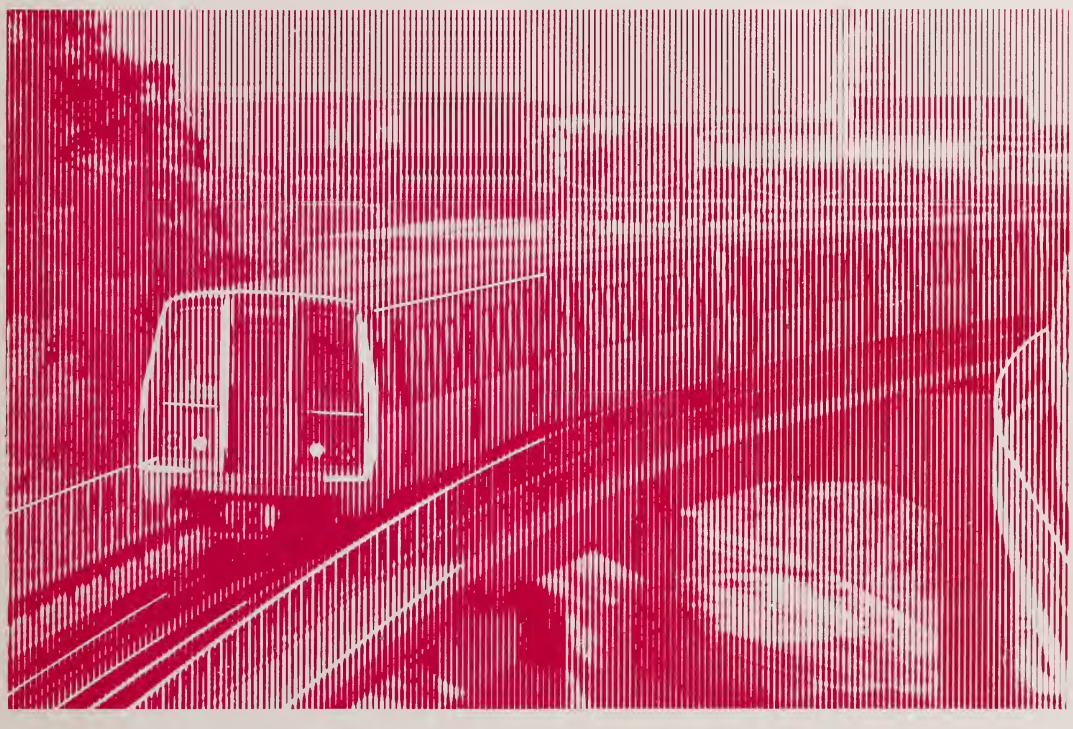
U.S. Department of Transportation
**Urban Mass Transportation Administration**

# THE UMTA SUBSYSTEMS TECHNOLOGY APPLICATION TO RAIL SYSTEMS (STARS) PROGRAM



**UMTA Technical Assistance Program**

# The U.S. DOT-UMTA STARS Program

The Subsystem Technology Applications to Rail Systems (STARS) Program, sponsored by the United States Department of Transportation-Urban Mass Transportation Administration, is fulfilling technical assistance needs of rail transit systems. These various needs, described to a U.S. DOT-UMTA and APTA team several years ago, were prioritized and became projects within UMTA's STARS Program. APTA, as the representative for the transit industry, has been supporting the STARS Projects by providing transit system assessment of progress made by UMTA toward fulfillment of each Project's objectives. The scope and depth of work performed on STARS Projects (e.g. AC Propulsion, Fare Collection Reliability, Improved Air Comfort Systems, Electromagnetic Compatibility, Cooperative Industry/Government Signal and Control, Escalator Maintenance Reduction) have been most beneficial to transit systems in reducing maintenance requirements and costs, increasing hardware reliability and improving equipment performance. APTA appréciates UMTA's technical assistance and the tasks which have been accomplished toward satisfying needs of the transit industry. APTA looks forward to additional cooperation from UMTA's Office of Technical Assistance for achieving further technological progress in equipment utilized by rail transit systems. The STARS Program has yielded both cost reductions and productivity increases to transit systems.

