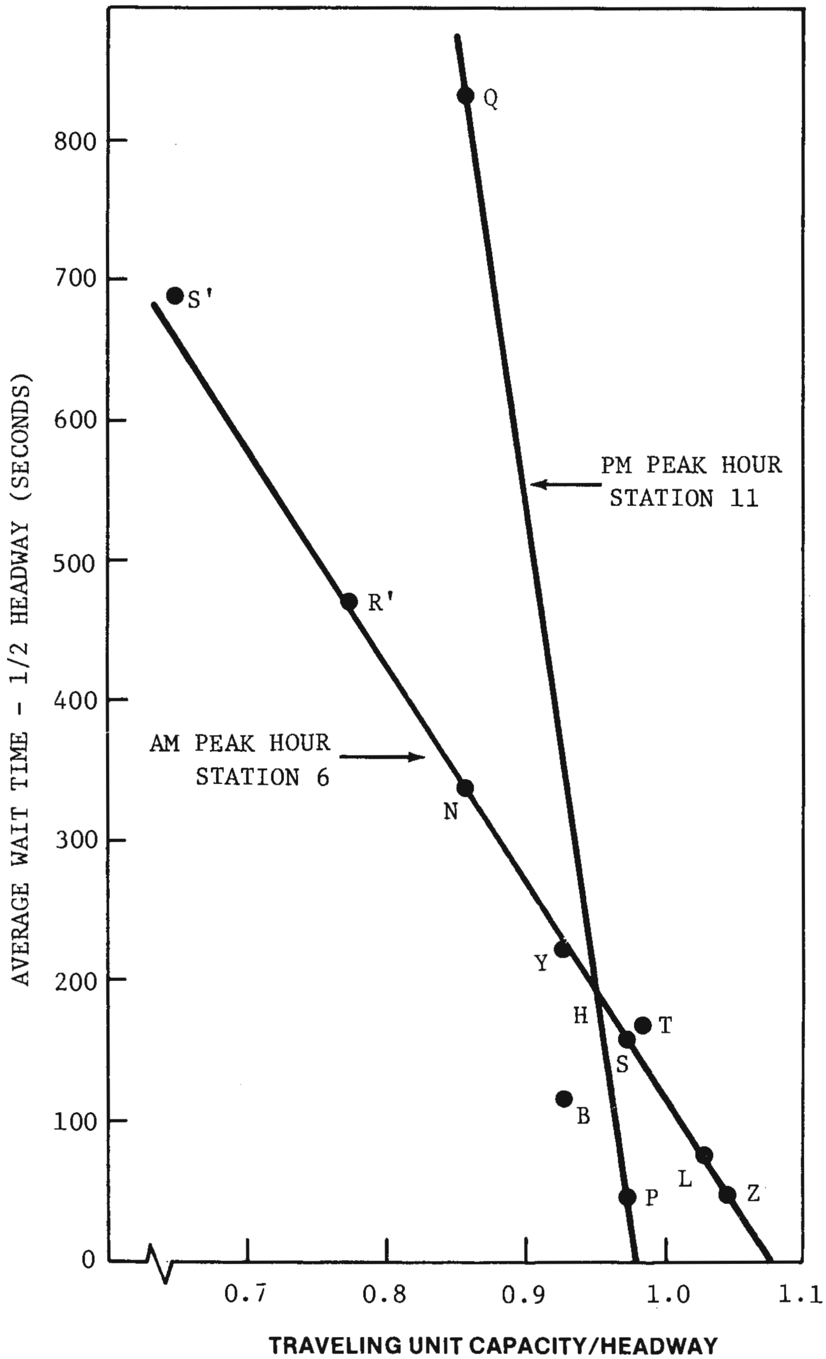


FIGURE 2.1.4 AVERAGE QUEUE TRANSIT TIME VERSUS FLOW CAPACITY FOR SLT 9

routes caused a vehicle congestion which created some adverse performance characteristics when attempting to increase flow capacity within the system. Route selection was an important factor in establishing the active fleet size. An example of one part of the station analysis is given in Figure 2.1.5 which shows ticketing and entrance-exit turnstile region area as a function of queue size.

GRT deployments were analysed on both line haul and areawide grid networks (see Table 2.1.2). Demand-responsive service was considered in the areawide grid case (it was not effective in the ART or SLT studies). An empty vehicle management strategy which disperses empties based on real time empty vehicle request information was found to provide better system performance than other strategies tested including storing vehicles at the station at which they become empty, storing empties at regional storage centers, and circulating empty vehicles on predefined routes.

A primary goal of the System Safety and Passenger Security project, performed by Dunlap and Associates, was to develop techniques to assure actual and perceived passenger safety and security in AGT systems having few operating personnel.

Results include the identification and evaluation of remote surveillance techniques for unmanned stations; development of strategies for the evacuation of unmanned vehicles; identification and evaluation of techniques for the delivery of safety services; studies of the impact of perceived security on ridership and the impact, in turn, of countermeasure technology on perceived security; and the establishment of deceleration limits and seat configurations for passenger retention during emergency braking.

With regard to crime countermeasures, an evaluative review of countermeasure technology has revealed that beyond the "good practice" architectural and procedural countermeasures, a comprehensive video-audio station surveillance system will be the most effective countermeasure for AGT systems. To this end, a prototype system was installed and evaluated in a New York Transit Authority station, Rockaway Park Beach--116th Street. This system, illustrated in Figures 2.1.6, 2.1.7, and 2.1.8, includes video and audio sensors (cameras and microphones), a monitoring system, a time lapse recording system and a time data encoding system. This system has been effective in eliminating crime, particularly harassment of patrons, and is quite economical. The cost of a surveillance system suitable for a large AGT station including such services could be provided using a central control system and a minimum of roving service employees.

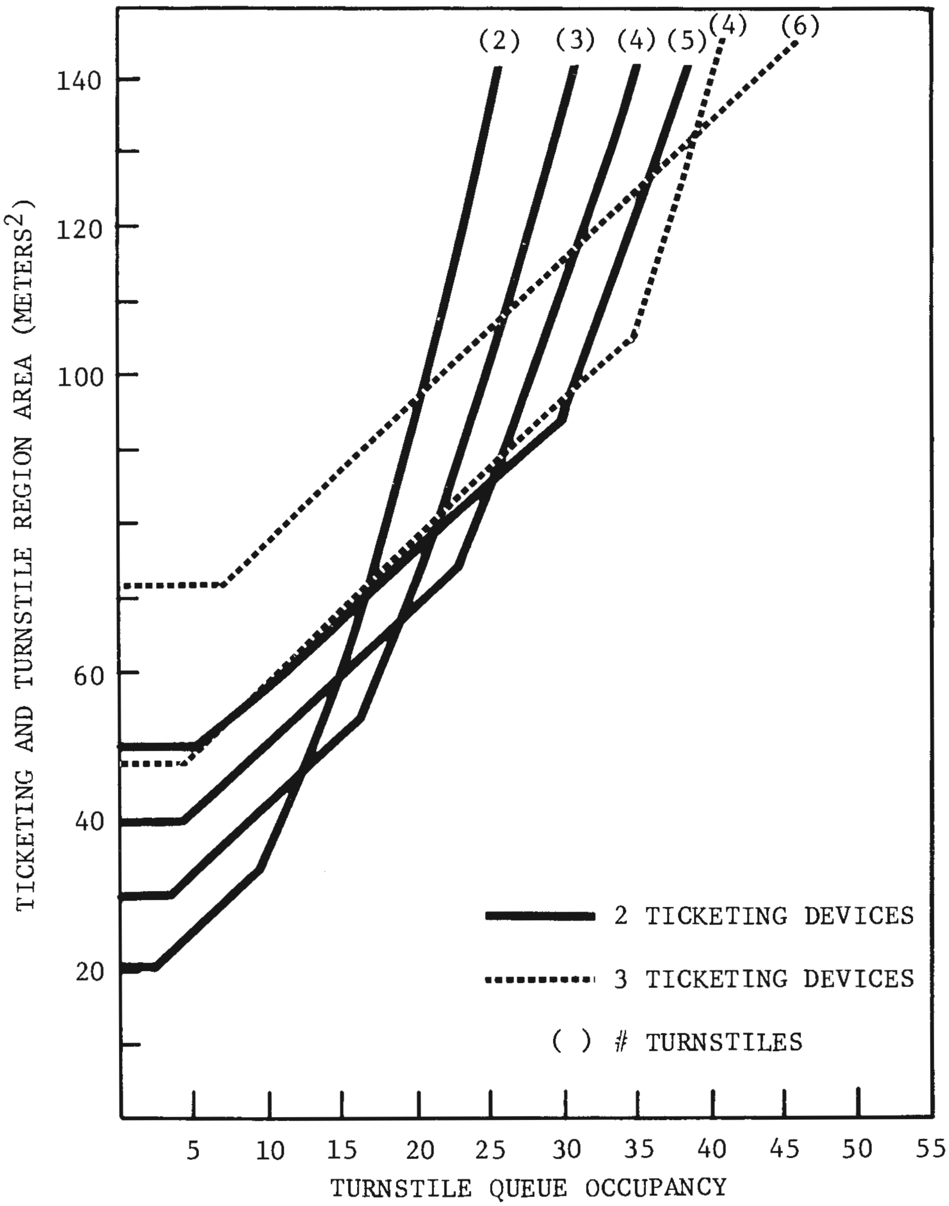


FIGURE 2.1.5. TICKETING AND ENTRANCE-EXIT TURNSTILE AREA AS A FUNCTION OF QUEUE SIZE

TABLE 2.1.2 - SUMMARY OF NOMINAL GRT DEPLOYMENT CHARACTERISTICS (1 OF 2)

Deployment Description			System Description				Performance Measures		
Deployment	Network Type	Daily Demand	No. of Stations	Guideway Lane Km	Vehicle Capacity	Total Fleet Size	Average Wait Time (s)	Average Travel Speed (m/s)	Maximum Average Percent Seated
GRT 2	Grid	113,314	28	104.1	50	104	96	13.9	73.2
							107	14.0	85.8
							89	13.6	74.6
							107	14.1	83.1
GRT 3	Grid	154,537	40	183.0	15	556	111	12.3	84.3
							112	12.1	86.7
							107	12.3	86.1
							110	14.2	98.7

*The four values refer to the AM Peak, Midday, PM Peak, and Evening demand period respectively.

TABLE 2.1.2 (Concluded)

Deployment Description					Performance Measures		Availability Measures	
Deployment	Network Type	Lane Utilization (m^2)	Noise Impacted Area (m^2)	Annual-Energy Consumption	Maximum Average Wait Time (s)	Maximum Average No. of Intermediate Stops	Vehicle Availability	Pass. Availability
					304	2.65		
					316	2.26		
GRT 2	Grid	236.3	554	57.4			0.998	0.986
					304	2.82		
					303	2.32		
GRT 3	Grid	406.6	6,235	289.3			0.993	0.984
					903	1.98		
					840	1.92		
					983	1.84		
					657	1.07		

*Passenger availability is based on a passenger delay threshold of five minutes.
**In addition, other measures available from the simulation include Cost Measures and Normalized Cost Measures.

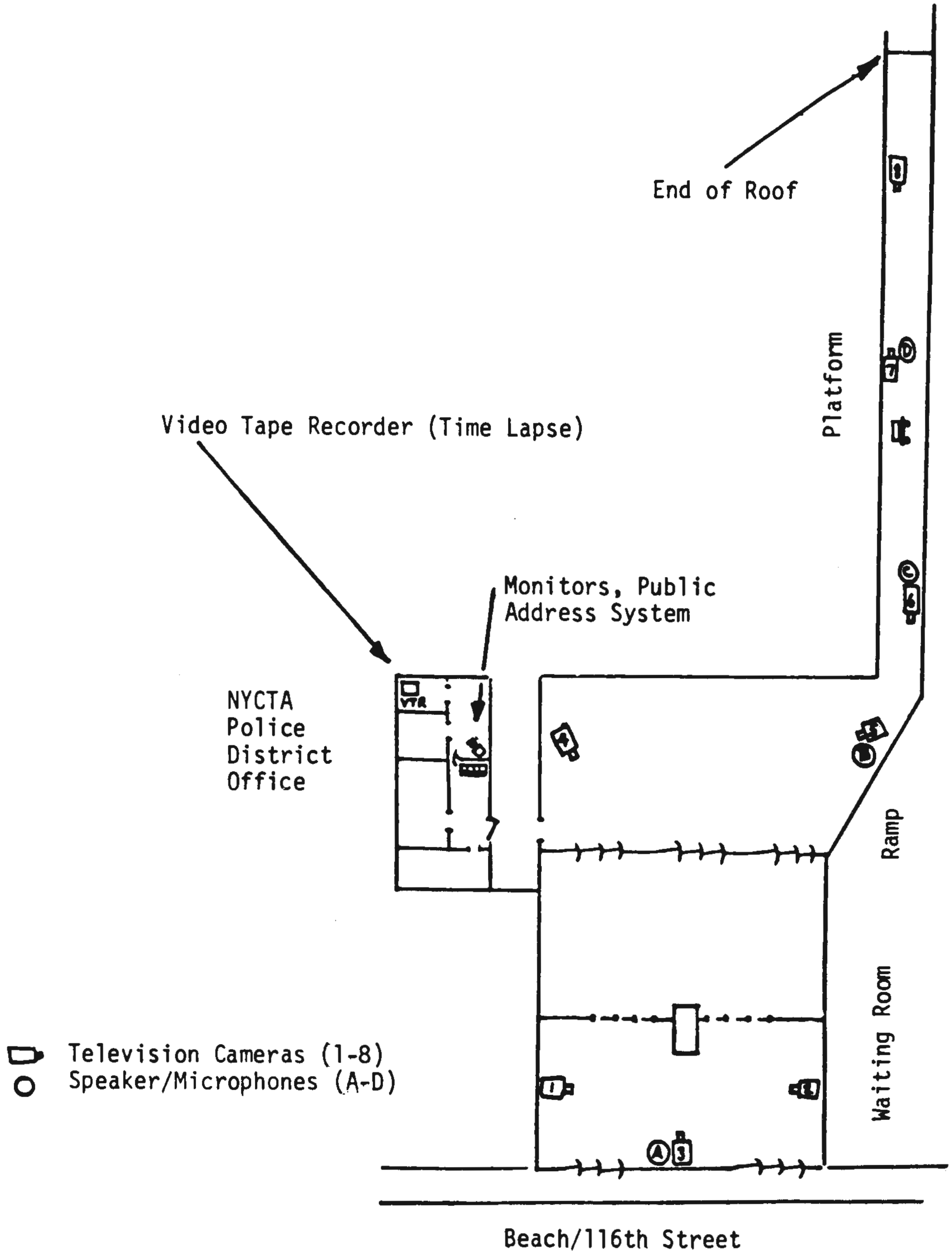


FIGURE 2.1.6. **ROCKAWAY PARK RAIL RAPID TRANSIT STATION CLOSED-CIRCUIT TELEVISION AND SOUND MONITOR SECURITY ENHANCEMENT SYSTEM.**

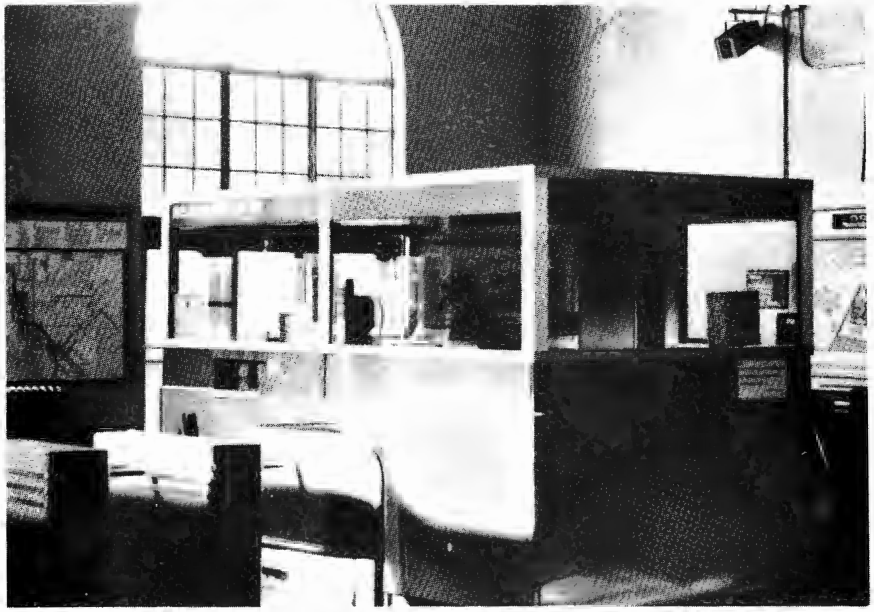


FIGURE 2.1.7. THE CLOSED-CIRCUIT TELEVISION MONITORS USED IN THE EXPERIMENT FEATURE VANDAL-RESISTANT ENCLOSURES.

FIGURE 2.1.8. THE CLOSED-CIRCUIT TELEVISION MONITORING FACILITY FEATURES MONITORS, A TIME LAPSE VIDEO RECORDER, AND A PUBLIC ADDRESS SYSTEM

Surveys of passenger perceptions of transit security revealed that personal security consideration is the single most significant factor in the ridership of the metropolitan rapid rail system studied. Further; the effect was greatest on women with the majority noting they would not use the system after darkness due to fears of criminal activity. The comprehensive surveillance system described above was used in a study to determine its effectiveness on enhancing perceived security. The surveillance system has a significantly positive effect on perceived security of female patrons but little or none on males.

A study of emergency deceleration and jerk was performed to determine the maximum safe emergency deceleration levels for AGT vehicles. A specially instrumented automotive van was used to test human subjects, with controlled braking rates provided by a hydraulic actuator shown in Figure 2.1.9. With a seat configuration as shown in Figure 2.1.10 which optimizes retention, yet is compatible with transit use, up to 80 percent of all forward-facing passengers will remain securely in their seats at decelerations up to 0.37 g's, independent of jerk.

The results of all these studies have been used to develop safety and security guidebooks which were reviewed by industry experts and researchers in DOT-sponsored workshops prior to publication. These guidebooks are not in the form of requirements or specifications, but provide the information required to make decisions on each topic depending on system-specific situations.

The Longitudinal Control and Reliability project identified and evaluated techniques to improve the reliability of the classes of AGT vehicles indicated in Table 1.2.1. The reliability studies were coupled with longitudinal control because the major contributors to reliability problems such as power collectors, power conditioners, motors, drive trains, brakes, suspension components, etc., are associated with the longitudinal control system. Specific techniques studied include fail-operational-redundant implementation and improved component design and application. Vehicle control concepts considered included fixed- and moving-block vehicle protection, vehicle-and point-follower control as indicated in Table 2.1.3, and electronic (platooned) and mechanical (trained) vehicle coupling.

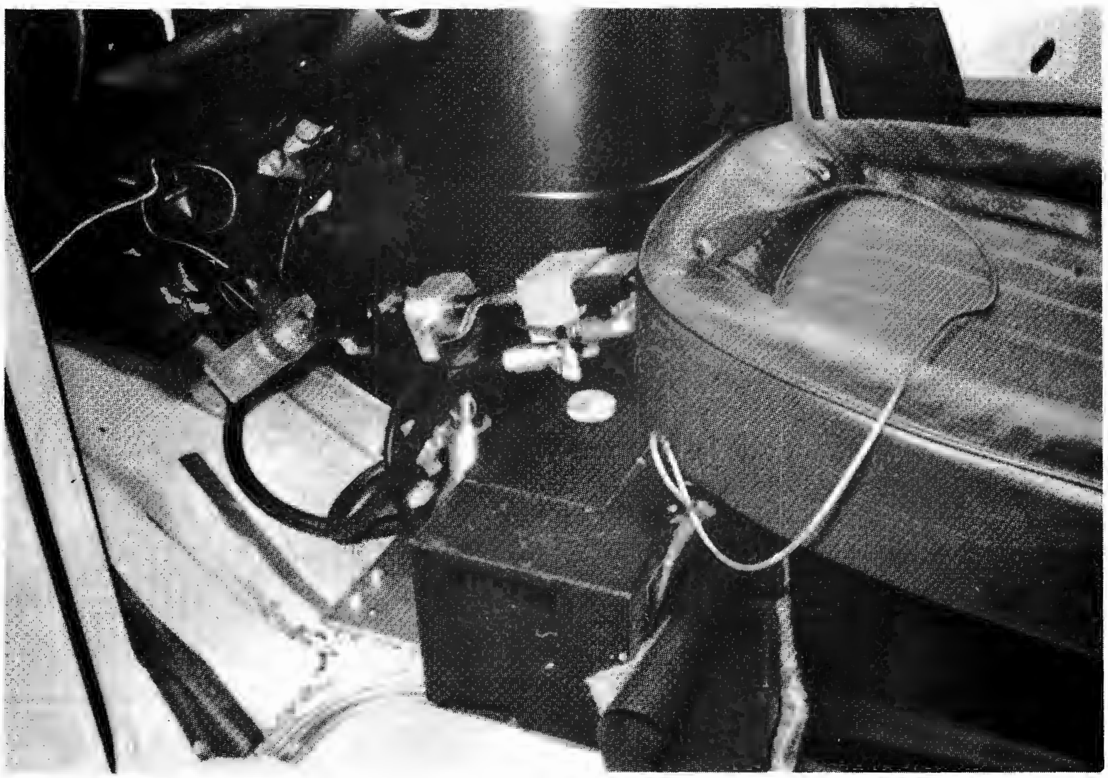


FIGURE 2.1.9. AN AUTOMATIC BRAKING CONTROL SYSTEM WAS USED IN THE DECELERATION TEST VEHICLE

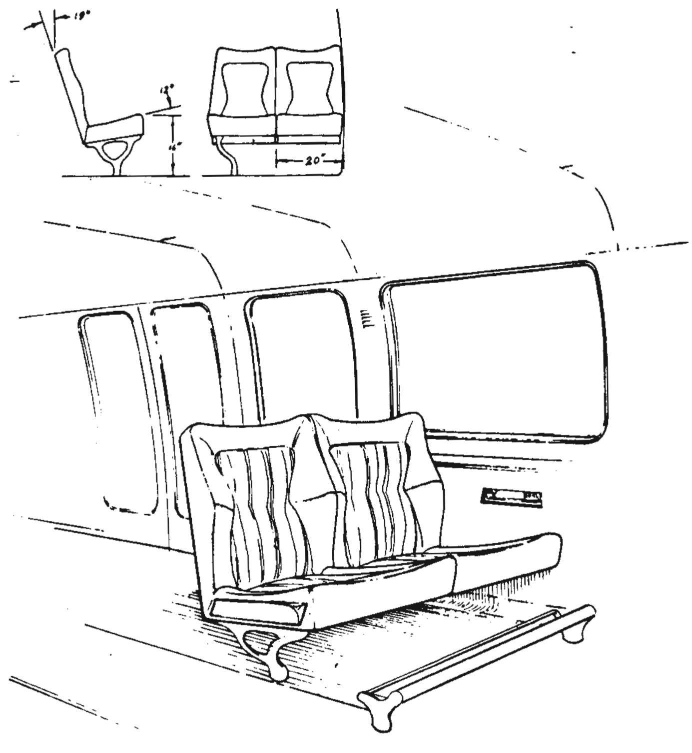


FIGURE 2.1.10. SEAT CONFIGURATION WHICH OPTIMIZED RETENTION DURING HIGH DECELERATION.

