

The image is a full-page photograph of a busy multi-lane highway in Atlanta, Georgia, with a dense traffic jam. In the background, the Atlanta skyline is visible, featuring several prominent skyscrapers, including the Georgia State Capitol and the Bank of America Tower. A yellow rectangular box is overlaid on the right side of the image, containing the Georgia Tech logo and the text 'Advanced Transportation Technologies And Research'.

Georgia Tech

Advanced
Transportation
Technologies
And Research

Contents

INTRODUCTION.....	1
RESEARCH PROGRAMS	2-6
Poor Visibility Warning System	2
Radar Propagation Studies	2
Traffic Monitoring Accuracy	3
Signal Timing Improvement	3
Automated Highway System	3
Traffic Data Integration	3
Adaptive Signal Control System	4
Geotechnical Engineering	4
ATMS Human Factors Study	4
Personal Communications Network	5
Electromagnetic Interference	5
Composite Structures for Bridges	5
Vehicle Noise Study	6
Adaptive Communications Techniques	6
Enhanced CB Radio	6
Ride Share System.....	6
Electric Vehicle Program	6
GT Motorsports	6
GDOT Information System	6
FACILITIES	7-8
ATMS Simulator	7
Future Car	8
Computer Vehicle Classification Reduction System	8
Knowledge-Based ATMS Software	8
EDUCATION	9
Graduate education	9
Continuing Education	9

Cover Photo

Increasingly, metropolitan cities such as Atlanta must coordinate multiple modes of transportation. (Photo courtesy of MARTA)



Increased urban traffic congestion is one of the impetuses for developing advanced transportation technologies.

Introduction

Transportation is a major research area at the Georgia Institute of Technology, with approximately \$25 million in externally supported programs. Sponsors include all levels of government agencies, private-sector companies, interest groups, and foundations. Research includes the broad areas of public and alternative modes of transportation, environmental impacts of transportation, and the design and operation of transportation systems and facilities.

Recent transportation research at Georgia Tech has resulted in the following accomplishments:

- Demonstration and evaluation of advanced traffic signal system interfaces and investigation of the relationship between vehicle behavior and air quality emissions;
- Development of airplane scheduling systems;
- Development and application of geographic information systems;
- Evaluation of transportation demand management actions;
- The awarding of nearly \$5 million for intelligent vehicle/highway systems (IVHS) research at Georgia Tech .
- Recognition of Georgia Tech by many organizations as a leading transportation university and selection by a national laboratory as one of three university partners in the transportation area;
- Excellent working relationships with state and local government agencies as evidenced by the agreement with the Georgia Department of Transportation to provide assistance in conducting transportation testing; and
- Georgia Tech's selection as a principal participant

in the Southern Coalition for Advanced Transportation with membership on the Coalition's Executive Board.

The focal point for these activities is the Transportation Research and Education Center (TREC). Over 80 faculty and research staff are associated with TREC, making it one of the largest centers of its kind in the United States. These faculty and staff represent many different schools and laboratories on the Georgia Tech campus.

Other centers at Georgia Tech that work in the transportation area include the Center of Excellence in Rotorcraft Technology, the Computational Mechanics Research Center, the Technology Policy and Assessment Center, the Logistics Engineering Center, and the Material Handling Research Center.

TREC is one of the few research organizations in the U.S. that can bring such a diverse set of capabilities to any transportation problem. In particular, Georgia Tech has a long tradition of successful interaction with industry and government agencies in solving practical problems. TREC is also committed to high quality research and education.

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Over 80 faculty and research staff are associated with the Georgia Tech Transportation Research and Education Center, making it one of the largest centers of its kind in the United States.

Research Experience

Given the variety of transportation modes in the Atlanta metropolitan area, it is not surprising that Georgia Tech researchers have so many years of experience in examining transportation alternatives. As environmental concerns and funding constraints become more pressing, expertise in innovative areas of transportation will be ever more important. The following paragraphs present highlights of Tech's recent transportation research in the area of advanced technology applications.