**American Public Transit Association**

U.S. Department of Transportation

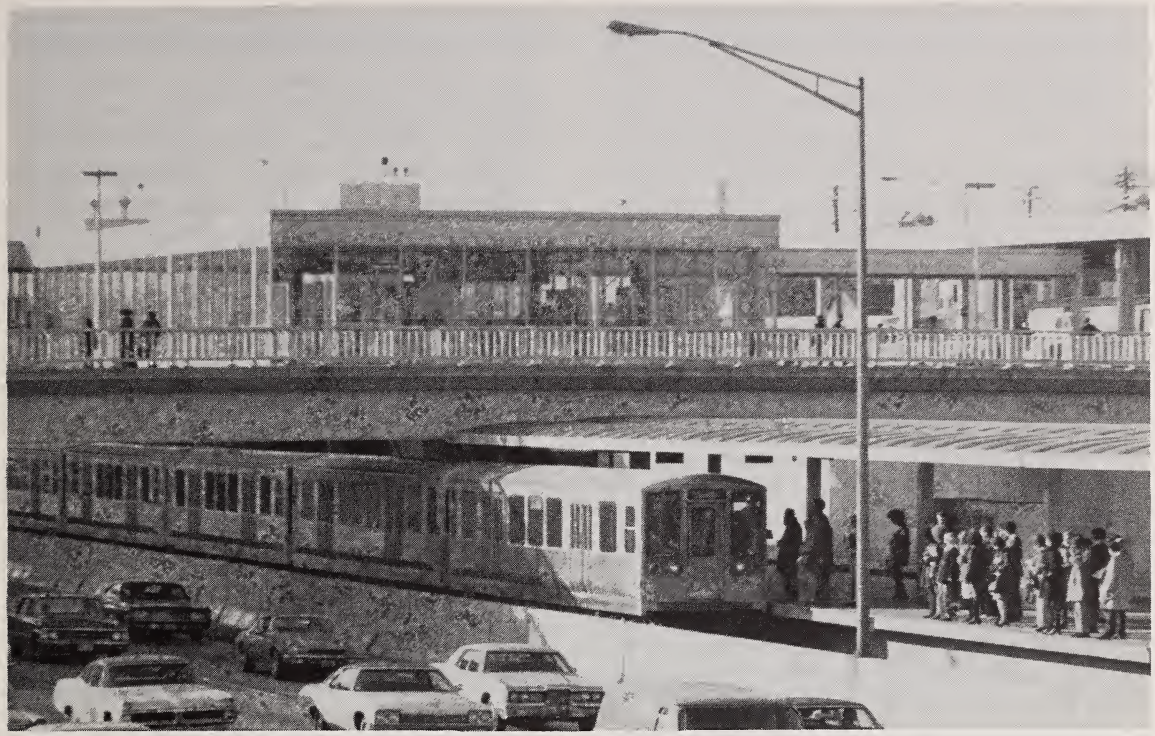
**Urban Mass Transportation Administration**

# THE UMTA SUBSYSTEMS TECHNOLOGY APPLICATION TO RAIL SYSTEMS (STARS) PROGRAM

---

**UMTA Technical Assistance Program**

# CONTENTS



# OVERVIEW

Urban rail mass transit systems in the United States are a vital link in the nation's transportation network. At the present time, 18 urban areas have rapid or light rail systems planned, under construction, or in operation: San Francisco, Chicago, Cleveland, Philadelphia, New York City, Boston, Washington, DC, Baltimore, Atlanta, Miami, Los Angeles, Newark, Pittsburgh, New Orleans, Buffalo, Santa Clara County, San Diego, and Portland.

In 1984 these systems comprised approximately 10,000 rail cars, 1,500 miles of track, and 800 stations. When commuter railroads are included, rail transit systems carry more than two billion passengers annually or more than one-third of all mass transit riders. The economies of the nation's urban areas are crucially dependent on these transit systems.

It was for the purpose of safeguarding and upgrading this public investment that the U.S. Department of Transportation (DOT) and the transit industry jointly launched the STARS Program in 1979. STARS, which stands for Subsystem Technology Application to Rail Systems, is a cooperative effort of DOT's Urban Mass Transportation Administration (UMTA) and the American Public Transit Association (APTA). APTA represents the transit industry, including transit authorities, state DOTs and metropolitan planning organizations, equipment suppliers and manufacturers, consultants and contractors, publications, and universities and associations. The objective of the STARS Program is to address the management and technical needs of the transit authorities. STARS is the only mass transit rail subsystem R&D program now underway in the United States.

The STARS Program is a multiyear, multimillion dollar effort. In DOT, overall responsibility for the Program lies with the UMTA Office of Systems Engineering within the Office of Technical Assistance in Washington, DC. DOT's Transportation Systems Center in Cambridge, Massachusetts assists UMTA in providing technical support to the STARS Program. APTA, with headquarters in Washington, DC, provides liaison and coordination between industry and UMTA. APTA's members provide technical expertise, demonstration test sites and equipment, continuing review of all work done under this Program.

The STARS Projects represent the expressed needs and potential solutions to problems of the transit authorities. The subsystem improvement areas were selected jointly by UMTA and members of APTA. Selection was based on research likely to yield a high payoff in improved transit performance and lower operating costs. In general, the STARS effort supplements industry initiative where technological risks and market size do not produce incentives for privately financed R&D equivalent to the benefits which can be achieved nationally.