TABLE 2.1.3 - LONGITUDINAL CONTROL SYSTEMS STUDIED IN THE VEHICLE LONGITUDINAL CONTROL AND RELIABILITY PROJECT

Classification	Minimum Headway (seconds)	Vehicle Protection	Vehicle Class	Operating Policies
Fixed Block Control	20 - 90	Fixed Block	Large GRT SLT	Not Applicable
Point-Follower	3 - 5	Moving Block	GRT	Constant Headway, Constant K-Factor, Constant Separation (Platooned)
Vehicle-Follower	3 - 5	Moving Block	GRT	
Point-Follower	0.5	Moving Block	PRT	Constant Headway, Constant K-Factor, Constant Maximum Collision Velocity, Constant Separation (Platooned)
Vehicle-Follower	0.5	Moving Block	PRT	

A computer reliability model was developed which allows evaluation of the reliability of various design approaches and the effects of various levels of redundancy and other enhancement techniques on longitudinal control systems. The studies indicate that more reliability improvements can be achieved through the use of an active redundant system with corrective maintenance.

Longitudinal control system designs were developed which can safely perform speed regulation and overtake maneuvers for all classes of vehicles including GRT in the 3 to 5 second headway range. Extensive simulations were carried out demonstrating the maneuver capabilities and strong stability of the control systems.

The longitudinal control designs and simulations were validated using two vehicles shown in Figure 2.1.11, originally developed for Transpo '72. The tests were carried out on the Otis 764 meter test track in Figure 2.1.12, near Denver, Colorado. The experimental control system features a Motorola microprocessor-based onboard controller shown in Figure 2.1.13, a triple-redundant Motorola microprocessor-based wayside safety system in Figure 2.1.14, and a dual redundant shared memory tandem mini-computer system for processing wayside control information shown in Figure 2.1.15. The programmability of the vehicle and wayside elements permits a wide range of longitudinal control techniques to be experimentally evaluated, as well as allowing simultaneous operation of two real and three simulated vehicles. A portable test data acquisition system shown in Figure 2.1.16, which makes extensive use of microelectronic technology, was used to collect test track data.

In addition to the control and reliability studies, Otis explored the problems associated with implementing automatic coupling on AGT vehicles. A survey of existing coupling hardware was performed, which included seven coupler manufacturers, and seven transit systems. AGT coupling maneuver requirements were identified, and several new coupler designs developed.

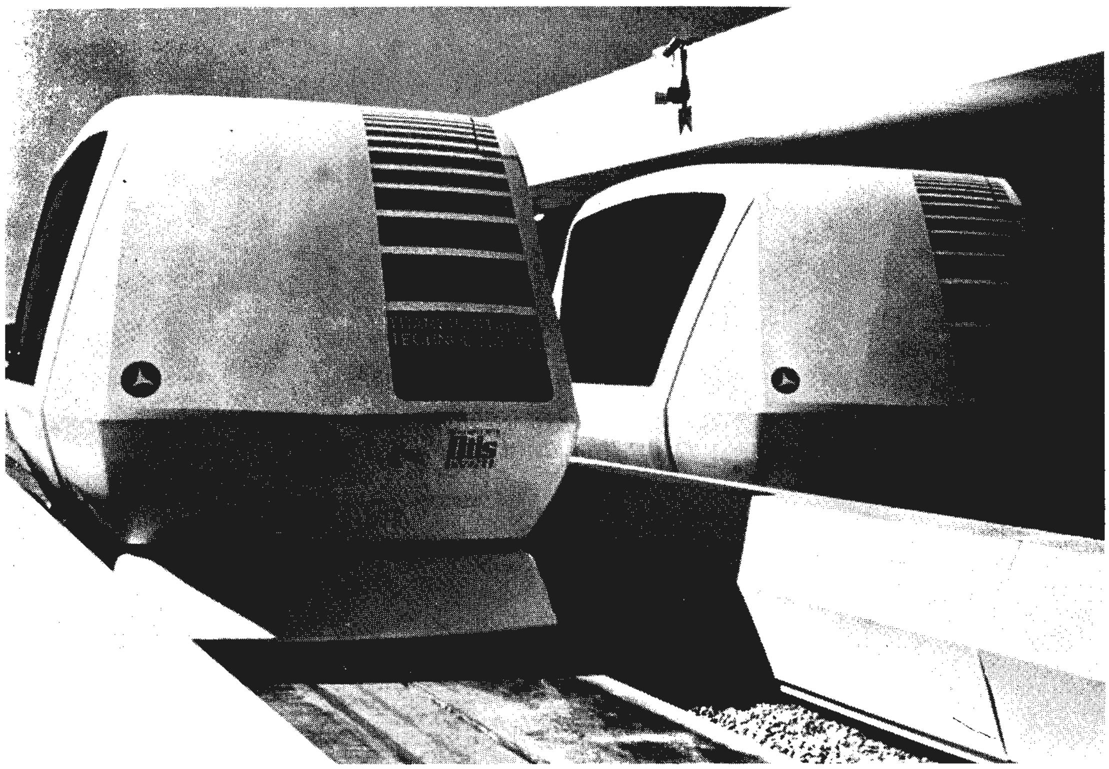


FIGURE 2.1.11. THE LONGITUDINAL CONTROL SYSTEM TEST VEHICLES WERE ORIGINALLY DEVELOPED FOR TRANSPO '72

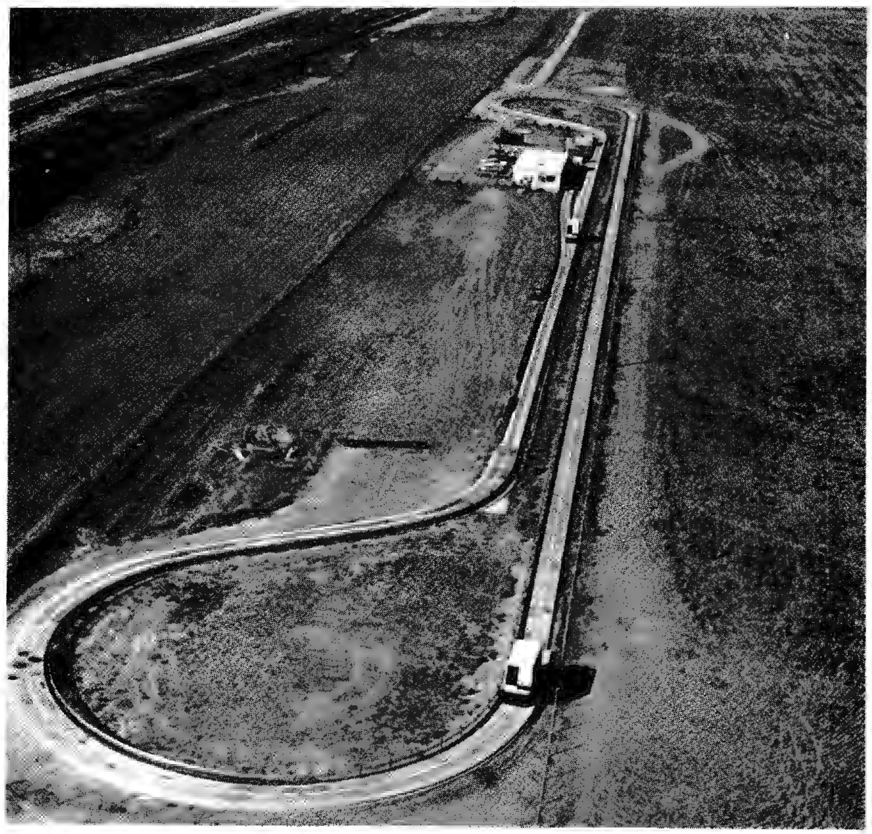


FIGURE 2.1.12. The Otis Test Track Features a Closed Loop and a Two-Berth Offline Station.

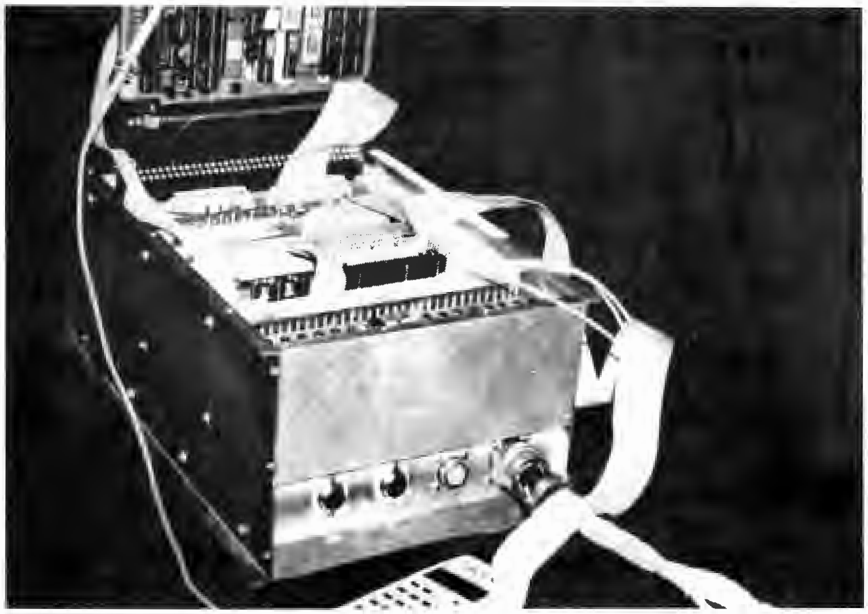


FIGURE 2.1.13. ONBOARD MOTOROLA M6800 MICROPROCESSOR-BASED PROGRAMMABLE AGT VEHICLE ONBOARD CONTROL SYSTEM

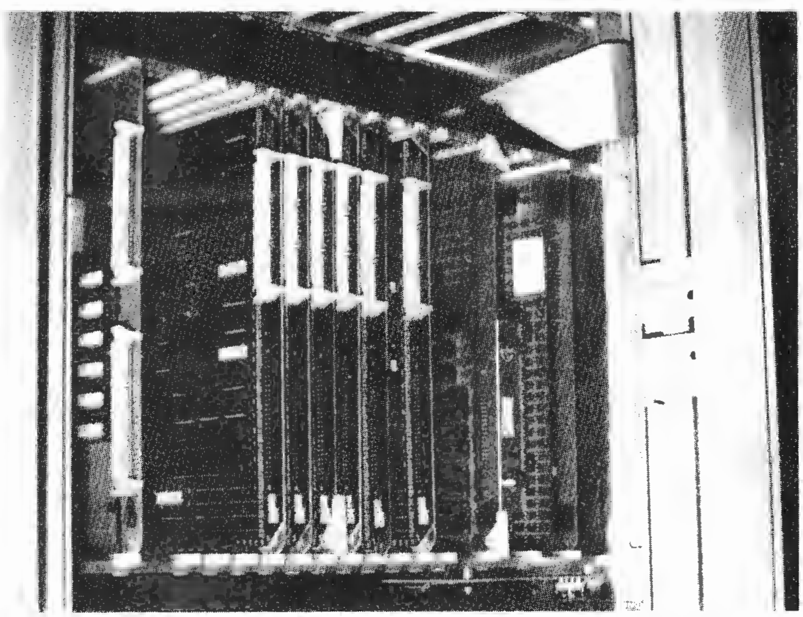


FIGURE 2.1.14. TRIPLE CHECKED-REDUNDANT FAILSAFE MOTOROLA M6800 MICROPROCESSOR-BASED WAYSIDE VEHICLE SAFETY MONITOR

FIGURE 2.1.15. TANDEM MICROCOMPUTER SYSTEM FOR PROCESSING WAYSIDE CONTROL INFORMATION.

FIGURE 2.1.16. A MICROPROCESSOR-CONTROLLED DATA ACQUISITION SYSTEM WITH A PRECISION CLOCK

Results of this study indicate that present ride quality jerk limitations must be relaxed and coupling accomplished at low relative speeds in order to achieve reasonable coupler complexity, weight and cost. As a result of gathering range limitations of conventional couplers, an actively positioned coupler such as that shown in Figure 2.1.17 has been designed to allow coupling maneuvers to be performed anywhere on an AGT system including sharp curves.

A longitudinal control data base was developed which includes an annotated bibliography of over 300 documents relating to previous work. Details of the project results, as well as over 400 cross-references, are also included.

The Vehicle Lateral Control and Switching (VLACS) project developed improved steering and switching techniques. The project was aimed at developing improved VLACS designs that reduce cost, weight, and complexity of VLACS systems. Comparative studies and experiments were made on purely mechanical and power-assisted mechanical systems utilizing a buried radiating wire as a lateral position reference as illustrated in Figure 2.1.18. A 12-degree of freedom vehicle model has been developed and validated. The vehicle model was used to refine and optimize VLACS designs. The variable geometry experimental test vehicle is illustrated in Figure 2.1.19. The Ackerman steering mechanization of the experimental vehicle (Figure 2.1.20) permits wide variations in steering geometry and suspension parameters. The wall-follower steering systems were evaluated on the 764-meter Otis test track. The wire-follower system was tested on a vehicle test facility at Lowry Air Base in Colorado, shown in Figure 2.1.21. Wire-follower and wall-follower, with and without power assists, were tested and evaluated.

Improved steering systems have the potential not only of improving vehicle ride quality, but to reduce guideway costs caused by reducing the small guideway tolerances required on the guideway steering surfaces. Ride quality measurements were taken at the Ford Fairlane system. The ride quality instrumentation is shown in Figure 2.1.22 and the guideway profilometer is shown in Figure 2.1.23. The results of the project provided a clear picture of the advantages and disadvantages of the three control approaches applied to each of the vehicle classes in Table 1.2.1.

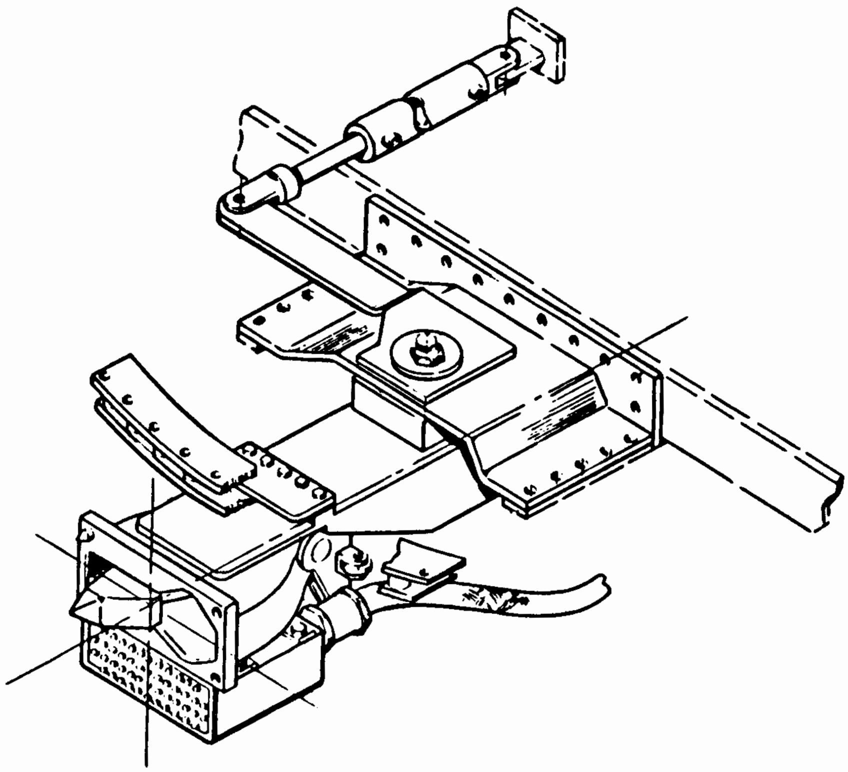


FIGURE 2.1.17. ACTIVELY STEERABLE TIGHT-LOCK AUTOMATIC COUPLER WITH ELECTRICAL CONNECTOR FOR COUPLING ON TIGHT CURVES

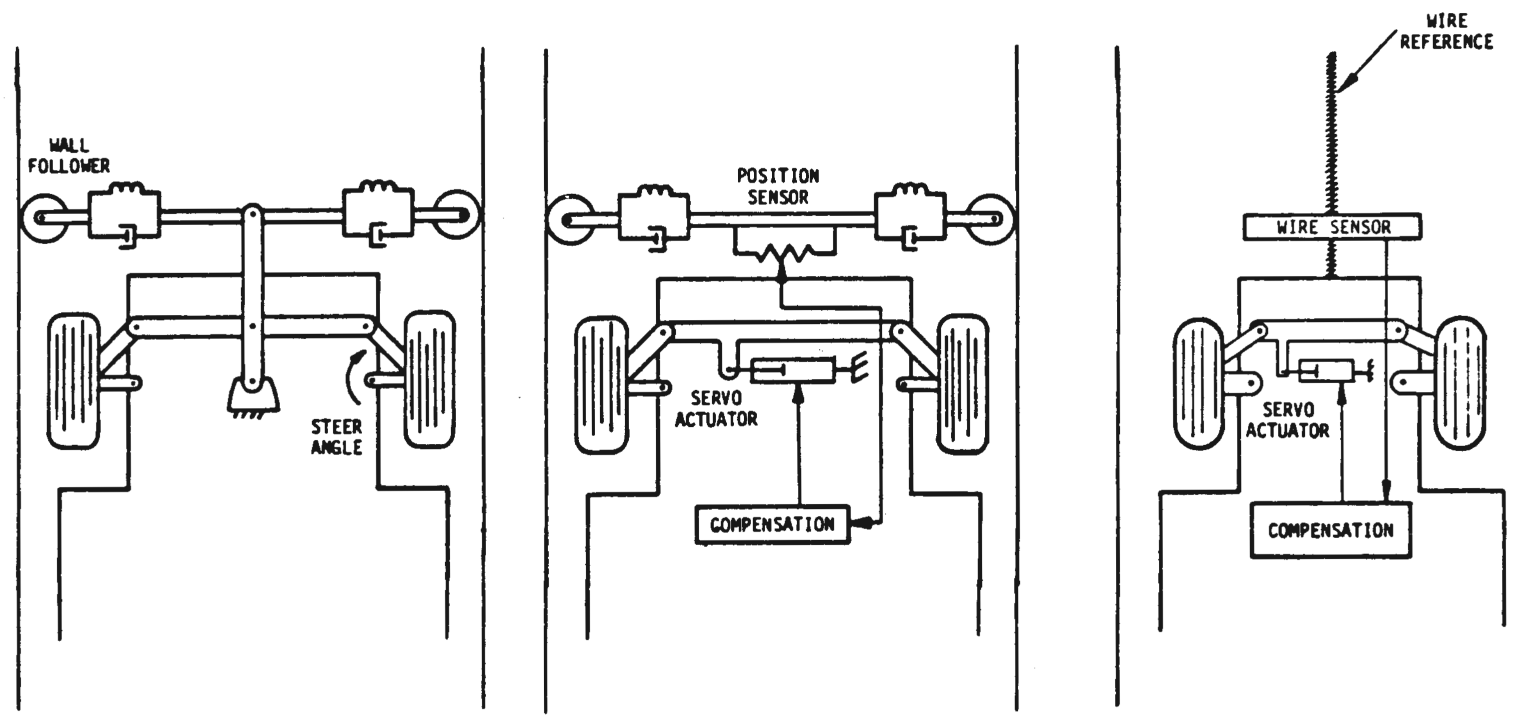


FIGURE 2.1.18. WALL-FOLLOWER PASSIVE, POWER ASSISTED WALL-FOLLOWER, AND WIRE-FOLLOWER LATERAL STEERING CONTROL SYSTEM SCHEMATICS

FIGURE 2.1.19. VARIABLE GEOMETRY LATERAL CONTROL SYSTEM TEST VEHICLE WITH A 2- OR 4-WHEEL DRIVE AND A SINGLE OR DUAL AXLE STEERING