Georgia Tech researchers have developed a prototype of an automated warning system for use on highways where visibility is poor.

Poor Visibility Warning System

Researchers at Georgia Tech are developing a prototype of an automated warning system for use when highway visibility is poor. The system, scheduled for installation in summer 1994, will monitor highway visibility in real time and presents warnings to drivers when adverse conditions occur. The prototype will be installed on a section of Interstate 75 in southern Georgia where fog is sometimes so thick that traffic must be rerouted off the freeway. Its designers are minimizing costs by using a forward-scatter visibility sensor developed for air traffic as a part of the Automated Weather Observation System. The prototype will be the first

fully automated system in the United States. Support for this project is being provided by the Federal Highway Administration, through the Georgia Department of Transportation.

Radar Propagation Studies

IVHS systems will use radar signals to receive information from traffic management centers and to sense features of the highway environment. To use this technology properly, system designers need to know the distinctive electromagnetic features of vehicles and other objects on highways as well as the impact of different weather conditions on signal propagation. Georgia Tech researchers have already produced a wealth of information about the behavior of radar signals at the frequencies needed for automobile collision warning systems.

One landmark study shed light on how different atmospheric conditions attenuate signals at microwave and millimeter-wave frequencies. Its findings are having an impact on the spectral frequency chosen for automotive collision avoidance systems. The results will be used to minimize spectral crowding and optimize system performance.

In a related area, Tech has made extensive measurements of the way signals reflect back to radars off snow-

Radar propagation research such as this vehicular signature identification study is a key element in the development of intelligent vehicle/highway systems (IVHS) applications.



covered terrain. At the millimeter-wave frequencies of 35 and 95 gigahertz, snow has been shown to be so reflective that it masks other targets of interest such as vehicles and trees.

A joint study with the U.S. Army Ballistic Laboratories quantified the effects of rain backscatter and attenuation on millimeter-wave sensor performance. This research aims to determine the improvement in sensor performance that can be achieved through use of circular instead of linear polarization.

In another project, General Motors funded a study at Georgia Tech to measure the dual-polarized radar cross sections of two automobiles and several roadside obstacles. The object of this work was to determine polarimetric differences between cars, natural and man-made roadside hazards, and pedestrians.

In related research, engineers at Tech performed radar cross section measurements at 35 gigahertz to generate electronic images of a Volkswagen Cabriolet and a Toyota pickup truck.

Traffic Monitoring Accuracy

Working with the Georgia Department of Transportation, Georgia Tech researchers field-tested commercially available automatic vehicle classification (AVC) equipment. The purpose of this study was to determine the levels of accuracy that can be achieved with different techniques and technologies. Vendors from throughout the world loaned AVC equipment to the project that was installed on an interstate freeway in the Atlanta metropolitan area.

Traffic streams were videotaped from two angles, and ground-truth data were obtained using a PC video card and a software interface developed at Tech. The ground-truth data were compared against results from each AVC system. These findings allow them to determine how accurately each AVC system sorted the vehicles into the 13 Federal Highway Administration vehicle classes. They also were able to evaluate the effect of sensor technology on accuracy, the equipment's ability to measure axle spacings and overall vehicle length, and the effect of traffic stream composition and weather on a pneumatic tube sensor and other types of axle sensors.

Two 48-hour tests were conducted to provide detailed results, and one seven-day test was performed to provide longer term accuracy statistics.

Signal Timing Improvement

Georgia Tech has prepared and published a report that synthesizes all available information on traffic signal timing. This study provides conclusions and recommendations for best signal timing techniques. It was sponsored

by the American Association of State Highway and Transportation Officials (AASHTO) through the National Cooperative Highway Research Program.