The STARS Program is divided into a number of subsystem research areas, each of which forms a separate STARS Project under the direction of a project manager. In this context, rail "subsystems" refers to equipment which can be acquired in new rail cars and associated infrastructures or retrofitted into existing ones, as well as to procedures which can be incorporated into management practices.

The STARS Projects are discussed in detail in this Digest. Projects described include: AC propulsion, electromagnetic interference and compatibility, air comfort system improvement, fare collection reliability, rail car door improvement, energy cost reduction, automatic train operation and control, train-line multiplexing, winterization and escalator design and maintenance.

The work of the American Public Transit Association in encouraging the involvement of transit authorities is vital to the STARS effort. To facilitate this involvement, in 1979 APTA established five standing STARS Liaison Boards, which correspond to the subsystem areas under investigation: the Car Equipment Liaison Board, the Fare Collection Reliability Liaison Board, the Electromagnetic Interference and Compatibility Liaison Board, the Escalator Maintenance Reduction Liaison Board, and the Cooperative Government-Industry Signal and Control Liaison Board. Each Board is comprised of a representative from each rail transit system who has been designated by his respective General Manager to represent the specific transit system.

Some of the STARS Projects, such as electromagnetic interference and compatibility, are directed at performance and safety improvements. Other Projects, such as fare collection reliability, are cost-reduction efforts. Currently, the total cost of operating rail transit systems in the U.S. is $1.5 billion annually. Only about one-half of this amount is recovered through the collection of fares. The remainder is provided by federal, state, and local agencies. Thus, cost reduction, along with safety, is a major priority in the transit industry. In the STARS Program, particular emphasis is being placed on the reduction of maintenance costs, since over the lifetime of rail equipment, maintenance is generally much more costly than original acquisition. The improvement of management practices is another important focus in the STARS Program.

A final important function of the STARS Program is to accelerate the flow of information on solutions and improvements which have been developed locally and could be adopted by a large proportion of the transit community. In this way, the

Program serves as a clearinghouse for current information on rail transit subsystems and a mechanism for developing and publishing criteria and specifications which can be adopted industry-wide.

Many valuable results have been achieved by the STARS Program to date. Under the STARS AC Propulsion System Project, two AC traction motors and control systems were designed through research and development contracts. In 1984, UMTA chose the AC system designed by Garrett AiResearch Corporation for test and evaluation at the Transit Test Center (TTC-Pueblo) and for demonstration in the New York City Transit Authority system.

Under the STARS Fare Collection Reliability Project, six grants to transit authorities have been awarded for automated hardware development. The Transportation Systems Center (TSC) reports that the efforts under this Project can save the U.S. transit industry $32 million annually as of 1984 and $46 million annually by 1988.

Under the STARS Electromagnetic Interference and Compatibility (EMI/EMC) Project, two volumes of Recommended Practices (proven methods) have been developed and used to solve EMI problems that threatened the safety and reliability of several rail transit systems. These documents are currently being processed for publication by the Institute of Electrical and Electronic Engineers (IEEE). Several additional Recommended Practices are being developed to assure the compatibility of new and different designs of equipment introduced (or proposed for introduction) into rail transit systems.

The STARS Air Comfort System Improvement Project was an outgrowth of the high failure rate and high repair costs of rail car air conditioning systems. A comprehensive industry analysis of common problems and proposed alternative solutions was completed in 1983. As an outgrowth of the study, a proposed alternating current modular air conditioning unit is under consideration for testing on a rail transit system.

Development efforts planned under the STARS Automatic Train Operation and Control Project will evaluate microprocessor-based automated subsystems and develop guidelines/methodologies to ensure their safety, reliability and maintainability. These guidelines/methodologies are essential to promote the transit authorities' acceptance of microprocessor technology in equipment for rail transit systems.

Descriptions of selected STARS Projects follow in this Digest. Technical documents reporting the results of research and development within each STARS Project area are listed in a bibliography following each Project description. Most of these documents are available to the public from the National Technical Information Service (NTIS), UMTA's Transit Research Information Center (TRIC), or the Transportation Systems Center (TSC). Procedures for contacting these sources to acquire documents or to obtain additional information are provided at the end of this Digest.

# STARS AC Propulsion System Project

Advances in solid state electronics over the past five years have made possible the development of a superior rail car propulsion system using an AC traction motor which will soon be available for application to transit systems in the United States. The primary advantage of the AC, or

alternating current, propulsion system is that its life cycle costs are lower than those of the direct current (DC) rail propulsion technology now in use in the United States. Studies indicate that savings ranging from $4,000/car/year to $10,000/car/year are possible. The effectiveness of AC propulsion has been proven in the European environment, where AC systems are being introduced in a range of vehicles from trolley-buses to railroad locomotives.