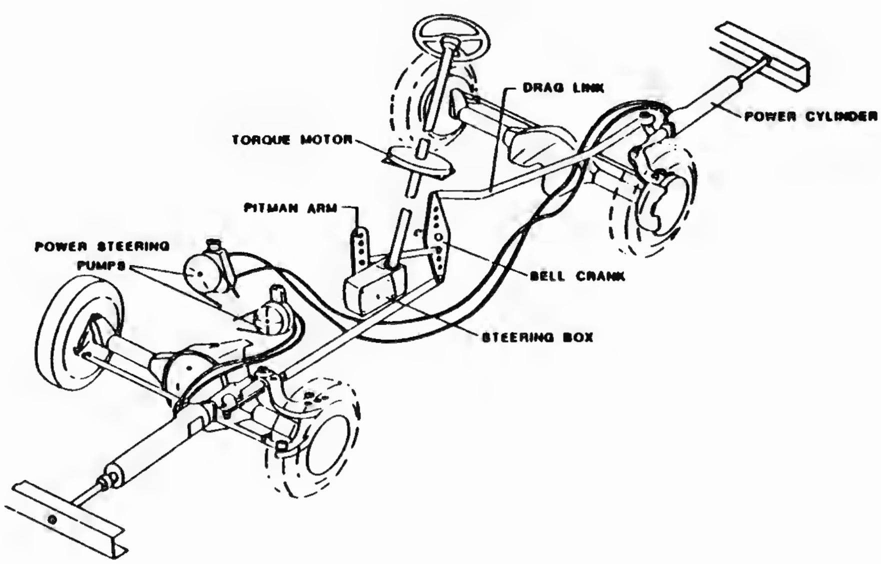


FIGURE 2.1.20. EXPERIMENTAL TEST VEHICLE POWER-ASSISTED FOUR-WHEEL VARIABLE GEOMETRY STEERING SYSTEM CONPONENTS

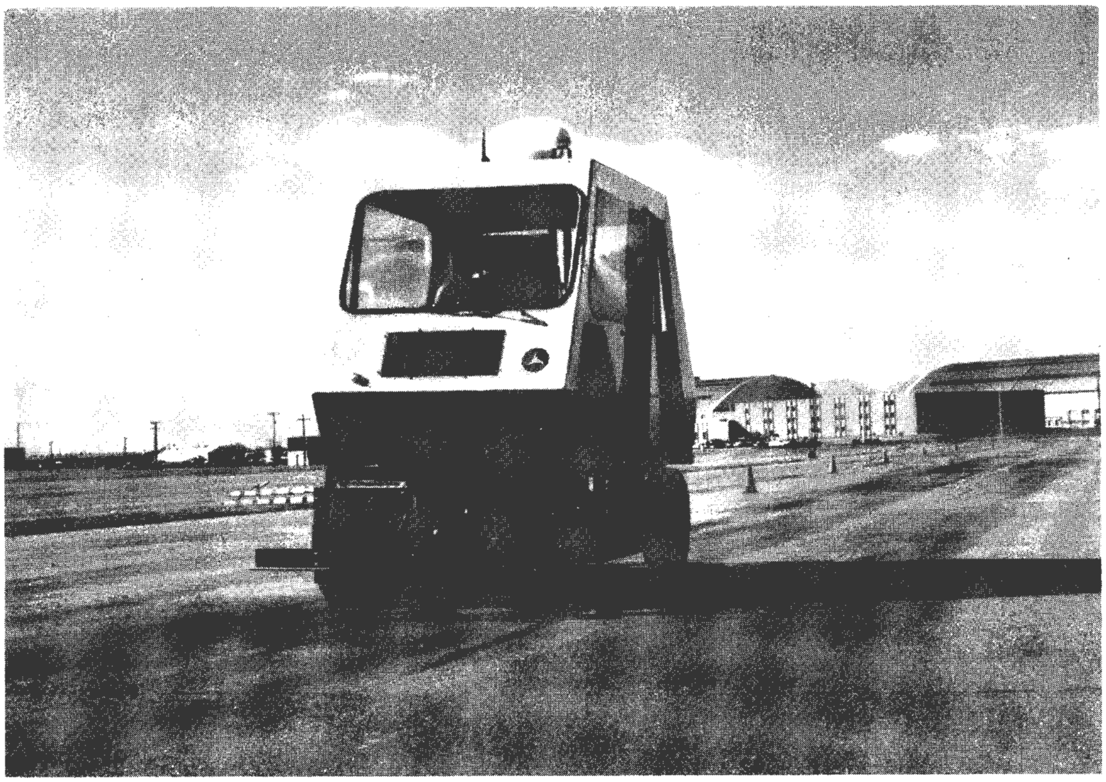


FIGURE 2.1.21. VLACS WIRE-FOLLOWER TEST FACILITY AT LOWRY AIR FORCE BASE.

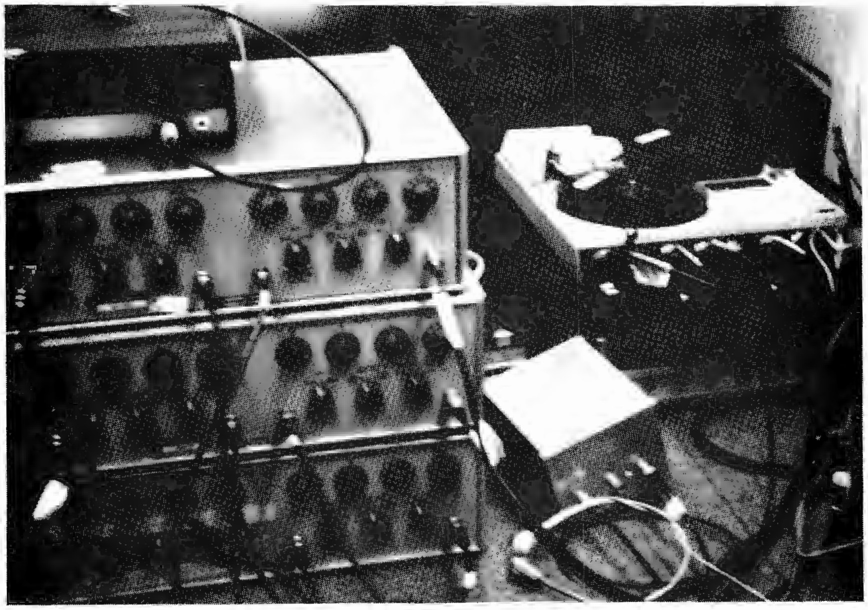


FIGURE 2.1.22. THIS TEST EQUIPMENT PERMITS RECORDING LINEAR AND ANGULAR ACCELERATIONS IN THREE AXES

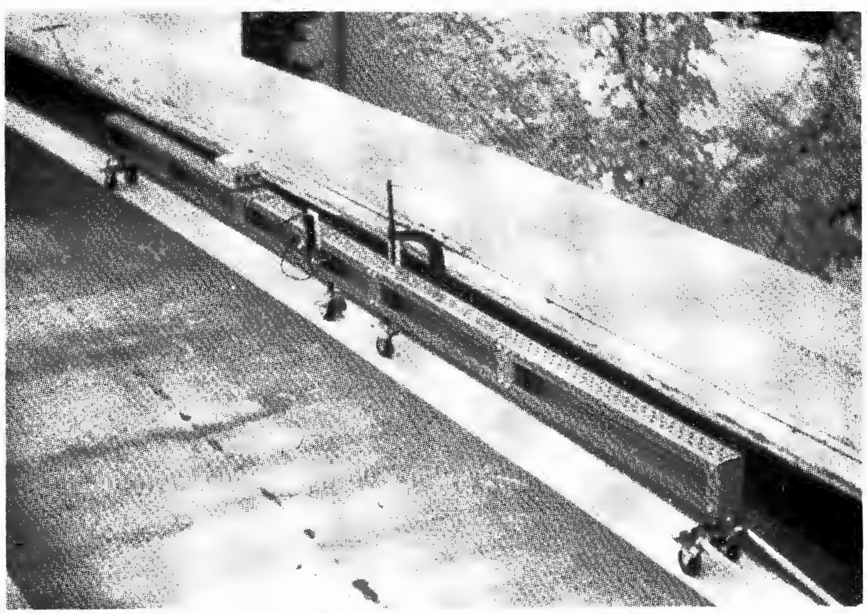


FIGURE 2.1.23. A 4.3-METER LONG PROFILOMETER WAS USED TO MEASURE GUIDEWAY RUNNING SURFACE ROUGHNESS

The major capital investment in an AGT system is the guideway and station infrastructure representing 50 to 70 percent of the cost of constructing an AGT system. The Guideway and Station Technology project performed by De Leuw, Cather and Company was aimed at reducing the capital, operating, and maintenance costs and reducing implementation time. The project included a comprehensive review of AGT guideway, station, and weather protection technology and development of improved guideway, station, and weather protection designs, improved construction techniques, and contracting methods, and power distribution systems.

The guideway and station technology review included over 22 AGT or AGT-related transit systems including the guideways shown in Figure 2.1.24. The review encompassed design considerations, site integration, construction management, vehicle design impact on guideway, and cost. Some examples of AGT guideway and stations are shown in Figures 2.1.25 through 2.1.27. The weather protection review encompassed AGT systems, highway and conventional rail transit. The review of weather provisions of existing AGT systems focused on the Ford Fairlane (Figures 2.1.28 and 2.1.29), Morgantown (Figure 2.1.30), Westinghouse test tracks, Dallas-Fort Worth Airtrans, and Toronto Zoo systems. A summary of the winter weather provisions at these sites is given in Table 2.1.4. Based on the review, three areas were found to present the greatest potential for winter weather problems: (1) icing of signal and power rails; (2) loss of traction caused by ice, snow or freezing rain; and (3) freezing and jamming of guideway switches.

The project developed improved design and fabrication techniques for existing AGT guideway and station design and also developed new and innovative guideway concepts as indicated in Figure 2.1.31. The benefits of prefabrication, offsite fabrication and slipforming to reduce installation time and costs received particular attention. Figures 2.1.32 and 2.1.33 show guideway prefabrication sections for the Ford Bradley Field installation. In addition, the project evaluated a wide range of column and footing technology as indicated in Figure 2.1.34. Results indicated that improvements to existing AGT guideway designs would reduce costs up to 15 percent. New and innovative guideway concepts offer significantly more potential cost savings but additional development work would be necessary for implementation.

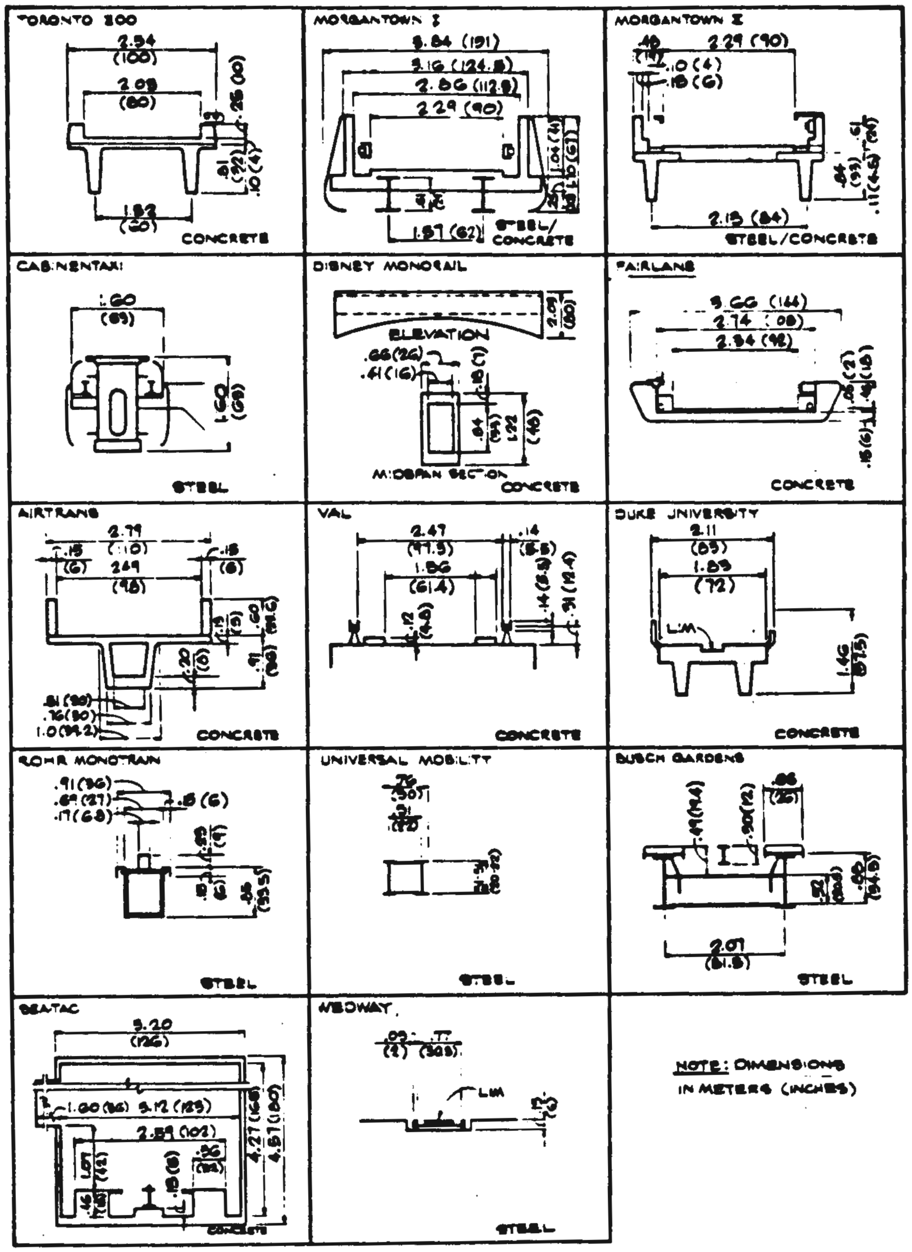


FIGURE 2.1.24. EXISTING AGT SYSTEM GUIDEWAY TECHNOLOGIES INCLUDED IN THE GUIDEWAY DESIGN REVIEW AND DESIGN IMPROVEMENT STUDIES.

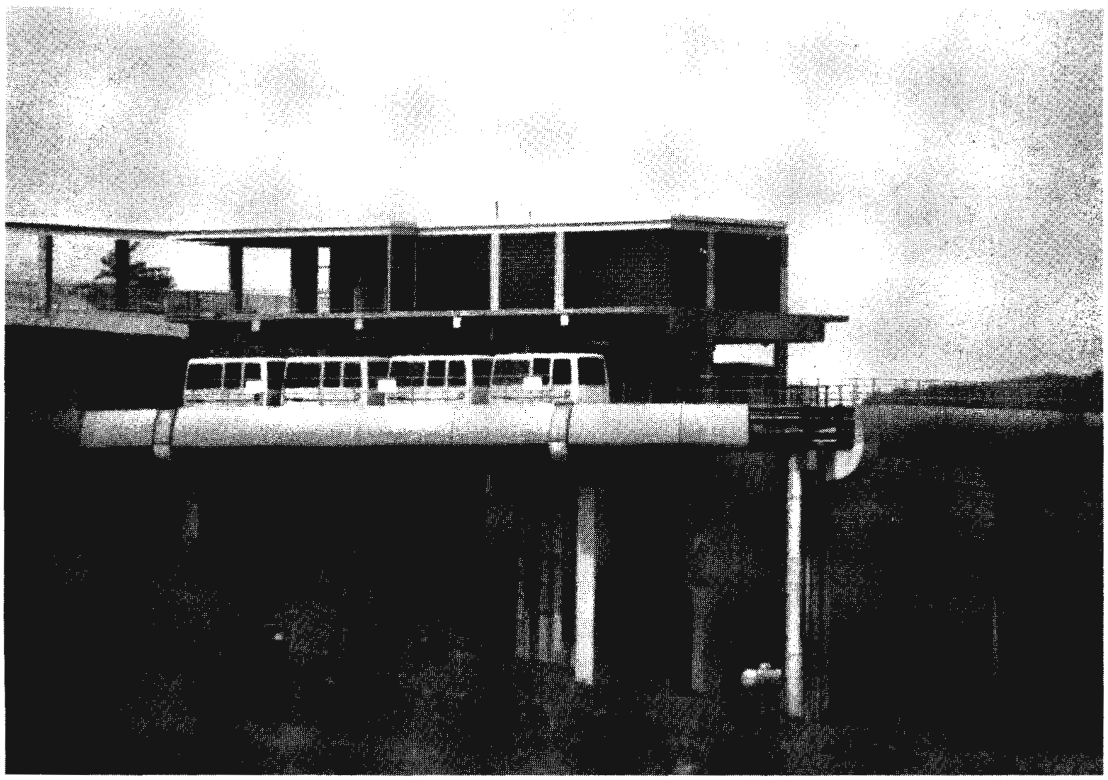


FIGURE 2.1.25. MORGANTOWN STATION AND GUIDEWAY.

FIGURE 2.1.26. WEDWAY MOVING PLATFORM STATION.

FIGURE 2.1.27. AIRTRANS STATION.

FIGURE 2.1.28. FORD FAIRLANE VEHICLE APPROACHING HOTEL STATION.

FIGURE 2.1.29. SPECIAL PURPOSE VEHICLE USED TO AID IN GUIDEWAY SNOW AND ICE REMOVAL AND POWER RAIL DE-ICING.

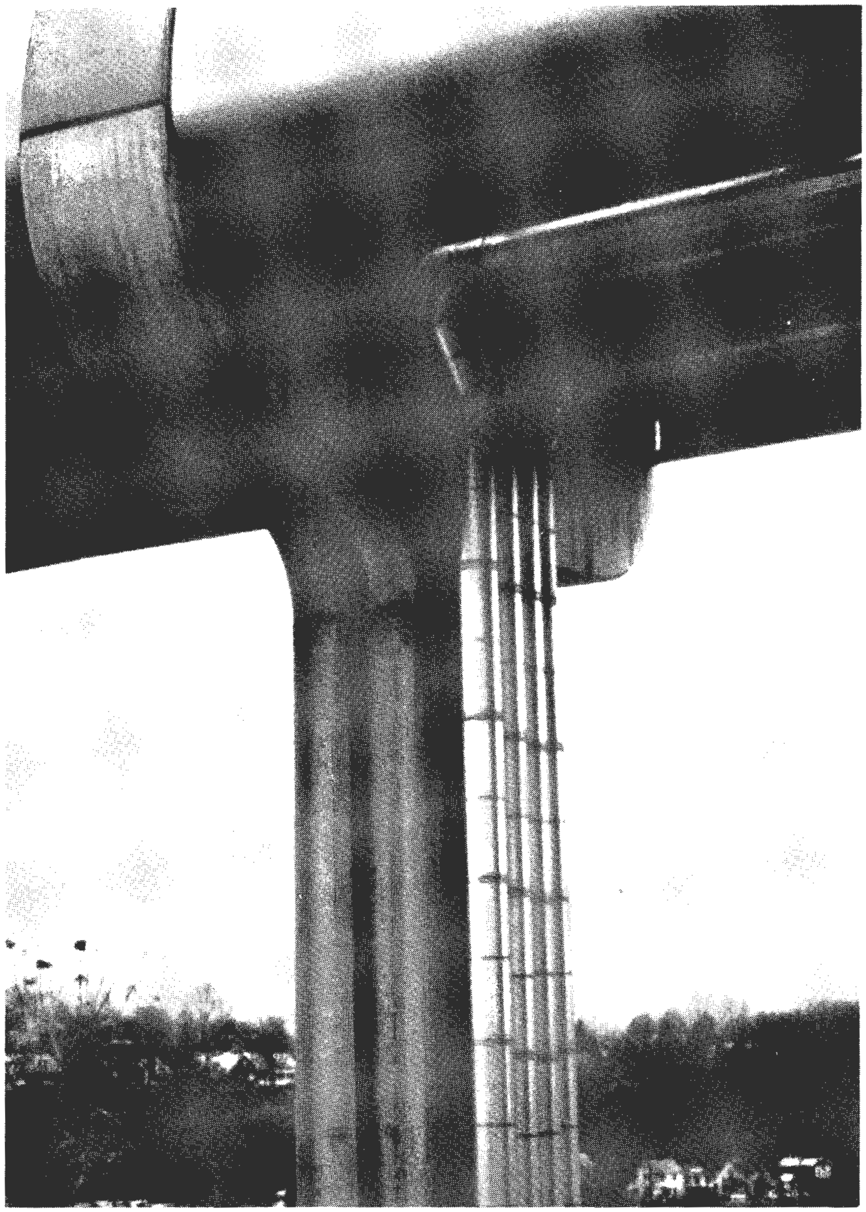


FIGURE 2.1.30. PIPES FOR DELIVERING GUIDEWAY HEATING FLUID FOR THE MORGANTOWN SYSTEM.

TABLE 2.1.4 - AGT SYSTEMS WINTER WEATHER PROVISIONS

Provisions	Airtrans	Fairlane*	Morgantown	South Park	Toronto Zoo
Guideway Traction Surface					
Primary	Ethylene Glycol Spray	Embedded Electric 645/m^2 (60 W/ft^2)	Embedded Pipe Electric 645 W/m^2, (60 W/ft^2	Selective Embedded Electric 645 W/m^2 (60 W/ft^2)	Sand/Urea Pellets
Backup	Snow Blower	Snow Blower	Snow Blower	-	Snow Blower
Snow Tolerance	2.5 cm (1 in.)	2.5 cm (1 in.)	None	4.5 cm** (1.8 in.)	2.5 cm (1 in.)
Prediction	Airport Weather Forecasts	Monitor Forecasts	Private Weather Service	Detector	Monitor Forecasts
Rails					
Primary	Ethylene Glycol Spray/ Wipe	Methanol Spray	Heated Ethylene Glycol Spray	Electric Heat	-
Backup	-	Manual Scrape	Manual Scrape	-	Manual Broom Underneath
Collectors	-	-	Heated	-	-
Switching	-	-	On-Board Heated	-	Switch Pit Heated

*Information reflects provisons through 1976-77 winter. Use of heating was discontinued during 1977-78 winter.