Automated Highway System

On highways of the future, Automated Highway Systems (AHS) will guide streams of automobiles along freeways through automatic control. As a vehicle pulls onto a highway entry ramp, sensors will query both the vehicle and the driver to make sure both are competent to enter

the automated highway. The vehicle then must be merged into the traffic flow until it reaches its destination exit ramp, at which time it would steer from the highway onto the off-ramp. Between the entrance and the exit, the AHS would be in full control of the vehicle.

Georgia Tech researchers are studying the technical challenge of executing vehicle entry and exit from such a system. Highly complex problems are involved in making the transition from automatic to manual control and in merge/diverge maneuvering. Engineers at Tech are developing measures of effectiveness (MOE) to allow evaluation and comparison of the various implementation strategies. The MOEs will take into account the distinctive demands of both urban and rural environments. They will be used to help draw conclusions and make recommendations.

Traffic Data Integration

Researchers are identifying and prototyping methods to integrate road system management functions that can be optimized in traffic data systems. The project has employed existing traffic data usage and traffic data gathering systems from the Georgia Department of Transportation, the Atlanta Regional Commission, and the City of Atlanta. Future data needs and future gathering systems are being identified based on the Intermodal Surface Transportation Efficiency Act. The final product will be an integrated system that consolidates all collected data, standardizes the format for presentation, and provides data to each office as needed.



In order to sort vehicles according to 13 classes designated by the Federal Highway Administration, sensors are imbedded in the pavement of highways.

Adaptive Signal Control System

This project, sponsored by the Federal Highway Administration, is developing an approach for a real-time, traffic-adaptive signal control system. Researchers expect it to result in better movement of traffic and improved control of traffic signals. In this study, Georgia Tech is defining the requirements for local controllers, developing a prototype system based on network optimization techniques, preparing an evaluation plan for the prototypes, conducting laboratory tests, and supporting independent evaluator field tests.

In related research, computer scientists at Tech have developed a neural network system called TERMINUS that optimizes traffic signal settings to speed up the flow of automobiles to areas of lesser congestion. The system responds to changes in traffic rather than basing its recommendations on static, preconceived snapshots of the world. The initial application of TERMINUS has been to simulate traffic conditions at Atlanta Braves baseball games to demonstrate how signal light settings might be coordinated for special events. Its developers believe the system could be effective in optimizing traffic signal settings during periods where multiple events are occurring in the same general area of a city.

Geotechnical Engineering

One task for geotechnical engineers is the characterization and utilization of soils and paving materials for roadways and bridges. Tech researchers are focusing on all phases of the transportation infrastructure, ranging from construction

of new facilities to the evaluation, repair, and rehabilitation of existing ones. Recent projects have examined the engineering behavior of materials used in pavements.

The aim of one such study is to develop improved laboratory testing procedures for evaluations of the resilient modulus in asphalt concrete, aggregate base, and subgrade soils. Another project sponsored by the Georgia Department of

Transportation and the Federal Highway Administration is making a study of both fine and coarse stone matrix asphalt concrete mix designs. One of the most successful research efforts to date is developing a loaded wheel tester to evaluate rut-

ting of asphalt mixes. This project has led to a standard test procedure used by the Georgia Department of Transportation.

Tech faculty have also investigated the design of foundation systems for highway structures. In a study sponsored by the Federal Highway Administration, a series of instrumented load tests on two drilled shaft foundations situated in residual soil and partially weathered rock of the Piedmont geology were conducted to evaluate load-displacement and load-transfer response.

Several faculty are also involved in the development of nondestructive testing methods for evaluating the condition of existing transportation infrastructure. One project is employing artificial neural networks to interpret nondestructive pavement tests. Other research is utilizing geographic information system (GIS) technology in earthquake hazard mitigation studies. With support from the U.S. Geological Survey, faculty are investigating the consequences of an earthquake in the New Madrid seismic zone on transportation facilities in Evansville, Indiana.

ATMS Human Factors Study

As much as Advanced Traffic Management Systems (ATMS) are automated, they cannot succeed unless they are "user-friendly" to the people who operate them. To enhance ease of use, the Georgia Tech Research Institute (GTRI) is leading a 39-month, Federal Highway Administration-sponsored program to address human factors issues involved in ATMS implementation.