The first large-scale test of AC propulsion was conducted in Cleveland in 1973 under an UMTA grant. Three cars were retrofitted with a WABCO/Reliance Electric Pulse Width Modulation System and were evaluated in revenue service over a one-year period. The reliability of the cars was not considered satisfactory, although considerable energy savings were documented.

The objective of the STARS AC Propulsion System Project is to sponsor development of an AC propulsion system that meets current transit system reliability and performance criteria. In 1982, two 18-month Phase I design contracts of approximately $2 million each were awarded to Westinghouse Electric Corporation and Garrett AiResearch Corporation to develop model AC systems designed to U.S. transit system performance requirements. In 1984, UMTA selected for prototype construction and demonstration the AC system design developed by Garrett and awarded the company a $3.2 million Phase II demonstration contract.

The objective in Phase II is to build and test the prototype to verify that the projected life cycle savings and performance requirements of AC propulsion will be realized in the U.S. environment. In 1985, as part of Phase II, the prototype will be demonstrated at the DOT Transportation Test Center in Pueblo, Colorado, and the following year, the New York City Transit Authority (NYCTA) will test the AC propulsion system in its R-44 rail cars for several months.

The STARS AC Propulsion System Project is managed by UMTA with technical support provided by the Transportation Systems Center. The APTA Car Equipment Liaison Board provides guidance on deployment potential. The STARS Electromagnetic Interference and Compatibility Project (EMI/EMC) has also performed analyses to help eliminate problems which might accompany the introduction of AC propulsion equipment in existing transit systems.

In the AC motor, the troublesome commutator and brush assemblies are eliminated. This simplicity of design greatly reduces maintenance requirements. Second, since the AC motor does not require external air to circulate through the motor, it is possible to totally enclose the motor in a steel shell, thus protecting it from dirt and moisture and further reducing maintenance costs. In addition, the AC motor and accompanying controls consume almost 5 percent less energy than a DC assembly of comparable power.

A 1983 study, entitled "Life Cycle Cost Analysis," completed for the AC Propulsion System Project by Garrett AiResearch, found that life cycle costs of AC propulsion systems are 35 to 40 percent less than for DC propulsion technology. These results, based on a costing methodology developed by N.D. Lea and Associates, assume a 30-year lifetime for a 100-vehicle fleet on the NYCTA system. Industry experts are predicting that AC technology will eventually replace DC propulsion systems in the United States.

**Bibliography**

"Life Cycle Cost Analysis," Garrett AiResearch Corporation, 1983.

"AC Inverter Propulsion System Operating Costs," Karl Berger, paper presented at the 1983 APTA Rapid Transit Conference, Pittsburgh, PA, June 22, 1983.

"The Status of Advanced Propulsion Systems for Urban Rail Vehicles," MITRE Corporation, May 1979, PB-79-298-770.

# STARS Electromagnetic Interference and Compatibility (EMI/EMC) Project

In 1978 the Chicago Transit Authority (CTA) tested rail cars equipped with chopper propulsion. Electromagnetic interference (EMI) emitted from the chopper control created failures in some of the CTA signalling systems. It was one of the first documented examples of rail transit electromagnetic interference or EMI. EMI includes interference between on-board and wayside electronic subsystems that produces abnormal operations. With the implementation of new electronic subsystems in existing rail systems, the safety and reliability problems caused by EMI have become a major concern of the transit industry today.

The STARS Electromagnetic Interference and Compatibility (EMI/EMC) Project was initiated in 1979 in response to these concerns. UMTA, with technical support from TSC, is working with industry organizations to address EMI/EMC problems experienced by transit authorities.

Representatives from transit industry suppliers, researchers, and UMTA/TSC personnel make up the Rail Transit EMI Technical Working Group (TWG) which guides and coordinates programs for analyzing, testing, evaluating and disseminating information on specific EMI problems. The EMI/EMC Project provides technical support to the TWG in the development of Recommended Testing Practices (RPs) for measuring and recording EMI data for subsequent analysis