**This value is typical of other Westinghouse installations. The value for South Park is 1.6 cm (0.63 in.).

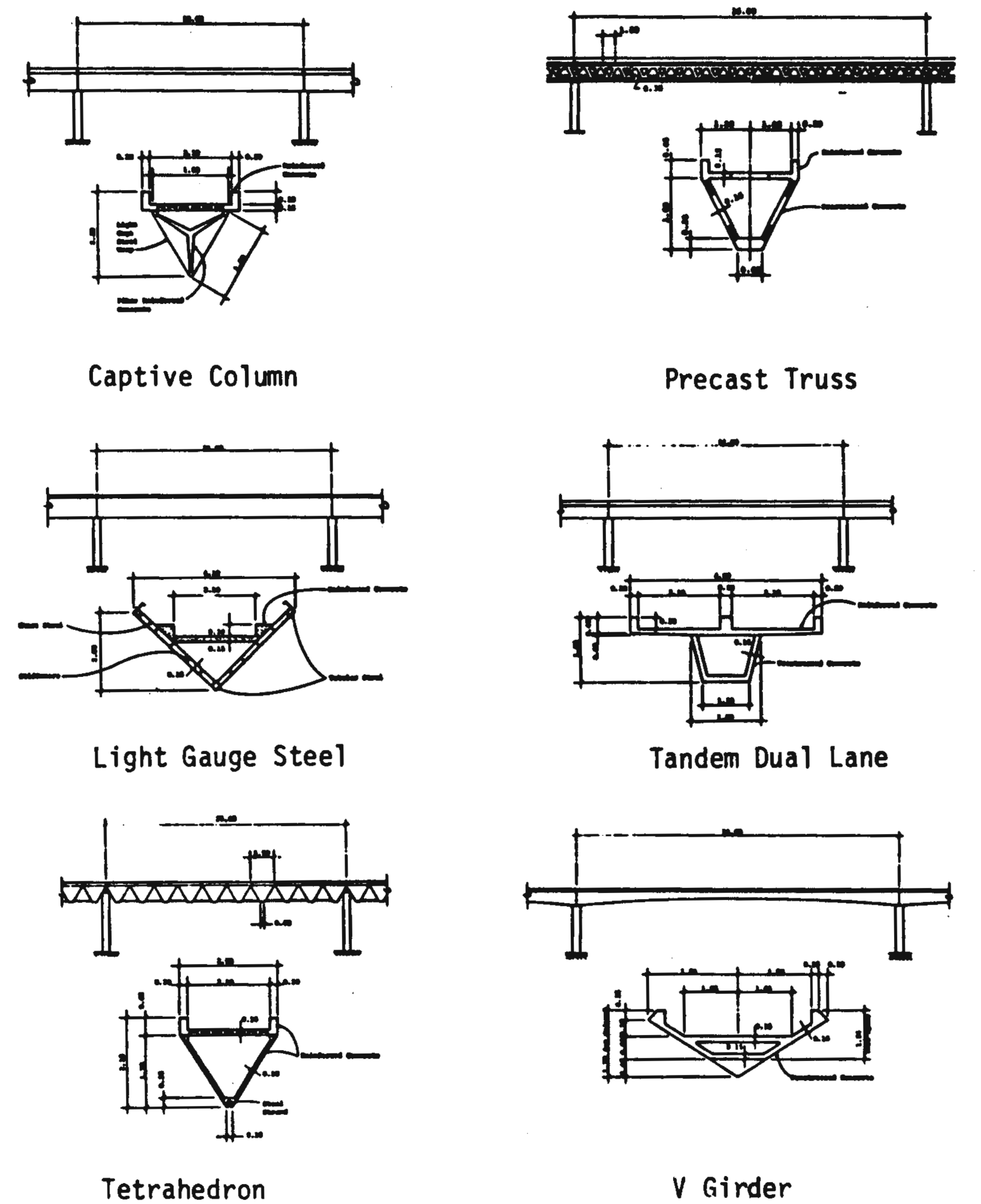
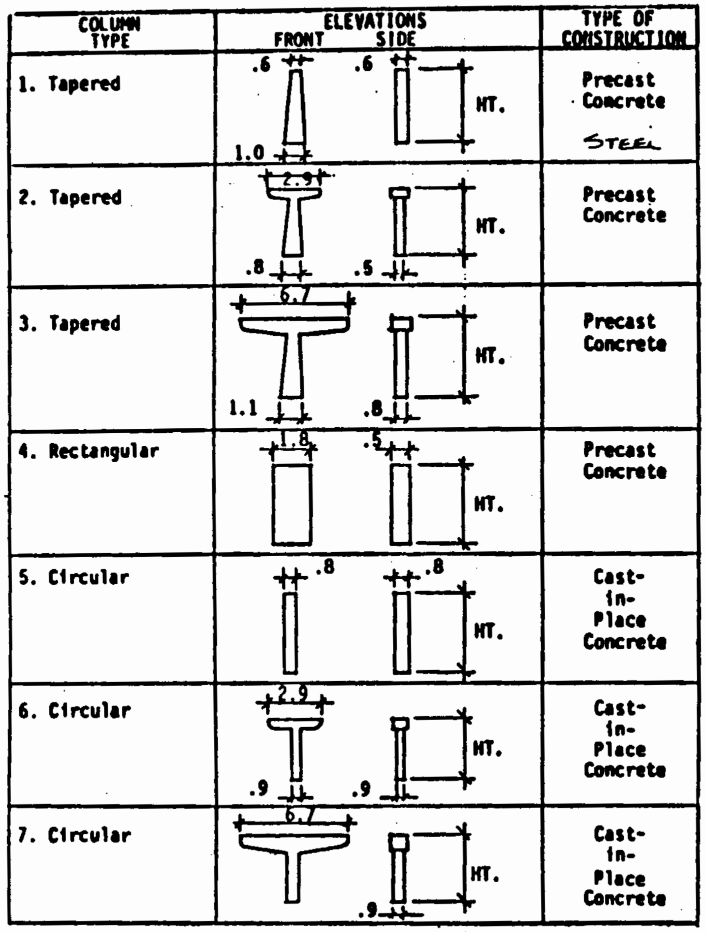


FIGURE 2.1.31. GUIDEWAY BEAM DESIGN VARIATIONS INCLUDED IN THE INNOVATIVE GUIDEWAY TECHNOLOGY STUDIES.

FIGURE 2.1.32. GUIDEWAY PREFABRICATION SECTION OF BRADLEY SYSTEM

FIGURE 2.1.33. GUIDEWAY PREFABRICATION SECTION OF THE BRADLEY AIRPORT SYSTEM.



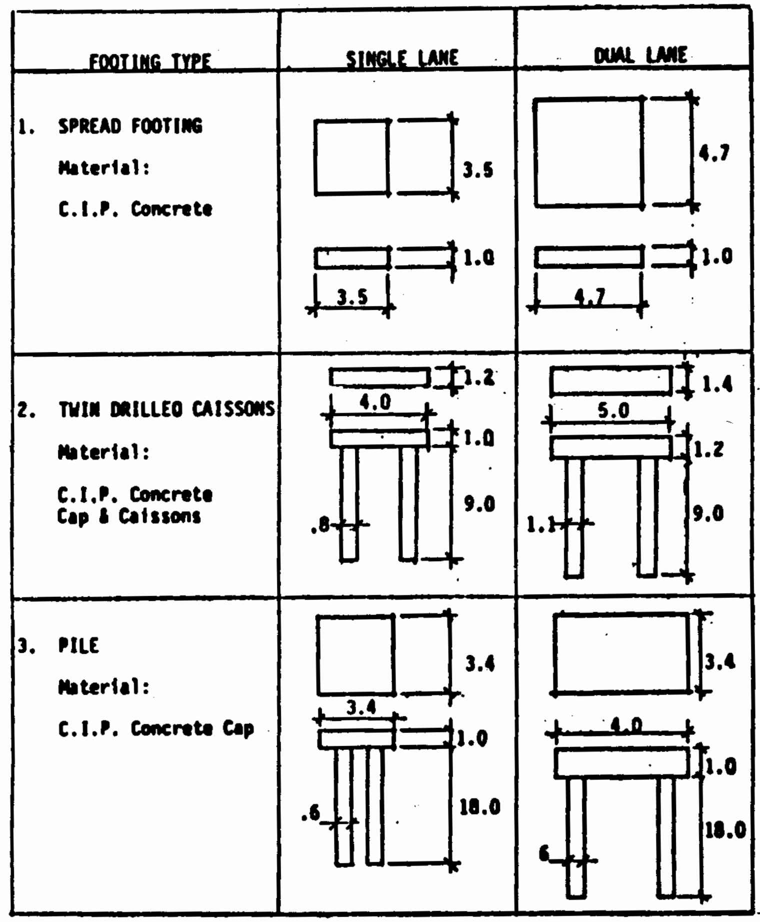


FIGURE 2.1.34. GUIDEWAY COLUMN AND FOOTING CONFIGURATIONS INCLUDED IN THE GUIDEWAY TECHNOLOGY STUDIES.

Case studies using techniques such as models and photomontage were used to study the visual impact of AGT structures and to explore the problems associated with installation in urban areas. A major project task was directed towards the development and evaluation of techniques to improve the all-weather operation capability of rubber-tired AGT systems. Methods such as improved power rail orientation, reduction of the heated guideway surface to the tread track widths and insulation techniques appear to hold the potential for saving up to 80 percent in guideway and power rail deicing energy. Figure 2.1.35 shows various guideway installation arrangements to reduce guideway heating losses.

2.2 Other Projects

In addition to the major projects described above, a number of smaller research projects were funded under the AGTST program addressing:

a. Vehicle Control,
b. Automated Mixed Traffic Vehicle Technology,
c. Automated Transit Technology Requirements,
d. Personal Rapid Transit,
e. Hardware Reliability and Service Availability,
f. Hydrostatic Drive Development
g. Vehicle Data Acquisition,
h. Entrainment and Platooning,
i. Station Security Features, and
j. Morgantown Design Analyses.

Independent non-profit organizations such as the Applied Physics Laboratory of Johns Hopkins University and The MITRE Corporation have played a valuable role in the UMTA AGT program through independent analyses and assistance in monitoring system design, integration, and test activities.

The Applied Physics Laboratory (APL) has been conducting theoretical studies on AGT system control since 1969. The current Vehicle Control research is extending previous results with particular emphasis on the problems of longitudinal control at medium to short headways, improved vehicle operation strategies for AGT stations including online acceleration and deceleration and analyses of communication and sensor requirements.

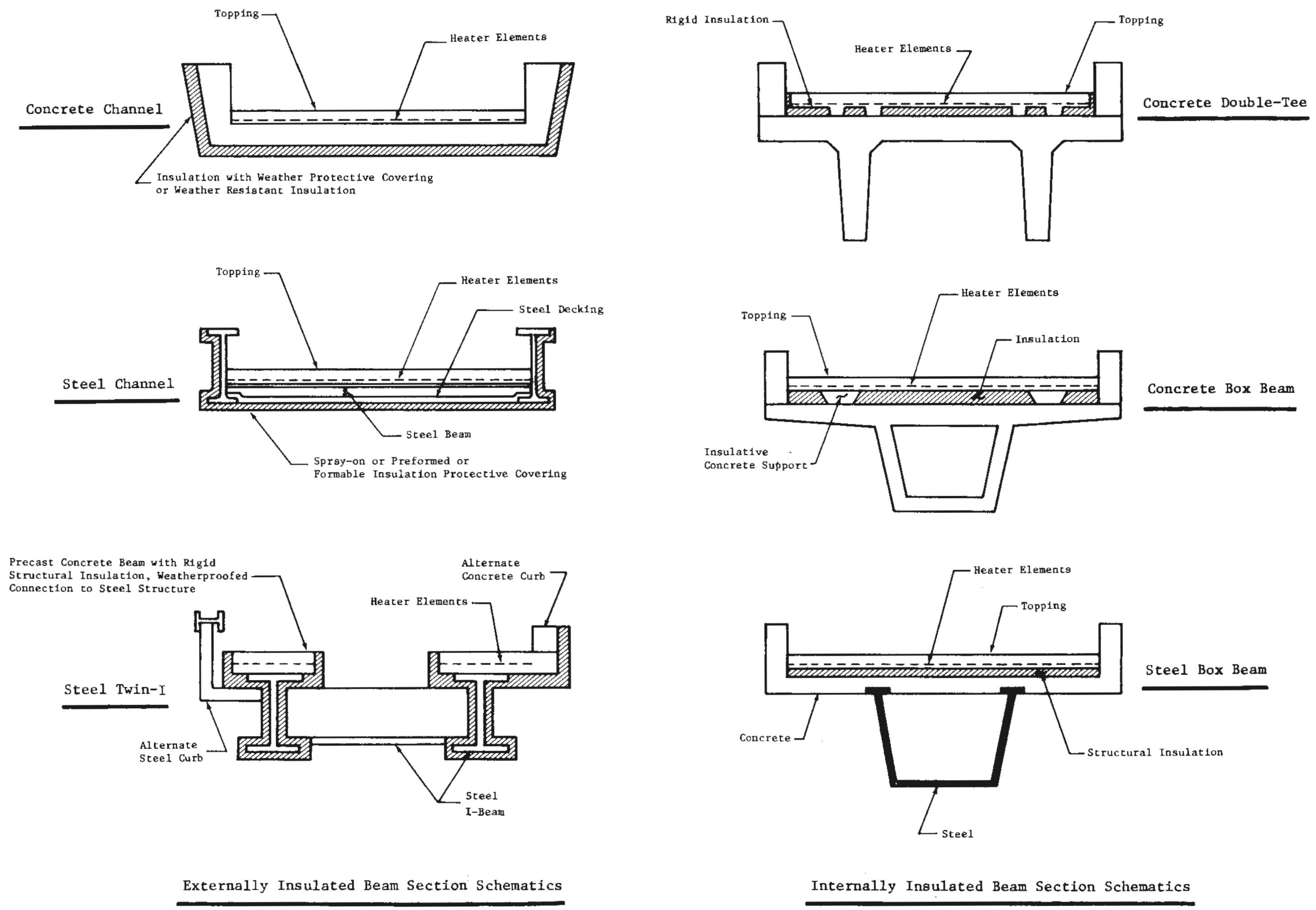


FIGURE 2.1.35. GUIDEWAY DESIGNS WHICH REDUCE HEATING LOSSES.

A control system has been developed utilizing a nonlinear control law which allows stable operation in the three second headway range while requiring only information on the position of the lead vehicle at a sampled data rate of 8 bits every second. Detailed analysis and computer simulations have been carried out for various maneuvers such as that shown in Figure 2.2.1 for a manuever in which a vehicle traveling 15 meters per second overtakes a leading vehicle traveling initially at 10 meters per second and then slowing to 5 meters per second. Studies have been carried out in the area of station operations to determine possible off-line station deceleration ramp length reductions at different headways, as well as mixed on and off-line station operations. An adaptive merging technique has been applied to station ingress and egress operations which allows off-line ramps to be shortened by allowing some acceleration and deceleration on the main line. Additional studies are being carried out for the implementation of vehicle control algorithms in micro-processor logic utilizing the Motorola 6800 series microelectronics.

APL is also utilizing a Hybrid Computer Vehicle handling program, which was originally developed for NHTSA to simulate and evaluate several types of steering approaches for AGT vehicles. This facility has the capability of simulating the dynamic operation of any type of rigid, wheeled vehicle in twelve degrees of freedom, and confirmed that for most steering operations, a simple six degree of freedom simulation gives adequate results.

The MITRE Corporation is performing a variety of research tasks as part of the AGTST Independent Studies activities. The Automated Transit Technology Requirements project is directed towards establishing performance characteristics (speed, cost, capacity) which will result in viable deployments for new transit technologies, and assessments of hybrid propulsion technology, and AGT energy requirements.

As part of a cost-benefit evaluation, MITRE performed a Times-Square/Grand Central Station application case study for the accelerating walkway. Based on actual ridership data for the existing rail shuttle system, accelerating walkway systems could provide shuttle service for $.04 to $.08 per trip. The accelerating walkway system for the 732-meter trip was divided into three dual-lane segments to increase reliability as shown in Figure 2.2.2.

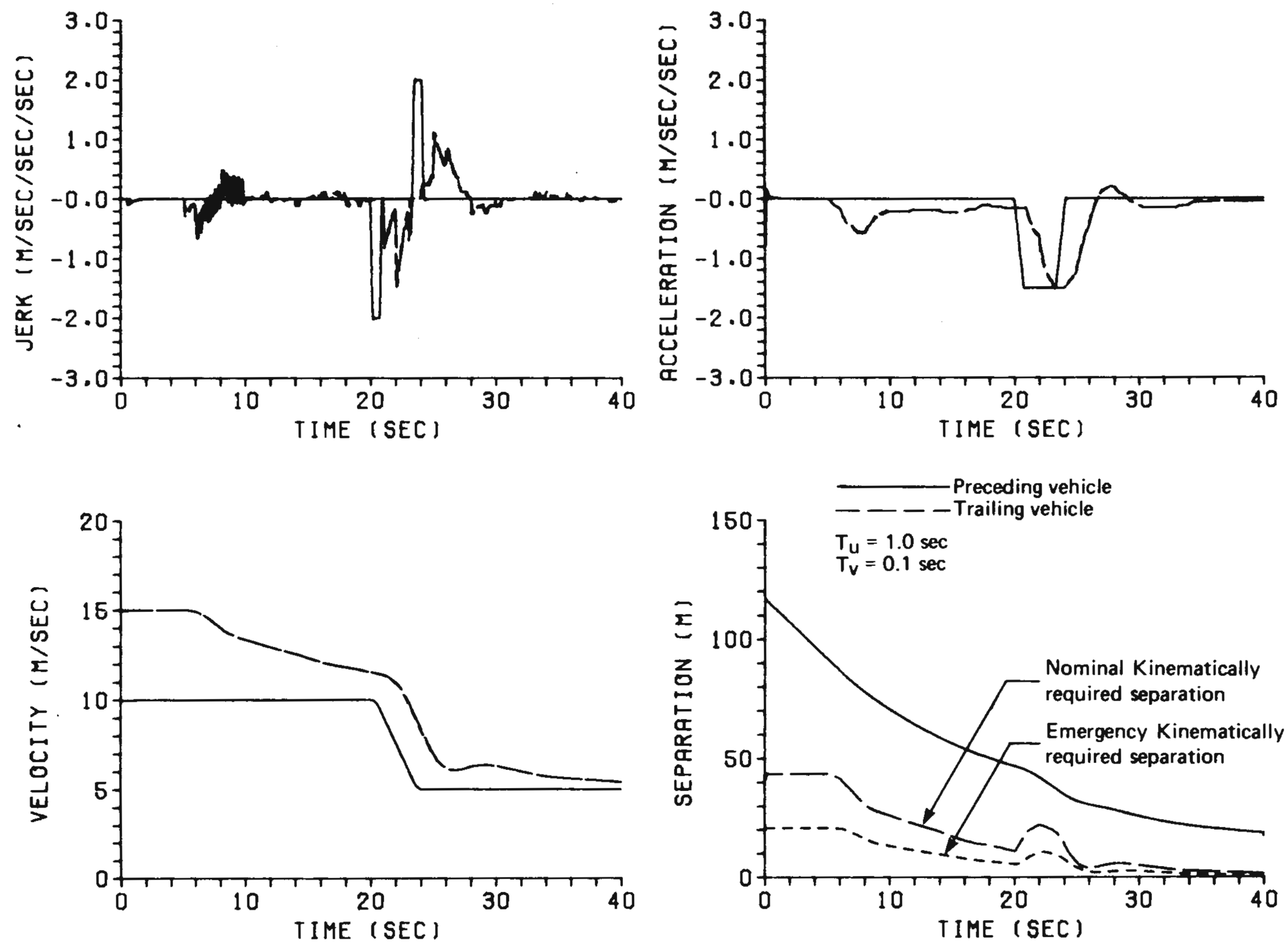


FIGURE 2.2.1. DETAILED NONLINEAR SIMULATION PERMITS ACCURATE PREDICTION OF VEHICLE CONTROL SYSTEM PERFORMANCE.