First, an interdisciplinary research team is determining just what ATMS means to professionals already working with them. The group is collecting the insights of some 20 persons who have been recommended by their peers as visionaries in IVHS research and theory. They also have visited about two dozen traffic management centers in the United States, Canada, and Europe and assessed each operation.

Second, the team is using the information it has collected to build a laboratory that simulates an "ideal" working traffic management center. State-of-the-art Silicon Graphics work stations will generate data displays and lifelike computer images of traffic situations on Atlanta streets and highways. Up to four operators will respond to simulated traffic situations. This capability will help them determine the best designs for traffic management center control systems. The lab is scheduled to become operational by April 1994.

Lastly, the researchers will distribute the information they have collected about ATMS human factors considerations in a handbook. Researchers are employing a user-centered design approach to develop human factors recommendations and guidelines for the design evolution of current technology traffic management centers toward full ATMS technology.

Researchers have developed a neural network system that optimizes traffic signal settings to speed the flow of automobiles to areas of lesser congestion.



Tech researchers have performed automobile noise studies for Ford Motor Company.



Personal Communications Network

Wireless personal communications networks (PCN) are an important technology for IVHS communications systems. It represents the third generation in cellular telephony beyond the original analog mobile cellular and digital mobile cellular systems. Georgia Tech is providing technology base support for the development of a commercial personal communications network for BellSouth Enterprises. As a part of this work for BellSouth, Tech engineers are examining potential modulation formats between a base station and mobile terminals. They are focusing on data transmission, frequency reuse considerations, security, privacy, and performance in the presence of propagation anomalies such as reflective multipath.

Electromagnetic Interference Problems

Electromagnetic interference problems must be anticipated and eliminated if the electronic systems needed for intelligent vehicle/highway systems are to be successfully fielded. Georgia Tech has several decades of expertise in the study of electromagnetic environmental effects. Several important recent studies have focused on transportation-related problems.

In one project, researchers are characterizing the worst-case electromagnetic environment (EME) across those radiofrequency bands to which automobiles might be exposed while operating on U.S. roadways and in accessible areas near strong RF emitters. Another study reviewed current practices and developed recommended procedures for the transient and electromagnetic interference protection, grounding,

shielding, and filtering of traffic equipment. Tech engineers also have characterized the electromagnetic interference and compatibility properties of electric vehicles by performing various radiated and conducted tests on three vehicles.

In addition, radiated and conducted measurements were performed on communication and train control cables of Atlanta's MARTA rapid transit system. This study evaluated the relative effectiveness of the installed galvanized rigid steel conduit in protecting trackside circuits from external noise and interference. In another project, researchers at Tech have devised recommendations for grounding and lightning protection design and installation guidelines for MARTA.

Finally, Tech has produced a three-volume handbook of practices and procedures for grounding, bonding, and shielding at air traffic control facilities.

Composites Structures for Bridges

In one program, researchers are developing accelerated test methods for determining the long-term behavior of fiber-reinforced composites (FRP) for bridges. These test methods will provide future researchers with common test methods, acceptable to the highway bridge design community.

In another study, faculty are performing a comprehensive literature search on work related to horizontally curved steel box and I-girders and making recommendations for future research on this subject.

Another project is developing analytical methods for FRP bridge decks and providing recommendations for design of experimental specimens based on manufacturing and design considerations.

Above, a human factors study is aimed at making advanced traffic management systems more user-friendly for operators.

Georgia Tech is participating in a research coalition to develop electric vehicles.

Vehicle Noise Study

In a study sponsored by Ford Motor Company, Georgia Tech researchers are developing methods to predict noise levels that drivers hear inside their automobiles while driving on the road. No way to completely predict noise inside cars has been developed to this point in time. To prepare cars for 25,000 miles of road study and many other tests, students used clay to mount hearing-aid microphones at 41 locations on the car. Locations were chosen by their potential for high noise levels: around the mirrors, near crevices and recesses, around corners, and on the underside of the car. Other data were compiled during the road tests. Data from this investigation may prove useful in the design of future cars.