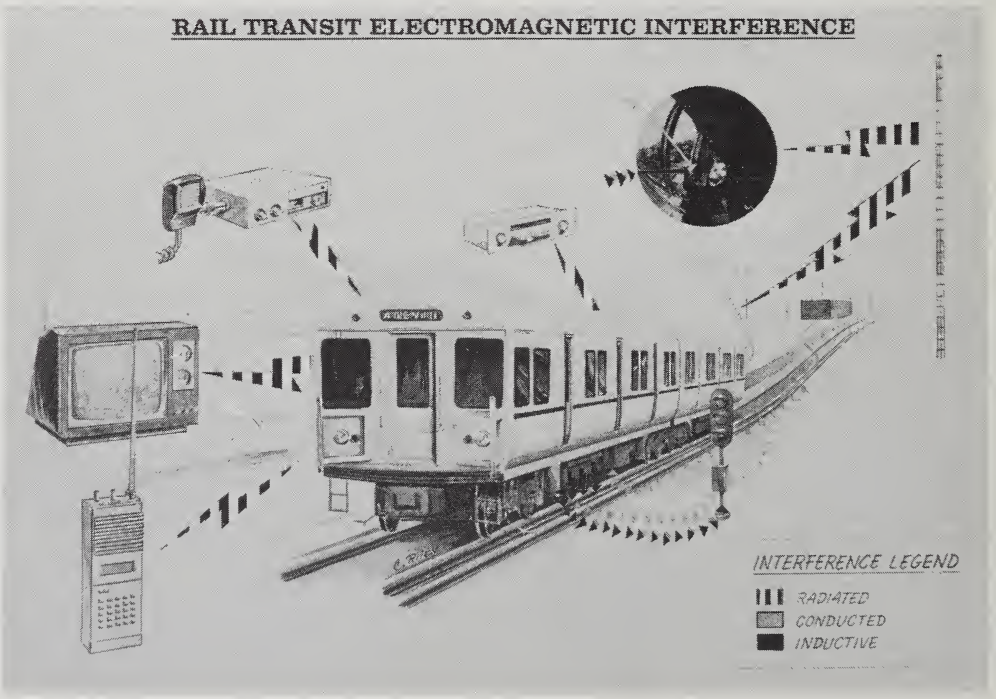
of EMI problems. The EMI/EMC Project has provided direct technical assistance to transit authorities to solve specific EMI problems.

The APTA Electromagnetic Compatibility Liaison Board conveys the EMI concerns of transit operators to UMTA/TSC and disseminates information on new testing and operating procedures. This Liaison Board is made up of technical personnel from transit authorities and is responsible for identifying their concerns regarding rail transit EMC.

Two types of EMI, inductive interference and conducted interference, are known to affect signalling systems resulting in the generation of false go signals which jeopardize both the safety and operational reliability of transit systems. Another type of interference, radiated EMI, is being examined to evaluate its potential threat to sensitive electronic equipment, such as computer installations and radio/TV equipment, located near transit rights-of-way.

The TWG, with technical support from the STARS EMI/EMC Project, has developed Inductive and Conducted RPs as guidelines for testing electromagnetic compatibility between audio frequency signalling and chopper-propulsion subsystems on rapid transit systems. The RPs are used to identify and characterize EMC problems in existing transit systems to determine the cause of specific interference problems. They could also assist in verifying that products and systems procured by transit authorities meet EMC operating requirements.

RPs are developed from analytical models and are verified and refined by thorough field testing at cooperating transit authorities. Prior to final drafting, RPs are distributed to members of the TWG and APTA for review and comment. Final RPs will be made available to the industry through the Institute of Electrical and Electronic Engineers (IEEE).



In cooperation with the IEEE, the EMI/EMC Project has developed two volumes of RPs, which will be IEEE standards, and plans to publish three additional volumes in 1984 and 1985. Volumes 1 and 2 address inductive and conducted interference between propulsion and audio frequency signalling systems. Other volumes will address radiated interference and EMI related to substations and power frequency signalling systems.

In support of the STARS AC Propulsion Project, the EMI/EMC Project is testing signalling systems to identify potential EMI problems that could result from the introduction of AC propulsion systems into existing transit systems. In addition, analytical work has been conducted to develop parameters for the analysis and design of AC propulsion systems including EMI countermeasures. The EMI/EMC Project is also monitoring EMI testing of the prototype AC propulsion systems being developed and tested.

The EMI/EMC Project has provided direct technical assistance to transit authorities to test and resolve specific EMC problems. Identifying and developing solutions to EMI problems are a cooperative government-industry effort, and the results are disseminated to the transit industry to assist in solving EMI problems.

## Bibliography


"Effects of the Metropolitan Dade County Rapid Transit System on the Electromagnetic Environment," Radiation Sciences, Final Report, August 1980, U.S. DOT Report No. UMTA-MA-06-0025-80-10.

"Harmonic Characteristics of Rectifier Substations and their Impact on Audio-Frequency Track Circuits," Vilas D. Nene, Final Report, May 1982, U.S. DOT Report No. UMTA-MA-06-0025-81-6, PB-82-229-659.

"Electromagnetic Interference Characteristics of Advanced Propulsion Systems for Urban Rail Vehicles," Vilas D. Nene, Final Report, February 1981, U.S. DOT Report No. UMTA-VA-06-0075-81-1, PB-81-212-730.

"Statistics of Chopper Interference on Multi-Car Trains," University of Lowell, Final Report, February 1981.

"Recommended Practices for Rail Transit Intra-System Electromagnetic Compatibility of Vehicular Electrical Power and Track Circuit Signalling Subsystems - Volume I: Inductive Recommended Practices, Volume II: Conductive Recommended Practices," Transportation Systems Center, May 1982.