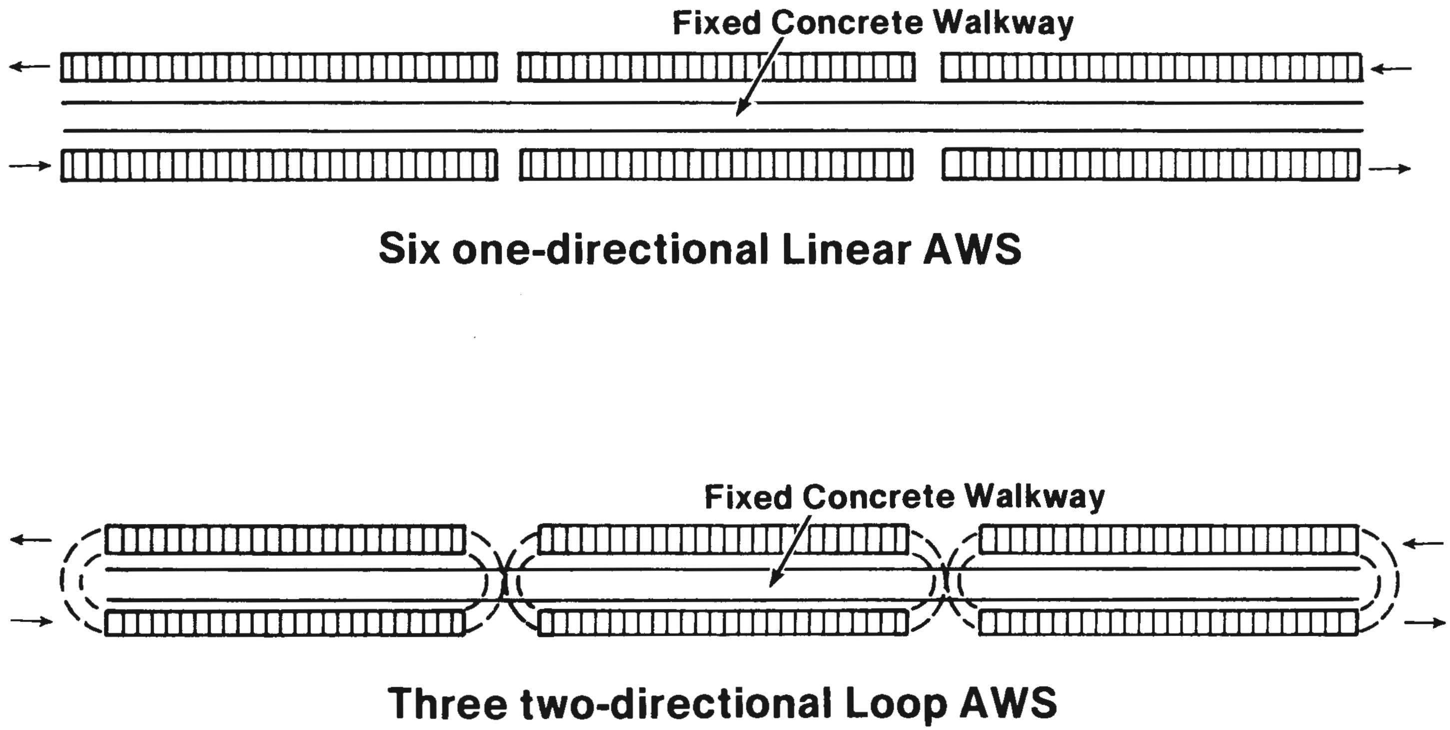


FIGURE 2.2.2. TWO DIFFERENT ACCELERATING WALKWAY DEPLOYMENT CONFIGURATIONS WERE CONSIDERED FOR THE CROSSTOWN-MANHATTAN TRANSIT APPLICATION.

The study results indicate that the accelerating walkway provides shorter trip time (Table 2.2.1) than the existing rail shuttle, the Flushing subway line and the buses, except for the rail shuttle during peak hours when average trip times are the same. Though the accelerating walkway speed is less than that of the alternative transit systems, the accelerating walkway average trip times are shorter because there is no wait time.

The innovative concept of an automated transit vehicle which is capable of safely mixing with pedestrian traffic on existing rights-of-way offers the promise of providing inexpensive transit in applications such as shuttles and loops in auto-free zones and other sites where passenger volumes do not justify the capital investment implied by conventional AGT or moving walkway systems. The Jet Propulsion Laboratory (JPL) in Pasadena, California, has been developing an Automated Mixed Traffic Vehicle transit technology which utilizes a small vehicle equipped with sophisticated sensors shown in Figure 2.2.3, and an automatic wire-following steering system shown in Figure 2.2.4 to permit the vehicle to operate at low (2-5 km/h) speeds in pedestrian areas or at higher speeds on semi-protected rights-of-way. The project is funded jointly by the National Aeronautics and Space Administration and the Urban Mass Transportation Administration. A battery-powered breadboard test vehicle has already successfully operated on a 600-meter loop at JPL, shown in Figure 2.2.5. Current studies are focusing on the development of a transitworthy vehicle design and improved control techniques including solid state optical sensors which are immune to external interference, and a flexible microprocessor controller. Although the experimental loop demonstration operated in mixed traffic with automobiles at the JPL facility, the first urban demonstration planned for the future will be in a strictly pedestrian environment.

A separate study was carried out by SRI International of Menlo Park, California to analyze the potential market for AMTV type systems in this country. This study has indicated that there are a large number of potential sites which could be served by this type of system including pedestrian areas, airports, CBD's, shopping centers, and suburban mixed-use developments. The cost to replace existing bus systems with AMTV systems providing equivalent service at some specific sites which were studied, could be amortized in as little as two years because of the lower AMTV operating costs compared to conventional bus.

TABLE 2.2.1 - TRIP TIME COMPARISON (IN MINUTES)[1]

	AWS			EXISTING SUBWAY SHUTTLE			FLUSHING SUBWAY LINE			BUSES		
	Wait Time	Travel Time	Total	Wait Time	Travel Time	Total	Wait Time	Travel Time	Total	Wait[2] Time	Travel[3] Time	Total
Weekday												
Peak	0	3.5	3.5	2.0	1.5	3.5[5]	5.0	2.5	7.5	1.0	5.5	6.5
Off-Peak	0	3.5	3.5	2.5	1.5	4.0	5.0	2.5	7.5	1.5	3.9	5.4
Night	0	3.5	3.5	5.0	1.5	6.5	10.0	2.5	12.5	20.0[4]	1.8	21.8[4]
Weekend												
Peak	0	3.5	3.5	2.5	1.5	4.0	7.5	2.5	10.0	2.5	5.5	8.0
Off-Peak	0	3.5	3.5	2.5	1.5	4.0	7.5	2.5	10.0	4.5	3.9	8.4
Night	0	3.5	3.5	5.0	1.5	6.5	7.5	2.5	10.0	20.0[4]	1.8	21.8[4]

[1]Extra transfer time of descending and ascending the stairs to the underground systems not included.
[2]Approximate average of the two bus lines.
[3]Uses 8.1 km/h for peak, 11.3 km/h for off-peak, and 24.2 km/h for night hours.
[4]These times could be reduced somewhat if buses operate according to published schedule.
[5]Existing shuttle system is overcrowded in peak hours.

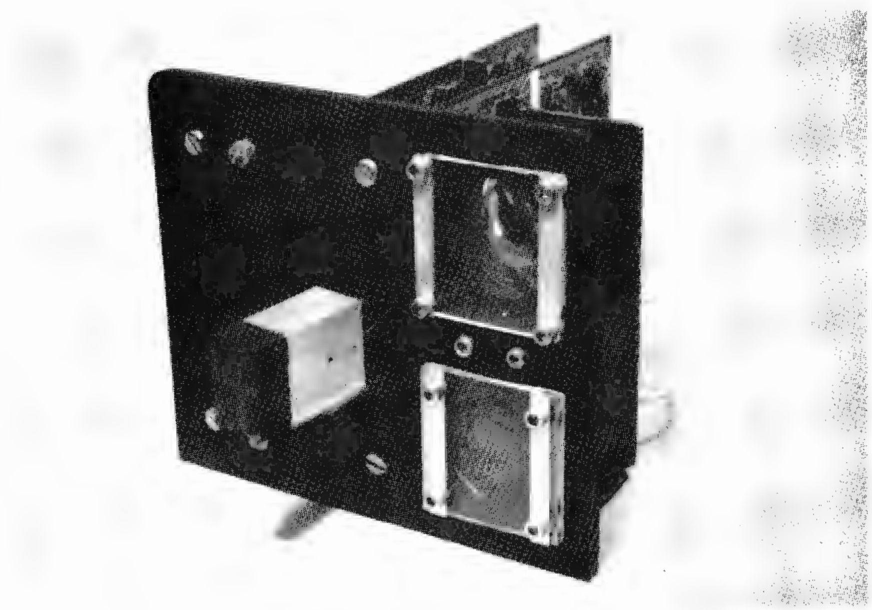


FIGURE 2.2.3. A MICROELECTRONIC-BASED SENSOR PROVIDES OBSTACLE INFORMATION TO THE AMTV CONTROL SYSTEM.

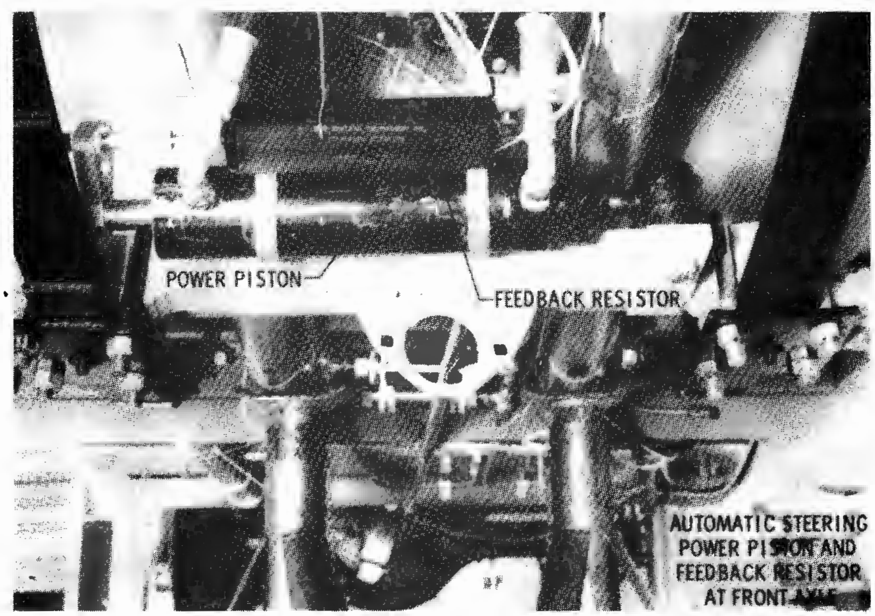


FIGURE 2.2.4. THE MIXED TRAFFIC VEHICLE-STEERING CONTROLLER FOLLOWS A RADIATING WIRE IN THE RUNNING SURFACE.

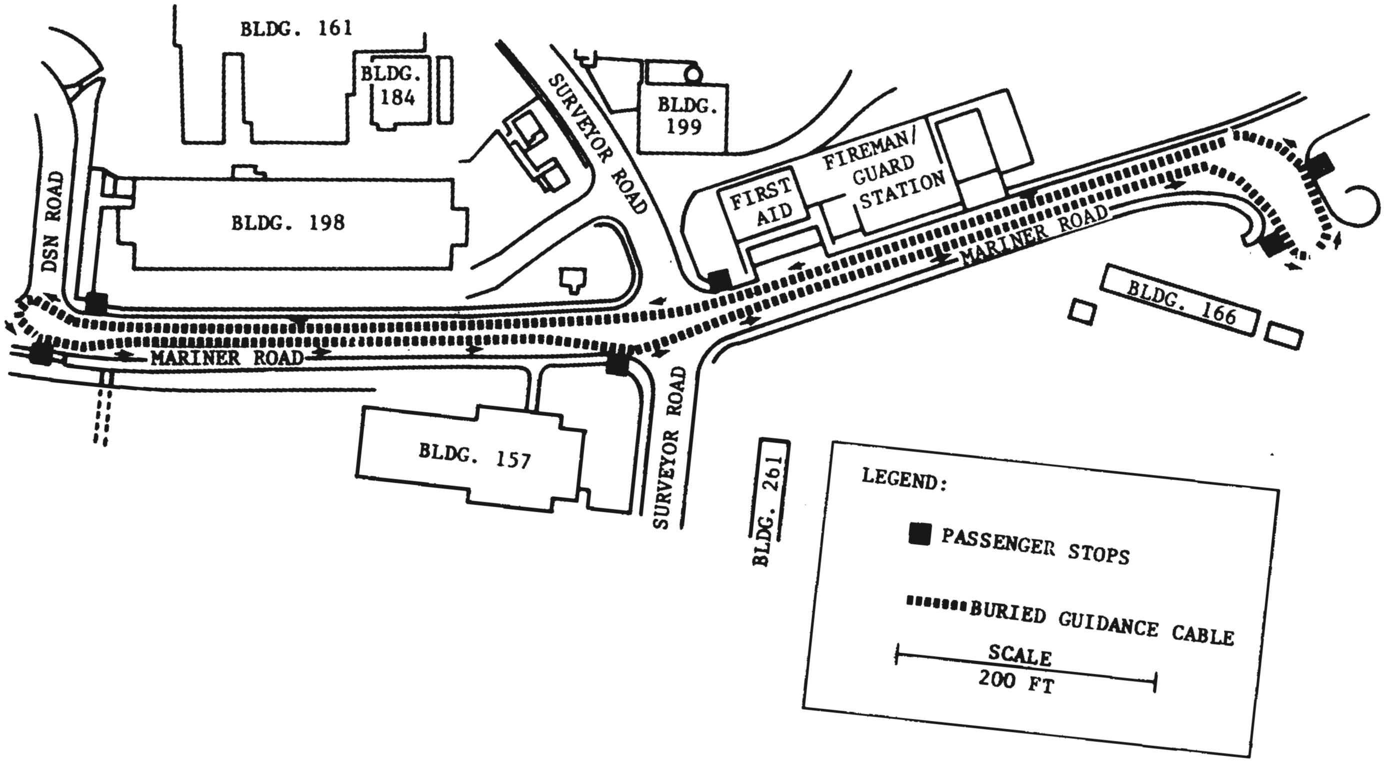


FIGURE 2.2.5. AN EXPERIMENTAL AUTOMATED MIXED TRAFFIC VEHICLE HAS BEEN OPERATED ON THIS 600-M LOOP AT THE JET PROPULSION LABORATORY.

MITRE has also been carrying out studies on system applications and economic analyses of the Automated Mixed Traffic Vehicle (AMTV) concept as a feeder to other transportation services such as existing transit systems, parking lots, and airports. An analysis is being carried out for a hypothetical baseline application at Washington National Airport using actual airport patronage data. The analysis addresses links between the terminals, links from terminals to parking and the Metro station; and links from parking to a walkway which was proposed by the FAA to link the Metro station with the terminal. Applications in which AMTV is economically feasible compared to alternate approaches (e.g., shuttle bus) will be identified and typical system designs worked out. Preliminary results indicate that an AMTV system could provide better service at a lower cost than bus for such feeder-type systems.

A significant contribution to AGT research was made in the early 1970s by the Aerospace Corporation in Los Angeles through an extensive in-house funded study of the feasibility of AGT systems using very small vehicles at fractional-second headways. The Personal Rapid Transit project provided funds to the Aerospace Corporation to update this research and to place the results in the public domain. The detailed study covered all facets of small vehicle AGT systems, including existing hardware and software, capital and operating costs, safety and reliability, urban applications and economics, environmental (noise, air pollution, visual) and energy impacts, planning methodologies, transportation alternatives, land use, and assessments of deployment impacts. A general methodology was developed for evaluating a small vehicle AGT system in an urban area, and illustrated by application to the Los Angeles area. The specification of service reliability as perceived by the passenger, operator, and developer, is an important issue in the development of procurement documents and in-service evaluation.

The Hardware Reliability and Service Availability project was established at Battelle in Columbus, Ohio, to survey and define measures of service availability which have been used by operators, manufacturers, and researchers to characterize the operating reliability of AGT systems. Service availability is defined as a measure of the effect of system failures on passenger and/or operator perceptions of service.

The contract resulted in a three volume report which surveys current practice in the transit industry; analyzes the buildup and dissipation of passenger delay times in various simple AGT systems after a variety of breakdowns and suggests a simplified measure. A workshop was held in October 1977 to disseminate the results of this effort.

The findings of this study include the following: (1) no single model or measure exists today that is in uniform use; (2) hardware reliability and maintainability are closely related to service availability, and (3) a simplified methodology can be applied based on the probable numbers of passengers delayed per year and the resulting probable total delay time.

The Hydrostatic Drive Development at Mobility Systems and Equipment, in Los Angeles, was directed towards the test of a hydrostatic drive for AGT vehicles. Hydrostatic drives permit the elimination of the complex electronic power modulator and the use of a common squirrel cage rotary induction motor, resulting in significant cost savings and a reduction in electromagnetic interference. However, an inherent characteristic of hydrostatic drives is a high acoustic noise level. The study included a survey of the state-of-the-art of hydrostatic drives, and the development of the design and performance requirements for a hydrostatic drive propulsion system for AGT. A detailed test program was carried out utilizing dynamometer simulation of a typical AGT duty cycle using two different sizes of hydrostatic motors. The test fixture which was used is shown in Figure 2.2.6. A microelectronic control system was designed and built to provide the repeatable AGT duty cycle profile for the series of tests. Temperature, pressure, and noise measurements were taken for various speeds and loads, and a reduction of noise level on the order of 22 db from 38 db to 16 db above ambient was achieved through noise abatement techniques.

A Vehicle Data Acquisition system has been developed by the Port of Seattle which collects and continuously records 20 minutes of data from 32 test points in a specially instrumented Sea-Tac Satellite Transit System Vehicle. The recorded data is useful to maintenance personnel to rapidly diagnose intermittent and total vehicle failures, thus reducing vehicle downtime and maintenance costs. This system uses an onboard microprocessor system based on the Intel 8080 and a semiconductor memory to record data which can then be dumped to a portable floppy disc

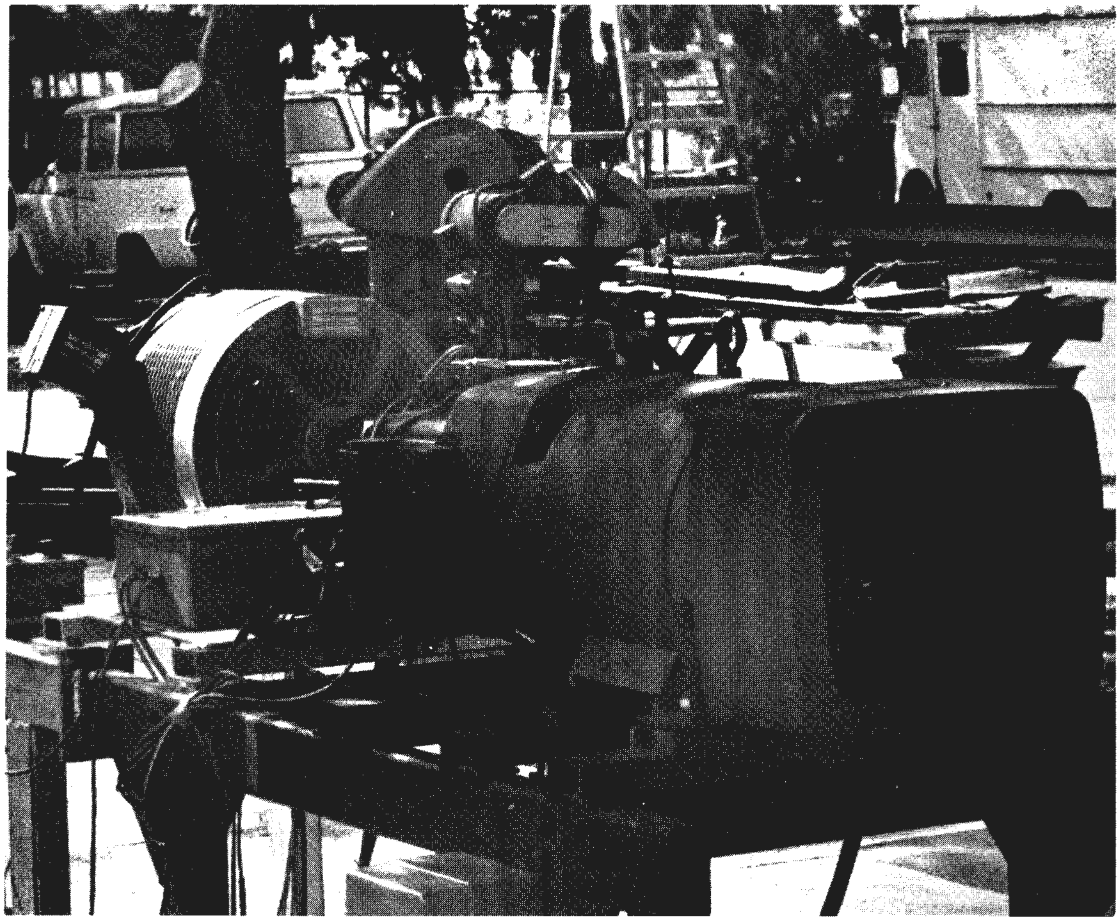


FIGURE 2.2.6. HYDROSTATIC DRIVE TEST ASSEMBLY.

memory unit (Figure 2.2.7) and transferred to a microprocessor terminal in the maintenance area for analysis (Figure 2.2.8). The system underwent a six-month in-service test on one vehicle to determine the actual improvement possible in maintenance time. In addition to speeding up corrective maintenance, the system has also been able to identify marginal conditions and incipient failures.

Dynamic interaction between the vehicle and the dynamics of elevated guideways can significantly affect ride comfort. The Massachusetts Institute of Technology has been performing research in this area under UMTA Office of University Research sponsorship since 1974. Sponsorship of this research continued under the AGTST program in the area of vehicle guideway dynamics (see Guideway and Station Technology) and operational analysis of Entrainment and Platooning in which a study was carried out to determine how the passenger-carrying capacity of AGT systems can be increased by operating vehicles in trains or platoons of varying length. System capacities between 5,000 and 10,000 passengers per hour could be achieved using these techniques. The longitudinal control systems needed to effect dynamic en/extrainment and to operate in platooned vehicle spacings of 30 to 60 cm were developed and their performance demonstrated by use of analysis and simulation with particular attention to stability, jerk limiting requirements, safety, and passenger comfort.