Adaptive Communications Techniques

Researchers are designing, developing, and demonstrating adaptive communications techniques to achieve greater covertness and interference avoidance in dense electromagnetic environments. This knowledge of the electromagnetic environment will be used to automatically select, in near real time, the best frequency, modulation type, and power level for covertly communicating with intended receivers. Candidate techniques include masking the desired transmissions with signals already in the environment and mimicking signals ordinarily present. Of primary importance to

the project is the development of a fast spectrum monitoring technique capable of classifying and recognizing various emitters in the spectrum in near real time.

Enhanced CB Radio

This program involved the design, development, fabrication, test and evaluation of a low-cost system for using citizen band (CB) radio to aid motorists who need help or emergency assistance.

The system consists of an automobile unit (digital adapter), a repeater unit (remote station), and a central receiving site (central control unit). Multiple-tone, selected calling has been used on CB radiofrequency carriers to transfer motorist information to the central control unit. There, a microcomputer verifies the caller and automatically alerts the correct assistance unit to respond. The pilot evaluation program used approximately 100 automobiles and was conducted in the Atlanta area.

Ride Share System

Georgia Tech has developed a geographic information system (GIS) based ride share matching system for the Georgia Department of Transportation. The system, now being implemented for a 26 county area around Atlanta, operates in a customized, existing ARC/INFO (Atlanta Regional Commission/INFO) environment. Employing a graphical interface, a user can get a report from the system that gives him the names and work phone numbers of prospective car poolers that live and work within a specified distance of the user.

Electric Vehicle Program

The Georgia Tech Research Institute and the School of Civil Engineering at Georgia Tech will participate in a Southern Coalition for Advanced Transportation (SCAT) program concerned with the development of electric vehicles. Technical assistance and guidance to SCAT will be provided in the areas of computer networking, battery technology evaluations, and progress by other consortia or entities having electric vehicle technology. Additionally, an electric-powered bus being developed by Blue Bird Body Company will be operated on the Georgia Tech campus and monitored and evaluated by the School of Civil Engineering. The bus will remain on the campus after the program for further research.

GT Motorsports

GT Motorsports is a Georgia Tech student organization established to compete in the Formula SAE design competition. The objective of this annual competition is to produce a prototype single-seat, open-wheeled race car designed for the weekend autocrosser. The cars are typically powered by motorcycle engines and weigh in at 450-600 pounds without driver. The approximately 30 student members take active roles in all phases of the project, from design to fabrication and testing to driving.

GDOT Information System

Georgia Tech is assisting the Georgia Department of Transportation (GDOT) in planning for implementation of the seven systems mandated by the Intermodal Surface Transportation Efficiency Act (ISTEA). As implemented, these seven systems will become an integral part of the state's decision-making process. This project will also provide an overall strategic plan with individual office implementation plans for a GDOT information system that handles all data used by the department including management information. When completed, GDOT will have the architectural concept in place for a fully automated department including the district offices.



Students in a Georgia Tech motorsports club build an open-wheeled race car for an annual design competition.

Research Facilities

Georgia Tech has extensive facility and equipment that are used or potentially useful in transportation research. Most are located on the Georgia Tech campus, but some are situated at the nearby Cobb County Research Facility, approximately fifteen miles northwest of Atlanta. Facilities include extensively equipped offices and laboratories in the disciplines of electronic systems, chemical and materials sciences, human engineering, sensors, and computing.

The electronics facilities include the:

- Electromagnetic measurements facility;
- Electromagnetic test facilities;
- Electronic fabrication facilities;
- Electromagnetic compatibility facility;
- Digital RF memory laboratory; and
- Signal processing and emitter identification laboratory.