"Recommended Practices for Rail Transit Intra-System Electromagnetic Compatibility of Vehicular Electrical Power and Track Circuit Signalling Subsystems - Volume III: Radiated," Transportation Systems Center, (Forthcoming).

"Statistics of Chopper Interference on Multi-Car Trains," F. Ross Holmstrom, (Forthcoming).

"Preliminary EMC Catalog of Emissions and Susceptibility—Vehicle Electrical Power and Track Circuit Signalling Equipment," OAO Corporation, October 1981.

"Status of Advanced Propulsion Technology in Japan," Vilas D. Nene, May 1982, U.S. DOT Report No. UMTA-MA-06-0025-81-5, PB-82-229-642.

# STARS Air Comfort System Improvement Project

Air conditioning failures present serious maintenance problems and high repair costs, especially for older equipment. Moreover, repair usually involves removing cars from service.

Research completed under the STARS Air Comfort System Improvement Project by Data Communications, Inc. documents the specific problems of rail car air conditioning systems and examines alternative improvements in design and maintenance. Cost-benefit ratios are applied to alternative approaches. The experiences of five transit authorities (BART, CTA, PATH, PATCO and WMATA) were examined in detail. Information was also provided by the New York City Transit Authority. In addition, policy issues relating to training, documentation, information systems and parts acquisition were assessed.

Special attention was focused on a modular air conditioning unit design which offers the potential of reducing life cycle costs and rail car down-time. A modular alternating current unit could be utilized in new cars or retrofitted into existing ones. Utilization of modular systems in combination with guidelines for equipment maintenance can be expected to substantially reducé air conditioning problems for rail transit systems.

The Phase I study documenting industry problems and alternative solutions has been completed. Phase II will focus on testing and evaluating a hardware alternative proposed in the Phase I report and will involve demonstration and evaluation of a modular alternating current unit.

**Bibliography**

"STARS Air Comfort System Improvement Program: Phase I, Final Report," 2 vols. Data Communications, Inc., Project No. IT-06-0250, November 1983.

# STARS Fare Collection Reliability Project

U.S. transit systems began to utilize automated fare collection in the late 1960s. The transit authorities hoped that automated equipment would produce lower operating costs and increased revenues. The flexibility of automated equipment was especially appealing because it would allow varying fares to be charged, based on length of travel and time of day, instead of a flat fare.

However, the benefits of automated fare collection were not realized in the 1970s. Instead of reducing operating costs, transit authorities found that the low reliability of automated equipment led to high maintenance costs and increased passenger delay and frustration.

The automated fare collection equipment now available has evolved from the vending machine industry. Compared to the older turnstiles, automated equipment is less able to withstand the severe environment and high service rates encountered in public transit systems.

But after the first decade of experience, it became apparent that a second generation of more reliable automated fare collection equipment could be built. In 1979, UMTA established the STARS Fare Collection Reliability Project to examine this possibility. At the request of UMTA, APTA established the STARS Fare Collection Reliability Liaison Board comprised of representatives from 14 transit authorities, equipment suppliers and consultants. Three major problems are being addressed under the Project: low equipment reliability, lack of equipment flexibility, and lack of quantitative and uniform data on equipment performance and cost.

The objective of the STARS Fare Collection Reliability Project is to develop information and provide technical assistance to transit authorities to aid them in procuring automated fare collection equipment and managing currently-owned equipment in a cost-effective manner. The Project is a multiyear, multimillion dollar effort, involving sponsored research, meetings and conferences, and the award of UMTA grants.

At the midpoint of the Project in 1984, significant results had been achieved. Efforts under this Project have led to the development of information, analytical methods and new fare collection hardware that, if utilized efficiently, will save the transit industry $32 million a year. These savings can be achieved by reducing the direct operating costs of fare collection, reducing losses due to illegal fare evasion and skimming, and realizing revenues from fare structures that reflect time of day and distance traveled.

The participating transit authorities, with technical assistance from TSC, have succeeded in developing uniform assessment methods including specific definitions of failure, reliability, maintainability, and system availability.

An important aspect of the Fare Collection Reliability Project was the development of a model to predict the impact and cost of proposed fare collection systems. Users can do sensitivity analyses and trade-off studies in order to evaluate specific alternatives at the design stage. The modeling activity was completed in 1984. Applications symposia for transit authorities are planned.

Transit authorities on the APTA Liaison Board have identified needed hardware improvements and have developed proposals for research grants in the areas identified. At the end of Fiscal Year 1983, eight grants using Section 6 and Section 3(a)(1)(C) Technology Introduction Program funds had been awarded totaling $1,750,000. Two of these projects are complete.