The Station Security Features project examined the security features required to adapt stations to the security characteristics of different urban sites. This project was performed by W.V. Rouse and Company and developed procedures and techniques for predicting requirements for AGT system station security.

Accomplishments of the project are the following: (1) characteristics of transit crime and criminals have been defined; (2) station design concepts have been documented and evaluated; (3) AGT station environments have been reviewed; (4) station security crime countermeasures have been documented; (5) neighborhood resources have been defined; (6) multiple regression analysis and factor analysis have been established as crime prediction techniques; and (7) countermeasure assessment techniques have been established including observation, sample surveys, statistical analysis; and specialized interviews such as key person and critical incidents evaluation.

FIGURE 2.2.7. THE CONTENTS OF THE VEHICLE DATA ACQUISITION SYSTEM MEMORY ARE TRANSFERRED TO MINI-MAGNETIC DISK UNIT.

FIGURE 2.2.8. A MICROPROCESSOR TERMINAL PERMITS WAYSIDE ANALYSIS OF THE RECORDED VEHICLE PARAMETERS.

Important elements of the Morgantown Design Analyses were documented in two reports. These reports which provide design details and development experiences incorporated into the operating equipment of the system, are valuable to others who may be designing similar systems. Of particular importance is the experience involving the effects of nonlinearities and variations in control system parameters which can significantly affect performance if not adequately considered in the design. To aid future designers, system design and supporting analyses were included in the reports.

In addition to the project work, a substantial effort has been made to communicate the results of the research to the transit community. Six workshops have been held covering areas such as passenger security, system performance measures, service availability, and system operation simulation and analysis in order to solicit comments from the transit industry, system manufacturers, consultants and Government experts. A major conference on AGT Technology Development was also held in Cambridge, Massachusetts which attracted 241 attendees. The major projects are providing data and guidelines for the design and specification of critical system elements which are being distributed to the DPM cities and other interested users. A contract was awarded to the American Public Transit Association to permit transit operator staff members to review areas where the special knowledge and experience of operators can substantially improve the usefulness of research results. Representatives from thirteen transit properties have reviewed reports and presentations providing many valuable comments on project activities.

3. PROGRAM RESULTS

3.1 Technical Reports

The results of the AGTST program are documented in a large number of reports. These reports are being processed by the National Technical Information Service (NTIS) as they become available. Information on ordering reports and the location of library copies is provided in Appendix C. Draft copies of many of the reports are already available and may be obtained by contacting Gwen Daniel, Advanced Development Division of the Office of Technology Development and Deployment.* Table 3.1.1 indicates report availability by PB number for reports already processed by NTIS or by estimated date of availability from NTIS.

3.2 Software Models

A number of the AGTST projects involve extensive use of computer simulation models to generate analysis results. These models are being made available through the Federal Software Exchange Center (FSEC). Availability is indicated in Table 3.2.1 by date or by FSEC number. Preliminary versions of some of the software are already available and may be obtained by contacting Gwen Daniel at the address given in Section 3.1.

3.3 Workshops and Conferences

An important activity of the AGTST program involves the sponsorship of workshops and conferences addressing critical automated transit technology issues. To date seven workshops have been held. The workshops generally involve representatives of research organizations, system manufacturers, transit system operators, consulting firms and local and state governments. The results of some of the workshops have been reported in separate proceedings or integrated into project reports. The workshops are identified in Table 3.3.1 which also indicates Proceedings availability.

3.4 Technical Papers

In addition to the above, members of the project teams have presented a large number of technical papers which are in the public domain. Table 3.4.1 provides a list of these papers.

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* Urban Mass Transportation Administration
Office of Technology Development and Deployment, UTD-42
400 7th Street, S.W.
Washington, D. C. 20590
(202) 426-4047

TABLE 3.1.1 - TECHNICAL REPORTS

Project/Report Title/Availability

System Operation Studies

Classification and Definition of AGT Systems - Final, Available December, 1979

Representative Application Areas for Automated Guideway Transit - Update, Available December, 1979

Automated Guideway Transit System Analysis Requirements, Volume I - Final, Available December, 1979

Automated Guideway System Analysis Plan, Volume II - Final, Available December, 1979

Measures of System Effectiveness, Available December, 1979

Systems Analysis of Shuttle Loop Transit Systems, Volume I, Available January, 1980

Systems Analysis of Shuttle Loop Transit Systems, Volume II, Available January, 1980

Systems Analysis of Shuttle Loop Transit Systems, Volume III, Available January, 1980

Systems Analysis of Automated Rail Transit Systems, Volume I, Available February, 1980

Systems Analysis of Automated Rail Transit Systems, Volume II, Available February, 1980

Systems Analysis of Automated Rail Transit Systems, Volume III, Available February, 1980

Comparative Analysis of AGT Systems In Central Business District Applications - Final, Available February, 1980

Comparative Analysis of Automated Rail Transit and Group Rapid Transit Systems In A Metropolitan Area Application - Final, Available February, 1980

TABLE 3.1.1 (Continued)

Quantitative Analysis of Alternative Automated Guideway Transit, Available February, 1980

Operational Control Strategies - Final, Available December, 1979

Detailed Station Model - Programmer's Manual, Available December, 1979

Detailed Station Model - User's Manual, Available December, 1979

System Cost Model - Programmer's Manual, Available February, 1980

System Cost Model - User's Manual, Available February, 1980

Feeder System Model - User's Manual, Available December, 1979

System Availability Model - Programmer's Manual, Available February, 1980

System Availability Model - User's Manual, Available February, 1980

System Planning Model - Programmer's Manual, Available February, 1980

System Planning Model - User's Manual, Available February, 1980

Discrete Event Simulation Model - Programmer's Manual, Available February, 1980

Discrete Event Simulation Model - User's Manual, Available February, 1980

Detailed Operational Control Model - Programmer's Manual, Available February, 1980

Detailed Operational Control Model - User's Manual, Available February, 1980

Feeder System Model Functional Specification, Available February, 1980

System Planning Model Functional Specification, Available February, 1980

TABLE 3.1.1 (Continued)

Availability Model Functional Specification, Available February, 1980

Cost Model Functional Specification, Available February, 1980

Discrete Event Simulation Model Functional Specification, Available February, 1980

Detailed Station Model Functional Specification, Available February, 1980

Detailed Operational Control Model Functional Specification, Available February, 1980

Discrete Event Simulation Model Technical Specifications, Available February, 1980

Detailed Station Model Technical Specifications, Available February, 1980

Detailed Operational Control Model Technical Specifications, Available February, 1980

Data Base Specification Technical Specifications, Available February, 1980

Data Base User's Manual, Available February, 1980

Model Implementation Reports, Available February, 1980

Downtown People Mover Simulation Case Study and User's Guide, Available December, 1979

Downtown People Mover Simulation Program Write-up, Available December, 1979

System Safety and Passenger Security

Braden, A., Jacobson, I., Hall, L. and Richards, L. "AGT Systems Safety and Passenger Security Study: Passenger Security," Available December, 1979

Benjamin, David E. "AGT Systems Safety and Passenger Security: Evacuation and Rescue," Available December, 1979

TABLE 3.1.1 (Continued)

Dauber, Robert L. "AGT Systems Safety and Passenger Security: Passenger Safety and Convenience Services," Available December, 1979

Richards, L.G., Hoffman, D. and Jacobson, I.R. "AGT Systems Safety and Passenger Security: Passenger Value Structure Model," Available December, 1979

Jacobs, H.H. and Benjamin, David E., "AGT Systems Safety and Passenger Security: Factors Contributing to the Retention of Seated Passengers During Emergency Stops," Available December, 1979.

Vehicle Longitudinal Control and Reliability

Schumacher, P., Editor, "A Review of Entrainment Technology," February 1979, UMTA-IT-06-0148-79-1, PB-300-372

Schumacher, P., Editor, "A Review of AGT Propulsion, Power Conditioning, Braking, and Power Distribution Technology," June 1979, UMTA-IT-06-0148-79-2, PB-300-373

Communications Technology Review, UMTA-IT-06-0148-79-3, Available January, 1980.

Longitudinal Control Technology Review, UMTA-IT-06-0148-79-4, Available January, 1980

Lorenz, D., et al., "Entrainment and Platooning Analysis and Design, February 1979, UMTA-IT-06-0148-79-5, PB-299-798

Lorenz, D., et al., "Entrainment and Platooning Analysis and Design, Appendix B - Trainsim Simulation Program User's Guide," February 1979, UMTA-IT-06-0148-79-6, PB-297-129

Petrino, E., et al., "Longitudinal Control Analysis and Design (Part A - SLT and GRT Systems)," May 1979, UMTA-IT-06-0148-79-7, PB-298-766

Schumacher, P., Editor, "Longitudinal Control Analysis and Design (Part B - PRT Systems)," May 1979, UMTA-IT-06-0148-79-8, PB-298-767

Womack, W., et al., "Reliability Enhancement Analysis and Design," May 1979, UMTA-IT-06-0148-79-9, PB-299-525

Final Project Report, UMTA-IT-06-0148-79-10, Available January, 1980

TABLE 3.1.1 (Continued)

Graver, C.A., and Womack, W.C., "Longitudinal and Lateral Control Cost and Weight Models," June 1979, UMTA-IT-06-0148-79-11, PB-299-526

Project Test Data, UMTA-IT-06-0148-79-12, Available January, 1980

Vehicle Longitudinal Control and Reliability Data Base, UMTA-IT-06-0148-79-13, Available January, 1980

Vehicle Lateral Control and Switchng

Haines, G., et al., "Vehicle Lateral Control and Switching Technology Review," March, 1978, UMTA-IT-06-0156-78-1, PB-284-799

Graver, C., and C. Fry, "Vehicle Lateral Control and Switching Cost and Weight Models," April, 1978, UMTA-IT-06-0156-78-4, PB-286-551

Vehicle Lateral Control and Switching Design and Analysis Report, Available January, 1980

Vehicle Lateral Control and Switching Detailed Hardware Implementation Studies, Available January, 1980

Vehicle Lateral Control and Switching Data Base Specifications, Available December, 1979

Vehicle Lateral Control and Switching Final Project Summary Report, Available January, 1980

Guideway and Station Technology

Stevens, R., "Guideway and Station Technology, Volume 1, Executive Summary," August 1979, UMTA-IT-06-0152-79-8, PB-299-553

Stevens, R., et al., "Guideway and Station Technology, Volume 2, Weather Protection Review," March 1978, UMTA-IT-06-0152-79-1, PB-287-522

Stevens, R., et al., "Guideway and Station Technology, Volume 3, Guideway and Station Review," September 1978, UMTA-IT-06-0152-79-2, PB-281-632

Stevens, R., et al., "Guideway and Station Technology, Volume 4, Design Guidelines," March 1979, UMTA-IT-06-0152-79-3, PB-295-613

TABLE 3.1.1 (Continued)

Stevens, R., et al., "Guideway and Station Technology, Volume 5, Evaluation Models," June 1979, UMTA-IT-06-0152-79-4, PB-299-034

Stevens, R., et al., "Guideway and Station Technology, Volume 6, Dynamic Model," July 1979, UMTA-IT-06-0152-79-5, PB-299-153

Stevens, R., et al., "Guideway and Station Technology, Volume 7, Guideway and Station Concepts," July 1979, UMTA-IT-06-0152-79-6, PB-299-411

Stevens, R., et al., "Guideway and Station Technology, Volume 8, Weather Protection Concepts," August 1979, UMTA-IT-06-0152-79-7, PB-299-746

Vehicle Control

Ford, B.M., Waddell, M.C., and Williams, M.B., "Analysis of Multiple Party Vehicle Occupancy in an AGT System," March 1976, UMTA-MD-06-0018-76-1, PB-251-930

Kershner, D.L., and Roesler, W.J., "Models for Assessing Trip Dependability in Automated Guideway Transit Networks," August 1976, UMTA-MD-06-0018-76-2, PB-258-129

Chiu, H.Y., et al., "Vehicle-Follower Controls for Short Headway AGT Systems - Functional Analysis and Conceptual Designs," December 1976, UMTA-MD-06-0018-77-1, PB-266-272.

Brown, S.J., Jr., "Point-Follower Automatic Vehicle Control: A Generic Analysis," May 1977, UMTA-MD-06-0022-77-1, PB-270-354

Pue, A.J., "A State-Constrained Approach to Vehicle-Follower Control for Short Headway AGT Systems," August 1977, UMTA-MD-06--0022-77-2, PB-272-239

Caywood, W.C., et al., "Guidelines for Ride Quality Specifications Based on Transpo'72 Test Data," October 1977, UMTA-MD-06-0022-77-3, PB-273-272

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TABLE 3.1.1 (Continued)

Pue, A.J., et al., "Operational Concepts and Implementation Techniques for Vehicle-Follower Control of AGT Systems," Available October 1979

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Automated Transit Technology Requirements

Minimum Propulsion Energy Requirements for Six Automated Guideway Transit Systems, Available January 1980

Automated Mixed Traffic Vehicle National Airport Case Study, Available January 1980

Lenard, M., "Review of Dual Mode Case Studies," April 1979, UMTA-VA-06-0041-79-5, PB-295-442

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Hardware Reliability and Service Availability

Leis, R.D., "The Development of Measures of Service Availability," (three volumes), June 1978, the Battelle Columbus Laboratories, UMTA Numbers UMTA-MA-06-0048-78-02, 03, and 04

Watt, C.W., Editor, "Automated Guideway Transit Service Availability Workshop," February 1978, UMTA-MA-06-0048-77-4, PB 282-295

Hydrostatic Drive Development

Adams, G.J., and L. Hoover, "Study on Hydrostatic Drives for Small AGT Vehicles," October 1978, UMTA-CA-06-0089-78-1, PB-(TBD)

Vehicle Data Acquisition

Haug, Andrew, "Vehicle Data Acquisition System", Available January 1980

Entrainment and Platooning

Shladover, Steven E., "Operation of Automated Guideway Transit Vehicles in Dynamically Reconfigured Trains and Platoons," April 1979, UMTA-MA-06-0085-79-1, PB-300-513

TABLE 3.1.1 (Concluded)

Station Security Features

Ray, C., et al., "Predicting AGT System Station Security Requirements," UMTA-MA-06-0048-78-5, Available December 1979

Morgantown Control and Communications

Lang, Robert P., "Morgantown Personal Rapid Transit Longitudinal Control System Design Summary," December 1975, UMTA-MA-06-0048-25-4, PB-256-139

Johnstone, Todd N., "Morgantown People Mover Inductive Communication System Design Summary," September 1978, UMTA-MA-06-0048-78-6, PB-295-750

TABLE 3.2.1 - SOFTWARE MODEL SUMMARIES

Feeder System Model (FSM) - performs two functions: (1) to map zone to zone demand data onto stations in an AGT network producing a station to station demand matrix; and (2) to determine utilization of mass transit, auto and walk modes for accessing system stations. Computer Characteristics: manuf.- IBM 370/168, memory - 2,728 k bytes, language - PARAFOR*, accessories - disk units, teletype.

System Availability Model (SAM) - uses system characteristic data, network and demand data to calculate vehicle and passenger availability measures and the required maintenance and standby fleet size for an AGT deployment. Also includes input performance summary data from SPM & DESM. Computer Characteristics: manuf.- IBM 370, memory - 574 k bytes core plus 1 Mb disc, language - PARAFOR*, accessories - disk unit and teletype.

System Cost Model (SCM) - calculates total investment and time phased costs over the system life cycle, and energy, pollution, and land use requirements of the deployed AGT system. Also network planning (SPM) and simulation (DESM) models data used as input. Computer Characistics: manuf.- IBM 370/168, memory - 240 k bytes, language - PARAFOR*, accessories - disk unit, teletype, tape (optional).

System Planning Model (SPM) - establishes the effects of general system parameters on the system measures of vehicle utilization and level of service parameters and reports the passenger and vehicle flows in the network. Also, FSM data is used as input. Computer Characteristics: manuf.- IBM 370/168 memory - 1950 k bytes, language-PARAFOR*, accessories - disk unit, teletype, tape (optional).

Detailed Station Model (DSM) - establishes station design parameters for the AGT deployment by using a discrete event modeling approach to represent the interrelated queing processes associated with vehicle and passenger activities in a transit station. Computer Characterstics: manuf.- IBM 370/168, memory - 910 k bytes, language - PARAFOR*, accessories - drum unit, teletype, tape (optional).

Discrete Event Simulation Model (DESM) - is designed to simulate the operations of specified AGT systems based on a discrete event process which is driven by a time ordered list of events maintained during the simulation. Computer Characteristics: manuf.- IBM 370/168 memory -3000 k bytes, language - PARAFOR*, accessories - disk unit, teletype, tape (optional).

*Extended Fortran IV

TABLE 3.2.1 (Continued)

Detailed Operational Control Model (DOCM) - simulates detailed vehicle motion within an isolated link, merge, or intersection and generates performance measures such as vehicle travel times, acceleration and jerk limits and queue lengths. Computer Characteristics: manuf.- IBM 370/168, memory - 500 k bytes, language -PARAFOR*, accessories - disk unit, teletype, tape (optional).

Trained Vehicle Simulation (TRAINSIM) - program aids in the analytical design of automated passenger vehicle control systems required to operate vehicles in two-car trains by utilizing a time domain simulation of the motions and interactions of coupled vehicles for both wheeled and air cushion vehicle dynamics. Computer Characistics: manuf.-Perkin-Elmer Interdata/70, memory - 50 k bytes, language - Fortran IV, accessories - 1 CRT, Trident Disk Pack and VERSATEC printer plotter.

Wheeled Longitudinal Control Simulation - program simulates the longitudinal control of a string of vehicles operating with a moving-block protection system and includes a detailed model of the vehicle and the wayside and on-board control systems. Computer Characteristics: manuf.- Perkin-Elmer Interdata/70, memory - 52 k bytes, language - Fortran IV (extended), accessories: 1 CRT, Trident Disk and VERSATEC Printer.

Personal Rapid Transit (PRT) Vehicle Control model simulates the longitudinal control of vehicles operating at fractional second headways and enables the user to select various control system operating policies and vehicle maneuvers. Computer Characteristics: manuf. - Scientific Data System 9300, memory - 24 k 24-bit words, language - Fortran IV, accessories: 2 tape drives, 1 CRT and 8 channel brush strip chart recorder.

VLCR Reliability Computer Model - provides a program for automated transit systems that will predict system failure rates based on component failure data and will also allocate failure rates to components based on system level goals. Computer Characteristics: manuf - Perkin-Elmer Interdata 7/32, memory -40 k bytes, language -Fortran, accessories: minicomputer w/disk and random access files.

*Extended Fortran IV

TABLE 3.2.1 (Continued)

VLACS Vehicle Simulation Model - simulates the lateral and vertical dynamic response of an automated guideway transit vehicle with rubber tires, front and rear steering and wire or wall following sensors. Computer Characteristics: manuf.- Univac 1110, memory - 60 k bytes, language - Fortran, accessories: 200 track drum, Textronix 4010 terminal.

VLACS Switching Analysis - program performs systems analysis of Automated Guideway Transit (AGT) switching parameters including vehicle speed, operational headway, switch spacing, and switch time to allow parametric studies of switching operations in AGT systems. Computer Characteristics: manuf.- Perkin-Elmer Interdata, memory - 25 k bytes, language -Fortran IV (extended) and V, accessories: none.

VLCR and VLACS Cost and Weight Model - is applicable to AGT and used to evaluate the life cycle cost and weight of four AGT vehicle classes including Shuttle Loop Transit (SLT), Group Rapid Transit (GRT) large and small, and Personal Rapid Transit (PRT). Computer Characteristics: manuf.- CDC 6600, memory - 75 k bytes, language - Fortran IV, accessories: batch processing.

AGT Vehicle Lateral Control System Simulation - is a model which simulates the dynamic response of AGT vehicles under automatic lateral control during vehicle maneuvers and also to external disturbances such as guidance rail discontinuities, wind gusts, and obstacles on the guideway. Computer Characteristics: manuf.- Perkin-Elmer Interdata 70 and 7/32, memory - 50 k bytes, language- Fortran IV (extended) and V, accessories: user supplied plot routines.

Station and Guideway Cost Model for AGT systems calculates the total life cycle cost of each of the guideway and station components and then aggregates the results to a per-lane kilometer investment cost, operations, and maintenance costs, and total annual costs. Computer Characteristics: manuf. - CDC 6400, memory - 41.6 bytes, language - Fortran IV, accessories: none.

Vehicle-Elevated Guideway Interactions - program computes the vehicle accelerations and guideway deflections occurring during vehicle passage over a flexible, randomly rough guideway. Computer Characteristics: manuf. - DEC VAX 11/78, memory - 67.580 k bytes, language - Fortran, accessories: 1 tape drive, 4 drum units, 1 terminal.

TABLE 3.2.1 (Concluded)

Station and Guideway Cost Model - calculates for AGT systems the total life cycle cost of each of the guideway and station components and then aggregates the results to a per-lane kilometer investment cost, operations, and maintenance costs, and total annual costs. Computer characteristics: manuf - CDC 6400, memory - 41.6 k bytes, language - Fortran IV, accessories: none.

Vehicle Elevated Guideway Interactions - program computes the vehicle accelerations and guideway deflections occuring during vehicle passage over a flexible, randomly rough guideway. Computer characteristics: manuf - DEC VAX 11/78, memory - 67.580 k bytes, language - Fortran, accessories: 1 tape drive, 4 drum units, 1 terminal.