Within these laboratories and facilities, the entire electromagnetic frequency spectrum normally used for physical sensing, visualization, and communication as well as computer modeling is covered. Other facilities in place to support transportation research include the following:

- Infrared measurements facility;
- Optical calibration and testing facility;
- Communications laboratory;
- Communications measurement facility;

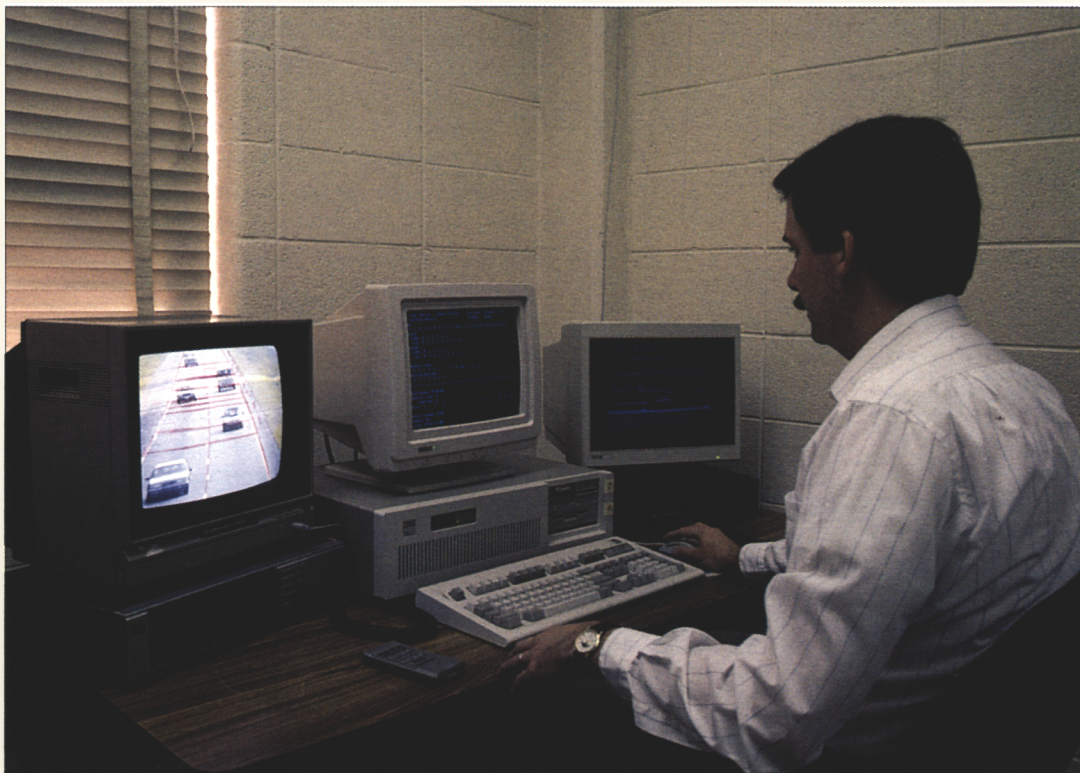
- Human factors studies facilities;
- Wind tunnels; and
- Acoustic facilities.

Specialized transportation facilities are described below.