As one example, a high reliability ticket vendor was developed by PATCO under an UMTA grant. The prototype has achieved reliability improvements by a factor of three in operational tests. Several fare collection equipment suppliers have expressed interest in obtaining the design to build and market the PATCO-developed ticket vendor to other U.S. transit systems.

Another example is an improved pass reader system that was developed under a grant to the Chicago Transit Authority. All the transit systems involved in the STARS Project have expressed particular interest in a pass reader system. Such a system offers advantages of relieving station attendant workloads, reducing internal and external fraud, improving cash flow, minimizing the number of cash transactions, and providing a means for obtaining accurate data on passenger flow and revenue.

Under another UMTA grant to the Regional Transportation Authority, the Illinois Central Gulf Railroad is working to improve the reliability of its bill acceptor. To date, design enhancements have led to substantial improvements during operational tests.

## Bibliography

"Automatic Fare Collection Equipment Reliability and Maintainability Assessment Plan for Urban Rail Transit Properties," Automated Services, Inc., Final Report, March 1981, U.S. DOT Report No. UMTA-MA-06-0025-81-1, PB-83-208-066.

"Overview of Rail Transit Fare Collection," Jet Propulsion Laboratory, Final Report, August 1980, U.S. DOT Report No. UMTA-CA-06-0116-80-1, PB-81-182-578.

"Description and Evaluation of the MBTA Magnetic Card Fare Collection System," Dynatrend, Inc., Final Report, July 1982, U.S. DOT Report No. UMTA-MA-06-0025-81-2, DOT-TSC-UMTA-81-42, PB-83-156-596.

"Performance Assessment Methods and Results for Transit Automatic Fare Collection Equipment," Input Output Computer Services, Inc., Final Report, October 1983, U.S. DOT Report No. UMTA-MA-06-0025-83-9, PB-84-122-522.

"Assessment of High Reliability Ticket Vendor Developed by PATCO," Dynatrend, Inc., Final Report, September 1983, U.S. DOT Report No. UMTA-MA-06-0025-83-8.

"Status Report on DOT's Fare Collection Project," Transportation Systems Center, and Port Authority of New York and New Jersey, prepared for American Public Transit Association 1982 Rapid Transit Conference, Cleveland, Ohio, June 14-17, 1982, U.S. DOT Report No. UM204-PP-82-5.

"Assessment of a New Type of Coin Acceptor," Transportation Systems Center, Office of Systems Assessment, Final Report, April 1983, U.S. DOT Report No. UMTA-MA-06-0025-83-5, DOT-TSC-UMTA-83-17, PB-83-218-867.

"Rail Transit System Maintenance Practices for Automatic Fare Collection Equipment," Transportation Systems Center, April 1983.

"An Assessment of Automatic Fare Collection Equipment at Three European Transit Properties," Input Output Computer Services, Inc., Final Report, December 1982, U.S. DOT Report No. UMTA-MA-06-0025-82-5, DOT-TSC-UMTA-82-36, PB-83-174-44.

"Investigation of Five European Rail Transit Fare Collection Systems," Transportation Systems Center, and Metropolitan Atlanta Rapid Transit Authority, paper presented to Transportation Research Board, Committee on Rail Transit Systems, January 20, 1982, U.S. DOT Report No. DOT-TSC-UM204-PP-81-14.

"Evaluation of Electronic Registering Fareboxes," Booz-Allen & Hamilton, Inc., Final Report, January 1984, U.S. DOT Report No. UMTA-MA-06-0120-83-2, PB-84-156-652.

"Rail Transit Fare Collection: Policy and Technology Assessment," Jet Propulsion Laboratory, Final Report, December 1982, U.S. DOT Report No. UMTA-MA-06-0025-82-4, DOT-TSC-UMTA-82-49, PB-83-163-493.

"Assessment of WMATA's Automatic Fare Collection Equipment Performance," Input Output Computer Services, Inc., Final Report, March 1981, U.S. DOT Report No. UMTA-MA-06-0080-81-1, PB-832-084-462.

"An Assessment of Rail Automatic Fare Collection Equipment Performance at Three European Transit Properties," Transportation Systems Center, paper presented at Transportation Research Board 62nd Annual Meeting, January 1983, U.S. DOT Report No. DOT-TSC-UM204-PP-82-11.

# STARS Rail Car Door Improvement Project

Reliable door performance is a major concern for transit operation and maintenance. In addition to direct maintenance costs, faulty door operation can be dangerous and contributes to schedule delays.

One major study under the STARS Rail Car Door Improvement Project was to examine the door subsystem reliability of six transit systems (BART, CTA, NYCTA, WMATA, MBTA, MARTA) and compare the results to a reliability base line. All of the systems examined had experienced unscheduled maintenance substantially above the base line. Factors identified as contributing to these high levels were problems of design, maintenance, safety features, and human factors.