TABLE 3.3.1 - WORKSHOPS AND CONFERENCES

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Roesler, W.J., Editor, "Automated Guideway Transit Workshop on Performance Measures, Evaluation Techniques, and Goals," Washington D.C., August 25, 1976, UMTA-MD-06-0022-77-4, PB-277-046

Watt, C.W., Editor, "Automated Guideway Transit Service Availability Workshop," Andover, MA., October 6-8, 1976, UMTA-MA-06-0048-77-4, PB-282-295

"Automated Guideway Transit Service Availability Workshop," Columbus, Ohio, October 26-27, 1977

"Conference on Automated Guideway Transit Technology Development," Cambridge, MA., February 28 - 2 March 1978, UMTA-MA-06-0048-7801

"American Public Transportation Association (APTA)/Automated Guideway Transit Technology Workshop," Washington, D.C.,. August 17-18, 1978

"Automated Guideway Transit/Systems Operation Studies," Cambridge, MA., August 21-23, 1978

TABLE 3.4.1 - TECHNICAL PAPERS

Abernethy, C., Plank, G. and Sussman, E. D., "Effects of Deceleration and Rate of Deceleration on Live Seated Human Subjects," Transportation Research Board Record, 1978

Adams, G., "Hydrostatic Drive Studies," Conference on Automated Guideway Transit Technology Development, Cambridge, Mass., February 28 - March 2, 1978

Benjamin, D., "Passenger Safety/Evacuation/Rescue for Automated Guideway Transit," Advanced Transit Association International Conference, Indianapolis, Indiana, April, 1978

Bitts, M., "Seattle-Tacoma International Airport Satellite Transit System Maintenance Program," Conference on Automated Guideway Transit Technology Development, Cambridge, Mass., February 28 - March 2, 1978.

Bitts, M. and Krause, A., "Maintenance and Operation of Satellite Transit Systems (STS)," Advanced Transit Association International Conference, Indianapolis, Indiana, April, 1978.

Brown, S. J., "Longitudinal Control Automated Transit Systems," presented at the 2nd Downtown People Mover Conference, Morgantown, W. Virginia, July 26 - 28, 1978

Chiu, H. Y., "A State-Constrained, Vehicle-Follower Approach to the Station Egress Problem," presented at the 1978 Advanced Transit Association International Conference, Indianapolis, Indiana, April, 1978

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Dooley, Thomas, Priver, Arthur S. and Yuan Li Shin, "Computer Models for AGT System Operations Studies," IEEE Vehicular Technology Conference, Denver, Colorado, March, 1978

TABLE 3.4.1 (Continued)

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Garrard, W.L., Caudill, R. J., Kornhauser, A. L., MacKinnon, D., and Brown, S. J., "State-of-the-Art Longitudinal Control for Automated Guideway Transit Vehicles," High Speed Ground Transportation Journal, Vol. 12, No. 2, 1978

Haines, G., "Vehicle Lateral Control and Switching Project Description," Conference on Automated Guideway Transit Technology Development, Cambridge, Mass., February 28 - March 2, 1978

Handleman, Mark, "Advanced Mass Transit Simulator," Workshop on Performance Measures, Evaluation Techniques and Goals, Washington, D.C., August 25, 1976

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Lenard, M., "Life Cycle Costs and Application Analysis for New Systems," Conference on Automated Guideway Transit Technology Development, Cambridge, Mass., February 28 - March 2, 1978

Meisenholder, G. W. and Johnston, A. R., "Control Techniques for Automated Mixed Traffic Vehicle," Joint Automatic Control Conference, 1977

Meisenholder, G. W. and Johnston, A. R., "Automated Mixed Traffic Vehicle Status," Conference on Automated Guideway Transit Technology Development, Cambridge, Mass., February 28 - March 2, 1978

Oglesby, Robert, "The Simulation of Availability in Automated Guideway Transit Systems," Automated Guideway Transit Service Availability Workshop, Andover, Mass., October 7, 1976

TABLE 3.4.1 (Continued)

Olson, C., "Independent Study of Personal Rapid Transit," Conference on Automated Guideway Transit Technology Development, Cambridge, Mass., February 28 - March 2, 1978

Pepler, R., "Systems Safety and Passenger Security," Conference on Automated Guideway Transit Technology Development, Cambridge, Mass., February 28 - March 2, 1978

Priver, Arthur, "Automated Guideway Transit System Technology Studies," Third U.S.-German Urban Transportation Workshop, Berlin, E. Germany, June, 1977

Priver, Arthur and Yuan, Li Shin, "Automated Guideway Transit System Technology Studies," Advanced Transit Association International Conference, Indianapolis, Indiana, April, 1978

Priver, Arthur, "Modeling - Vehicle Requirements," Downtown People Mover Workshop, Morgantown, W. Va., July, 1978

Pue, A. J., "A State-Constrained Approach to Vehicle-Follower Control for Short Headway Automated Transit Systems," ASME Journal of Dynamic Systems, Measurement and Control, Vol. 100, No. 4, December, 1978, pp. 291-297

Pue, A. J., "Vehicle-Follower Control Approach for Short-Headway AGT Systems," Conference on Automated Guideway Transit Technology Development, Cambridge, Mass., February 28 - March 2, 1978

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Richards, L., Jacobsen, I., Pepler, R. and Bloom R., "Perceived Safety and Security in Transportation Systems as Determined by the Gender of the Traveler," D.O.T. Conference on Women's Travel Issues, September, 1978

Schumacher, P. J., "The Vehicle Longitudinal Control and Reliability Project," Conference on Automated Guideway Transit Technology Development, Cambridge, Mass., February 28 - March 2, 1978

TABLE 3.4.1 (Continued)

Shladover, S. E., "Overview of Automated Guideway Research at M.I.T.," Conference on Automated Guideway Transit Technology Development, Cambridge, Mass., February 28 - March 2, 1978

Shladover, S. E., "Longitudinal Controller Design for Dynamic Entrainment and Platooning of Automated Guideway Transit Vehicles," Advanced Transit Association International Conference, Indianapolis, Indiana, April, 1978

Shladover, S. E., "Dynamic Entrainment of Automated Guideway Transit Vehicles," Advanced Transit Association International Conference, Indianapolis, Indiana, April, 1978

Shladover, S. E., "Dynamic Entrainment of Automated Guideway Transit Vehicles," High Speed Ground Transportation Journal, Winter 1978

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Shladover, S. E., "Vehicle-Follower Control for Dynamic Entrainment of Automated Guideway Transit Vehicles," Journal of Dynamic System Measurement and Control, 1979

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Sklar, S. J., Bevans, J. P. and Stein, G., "Safe Approach Vehicle-Follower Control," IEEE Transactions on Vehicular Technology, February, 1979

Stevens, R., "Automated Guideway Transit Guideway and Station Technology," Conference on Automated Guideway Transit Technology Development, Cambridge, Mass., February 28 - March 2, 1978

Stevens, R., and Nicarico, T., "All-Weather Protection for Automated Guideways and Stations," Second International Symposium on Snow Removal and Ice Control Research, Hanover, N. H., May 15 - 19, 1978

TABLE 3.4.1 (Concluded)

Stevens, R., "Unique Aspects of Guideway and Stations for Automated Guideway Transit Systems," Transportation Research Board Fifty-Eighth Annual Meeting, Washington, D. C., January 15 -19, 1978

Stupp, G. B., Chiu, H. Y., and Brown, S. J. "Vehicle-Follower Control With Variable Gains for Short Headway Automated Guideway Systems," ASME Journal of Dynamic Systems, Measurement and Control, Vol. 99, No. 3, September, 1977, pp. 183 - 189

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Thompson, James, "Automated Guideway Transit System Operation Studies, A Progress Report," Conference on Automated Guideway Transit Technology Development, Cambridge, Mass., February 28 - March 2, 1978

Thompson, James, "Automated Guideway Transit System Operation Studies: Methods and Experience," Transportation Research Board Fifty-Eighth Annual Meeting, Washington, D. C., January 15 - 19, 1979

APPENDIX A - STATUS OF AUTOMATED TRANSIT TECHNOLOGY

A.1 Overview

From the over 40 AGT system development projects, varying from conceptual description to full-scale prototype test and evaluation, it is possible to make some general assessments of the progression of AGT technology, as illustrated in Figure A.1.1.

This section provides a brief survey of existing or planned AGT systems and their applications in the United States and abroad.

A.2 Domestic Developments

In the United States emphasis has been placed on the deployment of operating systems; whereas, foreign programs have focused on prototype development and testing. As a result, the domestic program has been characterized by more conservative technological development, particularly with respect to headways and vehicle size reduction aimed at producing hardware for near-term application (such as Transit Expressway, AIRTRANS, and Morgantown systems). AGT system technology has dominated the domestic scene, and several intermediate headway AGT systems have reached the engineering prototype stage.

At present, there are approximately 20 AGT systems in operational service. Ten AGT prototype systems are being used for technology development and testing.

Descriptions of the significant AGT developments in the U.S. are provided in Tables A.2.1 and A.2.2. Table A.2.1 provides vehicle dimensions, weights, capacities, and a description of the major technical approaches that have been adopted in each development. Table A.2.2 provides the major performance attributes (speed, headway, passenger carrying capacity) and a brief indication of current development status.

A.3 Foreign Developments

A significant amount of AGT system development activity has occurred outside of the U.S. Foreign activities have concentrated on the development of prototype technology rather than system deployment. Principal foreign developments are summarized in Tables A.3.1 and A.3.2.

TABLE A.2.1

TECHNICAL FEATURES OF DOMESTIC AGT SYSTEMS

System	Manufacturer	Vehicle Dimensions Length (M)	Width (M)	Height (M)	Empty Weight (Newtons)	Number of Seats	Number of Standees	Total Vehicle Capacity	Crush Load	Suspension Type	Steering Type	Switching Type	Propulsion Type	Vehicle Control	Network Control
AIRTRANS	LTV	6.40	2.14	3.05	62,270	16	24	40	60	RTOC, SPDR	RGW, SGW	WA, CGW	DCTM	PF, FB	ASY
Aerial Transir System	Pullman Standard	3.66	1.68	1.59	21,350	6	0	6	6	SWOR, SPDR	SWOR	WA, SWOR	DCTM	PF	SLG
Bradley Field	Ford	7.53	2.04	2.65	63,600	10	14	24	30	RTOC, SPDR	RGW, SGW	OB, CGW	DCTM	PF	SLG
Busch Gardens	Westinghouse	11.06	2.99	3.35	117,880	8	92	100	150	RTOC, SPDR	RGW, SGW	WA, CGW	DCTM	PF, FB	ASY
California Expo	Universal Mobility	4.27	1.83	2.25	10,670	12	0	12	12	RTOS, SPMR	RGW, SGW	WA, CGW	DCTM	PF, FB	ASY
Carowinds	Universal Mobility	4.27	1.83	2.25	10,670	12	0	12	12	RTOS, SPMR	RGW, SGW	WA, CGW	DCTM	PF, FB	ASY
Dashaveyor	Bendix	7.01	2.04	3.29	80,000	12	20	32	50	RTOC, SPDR	RGW, SGW	WA, CGW	DCTM	VF, FB	ASY
Duke University	OTIS-TTD	6.10	3.29	2.99	53,350	12	0	12	12	AC	RGW, SGW	OB, CGW	SLIM	PF, FB	ASY
Fairlane Shopping Center	Ford	7.53	2.04	2.65	63,600	10	14	24	30	RTOC, SPDR	RGW, SGW	OB, CGW	DCTM	PF	SLG
High Capacity PRT	Aerospace	3.05	1.52	1.52	8,000	6	0	6	6	RTOC, SPMR	RGW, SGW	WA, AMAG	LSM	PF	QSY
Hershey Park	Universal Mobility	4.27	1.83	2.25	10,670	12	0	12	12	RTOS, SPMR	RGW, SGW	WA, CGW	DCTM	PF, FB	ASY
Houston International Airport	Rohr	12.20	1.52	2.29	32,000	6	4	10	14	RTOC, SPDR	RGW, CGB	WA, CGW	DCTM	PF, FB	ASY
Advanced GRT	Boeing	4.82	2.04	2.59	39,600	12	0	12	12	RTOC, SPDR	RGW, SWF	OB, CGW	DCTM	PF	QSY
Advanced GRT	OTIS-TTD	5.79	3.05	2.74	48,000	12	0	12	12	AC, SPDR	RGW, SGW	OB, CGW	SLIM	Hybrid	Hybrid
Advanced GRT	Rohr	5.94	2.23	2.44	42,700	12	0	12	12	AMAG	AMAG	OB, AMAG	SLIM	VF	ASY
Jetrail	Stanray Pacific	3.66	2.23	2.23	39,600	6	4	10	14	RTOS, SPMR	RGW, CGB	WA, GB	ACIM, ECC	VF, FB	ASY
King's Dominion	Universal Mobility	4.27	1.83	2.25	10,670	12	0	12	12	RTOS, SPMR	RGW, SGW	WA, CGW	DCTM	PF, FB	ASY
King's Island	Universal Mobility	4.27	1.83	2.25	10,670	12	0	12	12	RTOS, SPMR	RGW, SGW	WA, CGW	DCTM	PF, FB	ASY
Magic Mountain	Universal Mobility	4.27	1.83	2.25	10,670	12	0	12	12	RTOS, SPMR	RGW, SGW	WA, CGW	DCTM	PF, FB	ASY
Miami Airport	Westinghouse	11.06	2.97	3.35	117,880	0	100	100	150	RTOC, SPDR	RGW, SGW	WA, CGW	DCTM	PF, FB	ASY
Monocab	Rohr	2.93	1.67	2.04	17,790	6	0	6	6	RTOS, SSMR	RGW, SGW	WA, CGW	DCTM	VF	ASY
Morgantown	Boeing	4.72	2.04	2.68	38,250	8	7	15	21	RTOC, SPDR	RGW, SWF	OB, GW	DCTM	PF	SLG
Pearl Ridge	Rohr	12.19	1.83	2.74	32,000	8	8	16	24	RTOC, SPDR	RGW, CGB	WA, CGW	DCTM	PF, FB	ASY
PRT	OTIS-TTD	4.36	2.65	2.50	32,000	6	0	6	6	AC, SPDR	RGW, SGW	OB, CGW	SLIM	Hybrid	Hybrid
Sea-Tac	Westinghouse	11.28	2.83	3.35	113,430	12	90	102	125	RTOC, SPDR	RGW, SGW	WA, CGW	DCTM	PF, FB	ASY
StaRRcar	Alden	3.81	2.04	2.74	33,440	6	4	10	12	RTOC, SPDR	RGW, SWF	OB, GW	ACIM, HST	PF	SLG
Tampa Airport	Westinghouse	11.06	2.83	3.35	95,640	0	100	100	125	RTOC, SPDR	RGW, SGW	WA, CGW	DCTM	PF, FB	ASY
Transette	Georgia Tech					4	0	4	15	RTOC, SPDR	RGW, SGW	WA, CGW	MBS	PF, FB	ASY
Uniflo	Fergusen	5.64	1.16	1.98	9,340	8	0	8	8	AC, SPDR	RGW, SGW	OB, CGW	LAM	VF	ASY
Walt Disney	Wedway	2.43	1.46	1.16	4,180	4	0	4	4	RTOS, SPDR	RGW, SGW	WA, CGW	SLIM	VF, FB	ASY

Note: See Glossary for meaning of abbreviations.

TABLE A.2.2

PERFORMANCE CHARACTERISTICS AND STATUS OF DOMESTIC AGT SYSTEMS

System	Manufacturer	Class	Line Speed (kmph)	Minimum Headway (sec.)	Seats Per Lane Per Hour	Passengers Per Lane Per Hour (crush load)	Status to Date	Station Code - Date
AIRTRANS	LTV	GRT	27	18	3,200	12,000	20.92 lane kilometers, 50 stations, 68 vehicles, 20% at-grade, 80% elevated, grid system with 17 interacting routes	CA-1974 (Dallas/Ft.Worth AP)
Aerial Transit System	Pullman Standard	PRT	32	8	2,700	2,700	Two full-scale test vehicles on 0.55 kilometer test track	PP-1972
Bradley Field	Ford	SLT	48	20	1,800	5,400	1.29 lane kilometers, 3 stations, 2 vehicle single path shuttle with bypass	CA-Not yet in service
Busch Gardens	Westinghouse	GRT	48	100	576	10,800	2.25 lane kilometers, 2 stations, 2 vehicles in one train; 60% at-grade, 40% elevated. Single Loop	CA-1975
California Expo	Universal Mobility	SLT	19	120	2,880	2,880	2.09 lane kilometers, 2 stations, 32 vehicles in 4 eight-car trains, single path loop	CA-1968
Carowinds	Universal Mobility	SLT	22	132	2,595	2,595	3.21 lane kilometers, 1 station, 32 vehicles in 4 eight-car trains, single path loop	CA-1973
Dashaveyor	Bendix	GRT	80	15	2,800	7,680	Two full-scale prototype vehicles on 0.15 kilometer test track	PD-1972
Duke University	OTIS-TTD	PRT	64	2	21,600	21,600	0.80 lane kilometers, 3 stations, 3 vehicles; 50% at-grade, 50% elevated	CA-Not yet in service
Fairlane Shopping Center	Ford	SLT	48	20	1,800	5,400	0.80 lane kilometers, 2 stations, 2 vehicles	CA-1976
HCPRT	Aerospace	PRT	64	0.25	86,400	86,400	Extensive Technical and Planning Studies 1/10 scale Model demonstrated at 0.5 second headways	RP-1972
Hershey Park	Universal Mobility	SLT	16	75	3,465	3,465	1.29 lane kilometers, 2 stations, 24 vehicles in 4 six-car trains	CA-1969
Houston International Airport	Rohr	SLT	19	60	1,080	2,520	1.93 lane kilometers, 8 stations, 18 vehicles in 6 three-car trains, 100% underground	CA-1972
Advanced GRT	Boeing	GRT	64	3	14,000	14,000	System Design Study in progress	DS-1974
Advanced GRT	OTIS-TTD	GRT	64	3	14,000	14,000	System Design Study in progress	DS-1974
Advanced GRT	Rohr	GRT	64	3	14,000	14,000	System Design Study in progress	DS-1974
Jetrail	Stanray Pacific	GRT	24	20	1,800	2,520	2.57 lane kilometers, 3 stations, 10 vehicles	CA-1969 No longer in service
King's Dominion	Universal Mobility	SLT	10	210	1,850	1,850	3.38 lane kilometers, 1 station, 54 vehicles in 6 nine-car trains; 5% elevated, 95% at-grade, closed loop	CA-1974
King's Island	Universal Mobility	SLT	10	180	2,160	2,160	3.22 lane kilometers, 1 station, 63 vehicles in 7 nine-car trains	CA-1974
Magic Mountain	Universal Mobility	SLT	13	60	4,320	4,320	1.29 lane kilometers, 3 stations, 36 vehicles in 6 six-car train closed loop	CA-1971
Miami Airport	Westinghouse	GRT	45	85	0	12,600	0.80 lane kilometers, 2 stations, 4 vehicles in 2 two-car train; 100% elevated, shuttle	CA-1977
Monocab	Rohr	PRT	48	5	4,320	4,320	0.30 kilometer test track with 2 prototype vehicles	PD-1972
Morgantown	Boeing	GRT	48	15	1,920	5,040	8.53 lane kilometer, 3 stations, 45 vehicles, linear shuttle, 80% elevated, 20% at-grade	CA-1975
Pearl Ridge	Rohr	SLT	13	240	480	1,440	0.37 lane kilometers, 2 stations, 4 vehicles in 1 four-car train; 100% elevated, linear shuttle	CA-1976
Hovair	OTIS-TTD	GRT	72	6	3,600	3,600	0.30 lane kilometers test track with 2 prototype vehicles	PD-1972
Satellite Transit System	Westinghouse	GRT	48	100	432	4,500	2.74 lane kilometers, 8 stations, 12 vehicles, 100% underground, 2 loops and a shuttle	CA-1973
StaRRcar	Alden	PRT	45	5	4,320	7,200	Two prototype vehicles on 0.30 kilometer test track	TD-1965
Tampa Airport	Westinghouse	GRT	45	70	0	6,375	2.25 lane kilometer, 8 stations, 8 vehicles, 100% elevated	CA-1971
Transette	Georgia Tech	PRT	24	15	960	960	Full-scale test vehicle on 0.11 kilometer test track	TD-1972
Uniflo	Ferguson	GRT	32-80	3	9,600	9,600	1 lane kilometer, 3 stations, 2 vehicles, closed loop, 100% at-grade	TD-1976
Disney World	Wedway	GRT	22	14	5,140	5,140	1.40 lane kilometer, 1 station, 150 vehicles in 30 five-car trains	CA-1975

Note: See Glossary for meaning of abbreviations.