ATMS Simulator

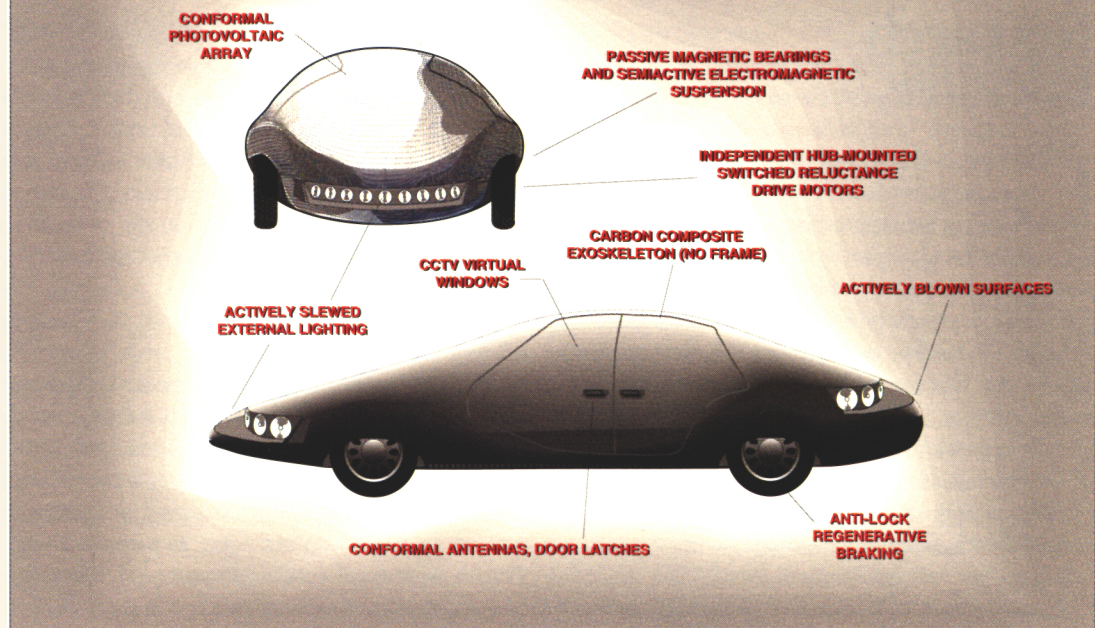
The Advanced Traffic Management System (ATMS) simulator provides a high-fidelity, man-in-the-loop simulation of the advanced control centers that will manage traffic on future roads and highways. The simulated control center is housed in a 550-square foot, two-room suite. Traffic flow on a roadway system of freeways and arterials is simulated using Georgia Tech's proprietary AUTOS traffic model. Traffic flow is fully interactive with operator traffic management actions. A network of seven Silicon Graphics touchscreen workstations simulates operator displays in the control center and provides experimenter control of test sessions. Closed-circuit television (CCTV) coverage of approximately 40 freeway locations is simulated using Georgia Tech's AUTOGRAPH hybrid animation process running on a SiliconGraphics Reality Engine2. In the CCTV views presented on monitors in the control room, traffic density and speed are consistent with flow calculated for that par-

The advanced control centers that will manage traffic on future highways are modeled by the ATMS simulator at Georgia Tech.



Using a video frame from a VCR, Tech researchers can show how well the Computer Vehicle Classification Reduction System software classifies vehicles.

GTRI FutureCar Test Bed



The ATMS Universal Traffic Orchestrated Simulation has been generated to support transportation research programs performed at Georgia Tech.

ticular link by the AUTOS model. Design is modular and rapidly reconfigurable through the use of modular hardware and software as well as VAPS rapid prototyping software for display design and implementation. A menu of traffic management problems is available to the experimenter for creating challenging but realistic traffic scenarios.

FutureCar

The FutureCar project at Georgia Tech is a testbed for interdisciplinary advanced technology demonstrations. In general, technologies that are two generations ahead of current off-the-shelf capabilities will be emphasized. Much of the current thinking regarding advanced modes of personal transportation focuses on methods for improving the automobile in its present form through infusion of new technology. The FutureCar testbed accommodates radical concepts in personal transportation that go beyond conventional thinking and in some cases violate automotive traditions.

The technology areas to be initially investigated as part of the FutureCar concept are energy capture, energy storage, power generation, power transmission, active and passive suspension and bearing systems, active and passive drag reduction techniques, vision systems, materials and structures, and ease of manufacturability and maintenance.

Georgia Tech has allocated internal funding to begin development of the FutureCar in the first quarter of 1994.

Computer Vehicle Classification Reduction System

Detailed vehicle classification, length, and axle spacings can be obtained using the Com-

A FutureCar testbed is being developed at Georgia Tech for advanced technology demonstration projects.

puter Vehicle Classification Reduction System (CVCRS). It employs video tape of the traffic stream from a pole off the side of the highway. The CVCRS consists of a PC/486 computer, a Data Translation DT3851A-1 Flexible Frame Processor, and custom software designed to aid a user in efficiently reducing the vehicular data stream to a standard file format. The user pauses the video on a vehicle and uses a mouse and cursor to "select" the front bumper, each axle, and the rear bumper. The CVCRS automatically measures vehicle length, number of axles, axle spacing and time, and makes an initial classification based on length and axles. The user has the option of accepting the initial classification or changing it if necessary to meet the Federal Highway Administration classification scheme. Calibration marks in the roadway are used to calibrate the system length measurements. The CVCRS allows the user to efficiently and accurately create ground truth data that can be used in detailed traffic analysis or verification of vehicle classification equipment.

Knowledge-Based ATMS Software

A software program called the ATMS Universal Traffic Orchestrated Simulation (AUTOS) has been generated to support the many transportation-related programs performed by Georgia Tech. AUTOS incorporates all modes of transportation to provide an effective management solution to the advanced traffic management system (ATMS). For example, the program addresses the special needs of buses, trucks, taxicabs and emergency vehicles as well as automobiles.

Education & Training

The expertise of Georgia Tech's faculty in the various areas of transportation technology is made accessible to students and members of the professional community through numerous graduate programs, short courses, and workshops.

Graduate curricula

The transportation graduate program at Georgia Tech provides in-depth knowledge of the basics of transportation system operation and design. Students are encouraged to add breadth to their education through exposure to the environmental, institutional, and societal contexts in which they will operate. Georgia Tech offers many courses relating to transportation, several of which are precisely attuned to the problems faced by IVHS designers. For example, courses are offered on the following topics:

- Computerized traffic surveillance and control;
- Advanced traffic operations;
- Advanced technology applications in transportation;
- Computer simulation in transportation;
- GIS applications;
- Transportation planning;
- Systems optimization;
- Logistics;
- Human factors engineering;
- Database management;
- Multimedia technology;
- Advanced environmental technologies;
- Materials engineering; and
- Communications/electronics.

Continuing Education

Georgia Tech's continuing education program has been rated as one of the best in the nation. Several courses have been offered in the transportation area, including the following:

Traffic engineering. Georgia Tech has offered traffic engineering courses to practitioners for many years. These courses focus on the basic principles of traffic flow and traffic engineering design. These courses now include topics associated with IVHS applications that traffic engineers will work with in coming years.

Traffic signal workshops. Tech's Continuing Education Department offers short courses and workshops on traffic signal engineering, operation, timing and analysis. Courses and workshops are designed for managers, engineers, planners, designers, and other professionals working in the transportation field who are familiar with traffic signal operation at local intersections.

IVHS short courses. The transportation continuing education program of TREC is presenting a series of short courses on intelligent vehicle/highway systems (IVHS). Topics include "An Introduction to IVHS" and "Commercial Vehicle Operations." The program will also incorporate topics in transportation other than those covered by IVHS and in the future will look to collaborative efforts with those interested in environmental issues.

Atlanta IVHS workshop. In July 1991, national experts on advanced transportation technologies participated with state and local officials from Georgia in a workshop to exchange information on the possibilities associated with such technologies. The objective of the workshop was to identify demonstration projects for the Atlanta area that will showcase state-of-the-art transportation technologies over the next five to seven years while providing long-term enhancements to Atlanta's transportation systems. The 1996 Olympic Games in Atlanta were identified as a unique opportunity to showcase to the world the types of technologies that are possible in a twenty-first century American city.

Tech's Continuing Education Department offers short courses and workshops on traffic signal engineering, operation, timing and analysis.



Participants in Georgia Tech continuing education workshops often receive hands-on experience at campus transportation facilities.

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