TABLE A.3.1

TECHNICAL FEATURES OF FOREIGN AGT SYSTEMS

System	Vehicle Dimensions			Empty Weight (Newtons)	Number of Seats	Number of Standees	Total Vehicle Capacity	Suspension Type	Steering Type	Switching Type	Propulsion Type	Propulsion Power (kw)	Vehicle Control	Network Control
	Length (m)	Width (m)	Height (m)											
TRRE/RAE CABTRACK UNITED KINGDOM	3.04	1.37	1.68	5,880	4	0	4	RTOC, SPDR	RGW, SGW	OB, CGW	DCTM	25	PF	QSLG
TRRE/RAE MINITRAM UNITED KINGDOM	-	-	-	-	6	6	12	RTOC**, SWOR, SPDR	-	OB, CGW	DCTM	-	-	-
MBB CABINENTAXI WEST GERMANY	2.29	1.58	1.50	5,880	3	0	3	RTOS**, SSDR, SPDR	RGW, SGW	OB, CGW	DLIM	-	VF	ASY
SIEMENS H-BAHN WEST GERMANY	3.50	2.29	2.50	24,520	8	8	16	RTOS, SSMR	RGW, SGW	OB, CGW	SLIM	-	VF	ASY
KRAUSS-MAFEI TRANSURBAN WEST GERMANY	6.50	2.20	3.20	88,260	14	8	22	AMAC, SPDR	AMAC, SGW	OB, AMAC	SLIM	-	VF	ASY
ENGINS MATRA ARAMIS FRANCE	2.29	1.32	1.89	6,380	4	0	4	RTOC, SPDR	RGW, SGW	OB, CGW	RSM	16	VF	ASY
ENGINS MATRA VAL FRANCE	25.50	1.93	3.04	22,560	62	63	125	RTOC, SPDR	RGW, SGW	OB, CGW	DCTM	360	VF	ASY
ALSTHOM NEYRPIC TELERAIL FRANCE	2.10	1.40	2.29	8,140	4	4	8	RTOS, SSMR	RGW, CGW	WA, GB	CABLE	-	PF	SLC
CEL URBA FRANCE	9.10	2.00	2.00	35,300	30	0	30	NPAC, SSMR	NPAC	WA, GB	SLIM	-	PF	ASY
GOVERNMENT CVS JAPAN	3.35	1.60	1.85	10,790	4	0	4	RTOC, SPDR	RGW, CGW	OB, CGW	DCTM	12	PF	SLG
KAWASAKI-FUJI KCV JAPAN	6.34	2.40	3.14	44,130	24	26	50	RTOC, SPDR	RGW, SGW	WA, GB	DCTM	100	VF	ASY
MITSUBISHI MAT JAPAN	6.40	2.20	2.90	-	16	16	32	RTOS, SPDR	RGW, CGW	WA, GB	DCTM	-	-	-
TOSHIBA MINI-MONORAIL JAPAN	7.16* 4.50	2.00 -	2.40 -	60,510 33,830	4 8	12 23	16 31	RTOS SPMR	RGW, CGB	WA, GB	DCTM	360	VF	ASY
NIIGATA TEKKO NTS JAPAN	7.50	2.29	3.40	62,270	24	26	50	RTOC, SPDR	RGW, CGB	WA, GB	DCTM	50-70	VF	ASY
HITACHI PARATRAIN JAPAN	15.00	2.20	3.00	106,800	44	36	80	RTOC, SPDR	RGW, CGB	WA, GB	DCTM	55	VF	ASY
NIPPON SHARYO VONA JAPAN	5.30	2.07	3.04	40,010	11	14	25	RTOS, SPDR	RGW, CGB	WA, GB	DCTM	55	VF	ASY
KOBE KRT JAPAN	4.72	2.03	2.67	64,480	10	15	25	RTOC, SPDR	RGW, SWF	OB, GW	DCTM	-	PF	SLG

Note: See Glossary for meaning of abbreviations

*two vehicle types

**Two vehicle configuration

TABLE A.3.2

PERFORMANCE CHARACTERISTICS AND STATUS OF FOREIGN AGT SYSTEMS

System	Classification	Line Speed (km/h)	Minimum Headway (sec.)	Seats Per Lane Per Hour	Passengers Per Lane Per Hour	Status to Date	Status Code and Date
TRRE/RAE CABTRACK UNITED KINGDOM	PRT	36	0.9	16,000	16,000	Extensive technical and planning studies performed; one-fifth scale model tested; estimated cost $0.7 million	RP, 1971
TRRL MINITRAM UNITED KINGDOM	GRT	48	10	2,160	4,320	Two design studies performed; planning studies for Sheffield and Glasgow complete; contract to be awarded for test and demonstration program; estimated cost $12-16 million	DS, 1974
MBB CABINENTAXI WEST GERMANY	PRT	35	0.5	21,600	21,600	Extensive technical and planning studies performed; five prototype vehicles operating on test track near Hagen; estimated cost $11 million	TD, 1973
SIEMENS H-BAHN WEST GERMANY	GRT	35	6.0	4,800	9,600	Full-scale prototype vehicle on test track	TD, 1974
KRAUSS-MAFFEI TRANSURBAN WEST GERMANY	GRT	50	15.0	3,360	5,280	Two full-scale prototype vehicles on 1 KM test track; extensive planning studies for Heidelberg and Toronto; estimated cost $25 million	TD, 1974
ENGINS MATRA ARAMIS FRANCE	PRT	50	0.2	72,000 14,400**	72,000 14,400**	Three full-scale prototype vehicles on 1 KM test track; planning studies for Paris and Nice; estimated cost $6 million	TD, 1972
ENGINS MATRA VAL FRANCE	GRT	96	60	3,720	7,500	Full-scale prototype vehicle on test track, ten-lane mile system with eight stations	CA, 1974
ALSTHOM NEYRPIC TELERAIL FRANCE	GRT	35	4.0	3,600	7,200	Full-scale prototype vehicle on test track	TD, 1973
CEL URBA FRANCE	GRT	50	60	1,800	1,800	Two prototype vehicles on test track	RP, 1973
GOVERNMENT CVS JAPAN	PRT	40-60	1.0	14,400	14,600	Sixty full-scale vehicles on 5.73 kilometer test track near Tokyo; estimated project cost $20 million	TD, 1974
KAWASAKI-FUJI KCV JAPAN	GRT	60	75	1,152	2,400	Two full-scale prototype vehicles on 0.5 kilometer test track	TD, 1974
MITSUBISHI MAT JAPAN	GRT	60	90	640	1,280	Full-scale prototype vehicle on test track	TD, 1974
TOSHIBA NINI-MONORAIL JAPAN	GRT	30	120	-	-	Full-scale prototype vehicle on test track	TD, 1974
NIIGATA TEKKO NTS JAPAN	GRT	50	70	3,600	9,000	Full-scale prototype vehicle on test track	TD, 1974
HITACHI PARATRAIN JAPAN	GRT	48	90	1,760	3,200	Full-scale prototype vehicle on test track	TD, 1974
NIPPON SHARYO VONA JAPAN	GRT	60	90	440	1,000	Two full-scale prototype vehicles on 0.4 kilometer test track	TD, 1974
KOBE KRT JAPAN	GRT	48	90	2,400	3,200	Test track completed - 0.93 KM length; Operational guideway 3.7 KM long; Installed for Ocean Expo of Okinawa in July 1975	TD, CA, 1975

Note: See Glossary for meaning of abbreviations.

APPENDIX B - PRIOR AND RELATED ACTIVITIES

B.1 Overview

In view of the advantages of automating transit, the Department of Transportation has been funding the development of AGT technology since the early 1960s. Significant previous programs include:

- Westinghouse Transit Expressway
- Morgantown System
- Transpo '72
- Advanced Group Rapid Transit
- Downtown People Mover
- AIRTRANS Enhancement
- Dual Mode
- New Systems Alternatives
- Automated Highway Systems

The phasing of these activities in shown in Figure B.1.1.

B.2 Westinghouse Transit Expressway

The Transit Expressway system was developed by the Westinghouse Electric Company under partial UMTA funding in the early 1960s on a two mile test track in South Park near Pittsburgh. The system featured the first automated rubber-tired vehicles and was capable of operation at 60-second headways. The vehicles had a capacity of approximately 100 passengers and a top speed of 80 km/hr. The system has found wide commercial application at airports and other sites.

B.3 Morgantown System

The Morgantown project was initiated in 1969 to develop an AGT system and to demonstrate the system in revenue service. The system was to operate with 21-passenger vehicles running at 15-second minimum headways. The objectives of the Morgantown project were to: (1) demonstrate the technological, operational and economic feasibility of a fully automatic urban transportation system; (2) to determine, through system evaluation and operational experience, the potential applicability of automated guideway transit to national needs; and (3) to qualify the system as a candidate for use in other locations under the capital grants program. Project authorization was given in the Fall of 1970 and the ground breaking ceremony was held in October 1971. Initial test operation began in October 1972 and an 8.7 (single lane) km, three-station guideway network was put into revenue service in October 1975.

The phase I system consisted of a fleet of 45 vehicles, three stations, and 8.5 km of guideway. It was operated in revenue service for thirty two months and carried nearly five million passengers. The operating fleet accumulated nearly 1.7 million miles with an excellent safety record. During the last year of operation, system availability had averaged close to 98 percent which was two percent above phase I specification requirements. For the last operational month system availability was 99.3 percent.

The phase II system began operational service in June 1979. The full system now has 73 vehicles, 5 stations, and 13.5 km of guideway. Demonstration of availability and O&M cost specification requirements for summer and winter operation will be completed by February 1980. The system operates entirely in a new demand mode and has new fare gates and a heated power rail throughout the system.

B.4 Transpo '72

Four AGT systems were demonstrated in limited configurations at Transpo '72; the Bendix "Dashaveyor", Ford "ACT", Otis "Hovair", and the Rohr "Monocab" systems. Two of these systems (Ford and Otis) have found commercial applicatioin in activity centers, and a third (Rohr) was developed further under the Advanced GRT project.

B.5 Advanced Group Rapid Transit

The goal of the Advanced GRT project is the development of advanced automated guideway transit technology suitable for broad application in cities. The system will achieve a lane capacity of 14,000 seats per hour with small (12-seat) vehicles. The system will use 12-seat vehicles capable of operation at 3-second minimum headways and speeds as high at 50 km/hr. The high lane capacity in the downtown districts will allow provision of a superior level of service with theleast possible guideway construction. The use of merge and diverge juncions without overpasses or underpasses is being stressed, in addition to the use of single rather than double guideway, thus reducing cost and minimizing problems of visual intrusion and compatibility with existing structures. Waiting and riding times will be held to a minimum, as will the number of intermediate stops encountered on a trip. A deployed system will have an excellent capability for attracting a significant percentage of the urban trips now serviced by automobiles. The system is envisioned for deployment in the post-1985 time frame and will benefit from the success of, and the market created by, the early DPM installations.

During Phase I, preliminary designs of the three competing concepts were produced by Rohr Industries, Otis Elevator Company and the Boeing Company. The design competition was continued through Phase IIA. In this phase, the contractors refined the designs and continued the process of development initiated in Phase I. The activities undertaken in Phase IIA included simulations of the command and control system hardware, and development and test of selected critical subsystems identified as high risk items during Phase I. In addition, the performance of each system was evaluated for a medium-size guideway network (43 lane kilometers, 12 stations). Such measures of performance as waiting times, travel times, fleet size and energy usage, as well as other important parameters, were obtained for various levels of passenger demand.

During the first quarter of FY 1978, a departmental task force conducted a comprehensive review of the AGRT program, evaluated the alternatives, and made recommendations for the future course of the program. At the time of the task force review, the three technologies which have been carried through Phases I and IIA were in competion for a single contract to fabricate and test the best system at the Pueblo Test Center. The Task Force recommended that UMTA proceed with multiple technologies, allowing two contractors (Boeing and Otis) to pursue the development of their system on test facilities located at their plants. The test facilities will permit complete verification of system performance at the engineering prototype stage and development of system hardware to the levels of reliability required for urban deployment. The Task Force also recommended continued development of the Rohr "Romag" magnetic levitation technology. This development is being performed by Boeing under license to Rohr.

B.6 Downtown People Mover

The objective of the Downtown People Mover (DPM) program is to demonstrate the benefits of installing fully-automated people mover systems in urban centers. The program is intended to show whether relatively simple automated systems can provide a reliable and economical solution to the local circulation problems in congested downtown areas. On 22 December 1976 the Department announced the selection of four cities--Cleveland, Houston, Los Angeles, and St. Paul--as DPM demonstration sites. In addition, Baltimore, Miami and Detroit were informed that they may divert funds from existing transit funding commitments for their proposed DPM systems. Later in June 1977, the Department received direction from Congress to consider four additional cities, Baltimore, Indianapolis, Jacksonville, and St. Louis as part of the DPM program.

The Department's response to this direction was to establish a two-tier DPM program in which the first-tier cities, Cleveland, Houston, Los Angeles, St. Paul, Detroit, and Miami, would be provided with funds to perform the first phase preliminary engineering efforts and environmental impact studies. Upon the successful completion of these design efforts and environmental reviews, these cities would be provided with capital grant assistance for the construction of their DPM systems. The second tier cities, Baltimore, Indianapolis, Jacksonville, Norfolk, and St. Louis, would be provided technical study funds to perform feasibility analyses of their proposed projects. If the results of these studies so warrant and if sufficient federal funds are available, these cities may also be provided with funds for their first phase preliminary engineering efforts. Any other city besides these eleven would be required to undergo an analysis of transportation alternatives prior to submitting an application for capital grant assistance and must await the successful operation of at least one of these initial demonstration projects.

Preliminary engineering grants were awarded to Houston, Los Angeles, Miami, St. Paul and Detroit. Technical study grants have been awarded to Baltimore, Indianapolis, Jacksonville, Norfolk, and St. Louis. Cleveland and Houston have withdrawn from the program. Los Angeles has essentially completed preliminary engineering, and Miami, Detroit, and St. Paul are expected to complete preliminary engineering in the summer of 1980.

B.7 AIRTRANS Urban Technology Program (AUTP)

The Dallas/Fort Worth (DFW) Airport AIRTRANS system is the largest and most complex AGT system currently in revenue service. The system features 21 lane km of guideway, 55 station stops and 68 vehicles. The vehicles have a 40-passenger capacity and are capable of operating at 18-second minimum headways.

The DFW Airport AIRTRANS system is a successful application of AGT in an airport environment. The system has the potential for utilization as an urban transportation system. However, there are a number of improvements to the existing system which are necessary to make it suitable for urban deployment. In order to accomplish these changes a two-phase program has been established.

Under Phase I, improved propulsion, steering, power and signal collection, and controls were developed. These improved subsystems underwent laboratory testing and then were installed in a test vehicle for evaluation and demonstration on the AIRTRANS system.

Improved subsystems for propulsion, steering, power collection, and system control were developed, underwent laboratory testing, and were installed in a test vehicle (modified AIRTRANS utility vehicle). The test vehicle performance was demonstrated on the AIRTRANS system guideway in November 1977 and operational data was collected to evaluate progress toward meeting subsystem performance goals. Phase I was completed in December 1977.

The Phase II program (24 months) was completed in December 1979. A new prototype urban vehicle was designed with new vehicle control electronics and software to give a smoother ride. A new vehicle audio announcement unit was developed and demonstrated. New power collectors and heated rail were tested on the Vought 18 foot wheel which was enclosed to simulate severe weather conditions. The new vehicle demonstrated bi-direction operation and semi-automatic coupling (mechanical only) during October 1979.

B.8 Dual Mode

In FY 1974 UMTA initiated and sponsored a nine-month concept development study for three Dual Mode transit systems by General Motors, Otis Elevator and Rohr Industries. This activity was not continued when funds for FY 1975 were not made available.

B.9 New Systems Alternatives

An extensive program has been initated to explore socio-economic aspects of implementing new systems in urban areas. This research program addresses the following types of basic questions regarding new systems including AGT, Dual Mode, AMTV, Cable-Suspended Transit and Accelerating Walkways:

1. Where and under what conditions will new system's service characteristics satisfy the travel needs and socio-economic requirements of the U.S. urban areas in a manner competitive with or superior to other transportation alternatives?

2. What are the roles of new systems in providing a balanced total transportation service, and how does it integrate with existing services?

3. What are the costs of development, construction, and operation of new systems, and how do these costs compare with those of other transportation alternatives?

4. Is there a potential market for a transportation technology with the characteristics of new systems?

The program is structured into five major activities: (1) Generic Alternatives and Market Analysis comparing AGT with other modes; (2) Assessments of existing systems; (3) Cost Analyses deployments; (4) Issues and impact studies of special topics; and (5) Communication of information on new systems.

Results of the program to date include assessments of the Dallas/Fort Worth Airport AIRTRANS, Love Field Jetrail, Messerschmitt-Bolkow-Blohm Cabinentaxi/Cabinlift, Tampa, Busch Gardens, Disneyworld, Kings Dominion, Ford, Houston, VAL, and the Sea-Tac Airport Satellite Transit AGT systems. The Morgantown People Mover assessment will be available in 1980.

The assessment activity is producing a large volume of useful data on AGT performance, costs, socio-economic, environmental and technology features.

B.10 Automated Highway Systems

Automation of vehicle operation on highways and expressways offers advantages in terms of increased capacity and travel speed and improved safety. Since 1960, the Federal Highway Administration has supported efforts leading toward the development of system specifications for an Automated Highway System. The Federal Highway Administration currently is sponsoring research on automated highway vehicle control at Ohio State University. Ohio State University is developing lateral and longitudinal automatic control concepts for automobiles. The lateral control concepts utilize a buried cable as a lateral postion reference. Electromagnetic radiation from the cable is measured by an array of coils on the vehicle and processed by an onboard computer to translate the lateral position error into appropriate steering signals. The longitudinal control research has focused on methods to provide the vehicle with position and velocity data along the path as well as methods to generate vehicle accelerator and brake commands and to coordinate the operation of vehicles.

APPENDIX C - SOURCES FOR TECHNICAL REPORTS

C.1 National Technical Information Service

Reports may be ordered directly from the National Technical Information Service (NTIS). Reports are ordered directly from NTIS by the order numbers indicated in the report listings. Inquiries about the availability or price of completed reports should be addressed to NTIS, not to the Urban Mass Transportation Administration. The NTIS Order Desk telephone number is: (703) 557-4650. Copies of the form used for ordering NTIS documents are reproduced on the last page; photocopies may be used for orders. Payment must accompany orders. Prices vary in proportion to the size of the document for copies on paper with eye-legible text (hard copy) and at present can be ascertained only by inquiries directed to NTIS. Most reports in NTIS are also made available on microfiche. Microfiche copies have a uniform price: $3.00 per volume for orders sent within the United States or $4.50 if sent abroad.

Payment for either standard or microfiche copies is acceptable in cash, by check, postal money order, GPO coupons, or charged to an American Express Card. Postage stamps are not valid as payment. It is possible to establish a deposit account at NTIS, from which payments for ordered documents are withdrawn. The purchase price includes postage at the fourth class rate. Three to 5 weeks must be allowed for delivery. Much faster delivery is provided by NTIS's Rush Order Service (703-557-4700), with an additional charge of $10.00 per document.

UMTA publishes an annual guide to its research reports entitled Urban Mass Transportation Abstracts. These volumes contain descriptive abstracts of reports sponsored by UMTA which are available from the National Technical Information Service, along with complete indices by author, title, project number, and subject. These abstracts and indices cover reports of UMTA's research, development and demonstration plus technical studies projects, and reports produced under the university research and training program. The following volumes are available from NTIS: Volume 1, October 1972 (466 abstracts), PB-213-212; Volume 2, September 1973 (195 abstracts), PB-225-368; Volume 3, July 1974, PB-264-905; Volume 4, December 1975, PB-277-290; Volume 5, December 1978, PB-297-355.

C.2 The Transit Research Information Center

Another repository is the Transit Research Information Center (TRIC), which operates within UMTA's Office of Transportation Management and Demonstrations. TRIC maintains a full collection of all UMTA-sponsored reports and can provide information related to these reports and their findings. Although TRIC does not stock copies of reports for distribution, it will provide a one-page technical abstract of any report upon request. One can also request, preferably in writing, abstracts of reports on specific subjects that have been sponsored by the Urban Mass Transportation Administration. TRIC also publishes and distributes monthly abstracts of new UMTA reports. Anyone wishing to receive these abstracts on a regular basis should address a request to: Urban Mass Transportation Administration, Office of Transportation Management and Demonstration, Transit Research Information Center, 2100 Second Street, SW., Room 6412, Washington, D. C. 20590.

C.3 The Department of Transportation Library

DOT's library contains approximately 500,000 volumes and pamphlets, 170 drawers of vertical file material, and receives more than 1,500 periodical titles. The library began operation in 1969 when the Washington libraries of the Bureau of Public Roads, Coast Guard, and Federal Aviation Administration were consolidated.

The Bureau.of Public Roads' library had extensive materials on urban mass transportation and the collection has been substantially enriched since it was taken over by DOT. The library contains all reports produced by UMTA's R&D program. Most library materials are available for interlibrary loan to other libraries.

MAIL ORDER TO:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road
Springfield, Va. 22161

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GLOSSARY

AC	-	air cushion
ACIM	-	air-cooled induction motor
AMAG	-	attractive magnetic force
ASY	-	asynchronous control
CA	-	commercial application
CGB	-	center guide beam
CGW	-	captured guide wheel
DCTM	-	direct current traction motor
DLIM	-	double-sided linear induction motor
DS	-	design study
ECC	-	eddy current clutch
FB	-	fixed block
GB	-	guide beam
GW	-	guide wheel
HST	-	hydrostatic transmission
LAM	-	linear air motor
LSM	-	linear synchronous motor
MBS	-	moving belt system
NPAC	-	negative pressure air cushion
OB	-	on-board
PD	-	public demonstration
PF	-	point follower control
QSY	-	quasi-synchronous longitudinal guidance
RGW	-	rubber guide wheel
RP	-	reduced scale prototype
RSM	-	rotary synchronous motor
RTOC	-	rubber tire on concrete
RTOS	-	rubber tire on steel

SGW	-	side guidance wheel
SLG	-	synchronous longitudinal guidance
SLIM	-	single-sided linear induction motor
SPDR	-	supported dual-rail
SPMR	-	supported monorail
SSDR	-	suspended dual-rail
SSMR	-	suspended monorail
SWF	-	side wall follower
SWOR	-	steel wheel on rail
TD	-	test track demonstration
VF	-	vehicle-follower control
WA	-	wayside actuated