The major conclusions of this research study indicate that: car door design guidelines should be developed for the transit industry; a modular approach to equipment should be adopted; maintenance and training guidelines should be established; and site-specific improvement programs should be instituted. Thirteen other recommendations to improve rail car door performance were developed under the study, including such areas as weatherstripping and door status indicator light improvements.

## Bibliography

"U.S. Rapid Railcar Door Systems Assessment Report," Booz-Allen & Hamilton, Inc., Final Report, June 1982, U.S. DOT Report No. UMTA-IT-06-0242-82-1, PB-82-263-005-A06.

# STARS Energy Cost Reduction Project

Energy represents a significant portion of operating costs for urban rail transit systems. Energy costs at WMATA account for 15 to 17 percent of its operating costs. UMTA, through its STARS Energy Cost Reduction Project, is investigating a number of possible cost reduction strategies.

Rail car propulsion represents about two-thirds of the energy budget for rapid transit systems, and energy conservation research has therefore focused on this area. New technologies have been developed in the areas of regeneration and energy storage. Performance modifications, such as coasting, offer other areas for energy savings. Non-traction power use has also been investigated. Participation in utility rate-setting structures is another, heretofore largely neglected, avenue for cost reduction. Evaluation of the above strategies is not a simple matter and would be difficult and costly without recent developments in the area of modeling and simulation.

A Booz-Allen study performed for UMTA, entitled "Energy Use in Ground Transportation" (June, 1983), resulted in a useful handbook on energy consumption in automobile, bus and rail transit. The study identified factors influencing energy efficiency and use. The final report contains a useful bibliography.

## Modeling and Methodology

A large number of factors influence energy costs and benefits. General categories include specifications of electrical networks, train performance, and

track configuration, as well as rate structure information. Evaluation of conservation strategies therefore requires analysis of large amounts of data. Energy management models constitute a major analytical tool in this work.

A considerable amount of work in this area has been done by the Rail Systems Center (RSC) at Carnegie-Mellon University. This work has been applied in the STARS Energy Cost Reduction Project in several investigations: one exploring the cost effectiveness of energy storage devices and another examining cost reduction strategies in the WMATA system. A basic approach is to model and simulate a conservation strategy in the environment of a given rail system. The predicted results can then be tested against actual operational data in order to validate the model. In the WMATA study, predicted cost savings had less than three percent error when compared to energy audits.

Models vary in the validity of their predictions. In a study of the BART system for UMTA, Dr. Vilas Nene of TransTech International compared four industry-developed models in predicting energy use by BART transit cars both with and without regeneration. When tested against actual consumption, only some models predicted well, with errors as low as one-half percent. Similar accuracy can be expected when these models are applied to other transit authorities. This TransTech International study should assist operators of transit systems to select models for site specific energy use investigations.

## Energy Storage and Regeneration

An interesting development in energy conservation is the application of technology through which the kinetic energy produced in braking can be stored and regenerated. Storage systems use fly-wheels or batteries to store energy either on-board a train or at stationary facilities. Braking energy can also be used to generate power which is fed into the traction power system for use by trains on-line or fed into the public utility through substations. Work carried out by the RSC applied their model to compute the return on investment (ROI) for regenerative methods.

Studies show that energy savings achieved by the above methods are considerable. In the case of PATCO, line savings were: regeneration, 32 percent; wayside storage, 28 percent; and on-board storage, 25 percent. When costs are included, conservative estimates for return on investment are: on-board fly-wheel, 14 percent; on-board battery, negative; wayside fly-wheel, 15 percent; wayside battery, 10 percent; and regenerative substation, 23 percent.

Although these results are site specific, they do suggest that other transit authorities can profitably explore regeneration technology. The methodology presented provides the tools and guidelines (including the ROI computer model) by which such an investigation may be carried out.

## Subway Tunnel Energy System (STES)

Another possible method of energy saving is to draw upon the nearly constant temperature inside subway tunnels. This air can, theoretically, support air source heat pumps more economically than when outside air is used. During winter, when outside temperatures are substantially lower than those in tunnels, this process may reduce the cost of heating adjacent buildings. When outside temperatures are higher in summer, the process is reversed for cooling purposes. The City of Philadelphia, with a grant from UMTA, is studying the feasibility and economics of this energy conservation concept under the STES Project.

## Energy Cost Reduction at WMATA

An energy management model developed by the RSC has been applied to WMATA to evaluate alternate conservation strategies. The study found that regeneration produced the largest savings—17 to 22 percent depending on the regeneration system employed. Coasting is another promising strategy.

Load factor improvement involves reducing the number of cars per train during off-peak periods. This can provide a five percent energy savings as well as reduce car maintenance. Carefully managing the demand interval and location of use of catch-up during peak periods can save $1 million a year and reduce maintenance costs. Finally, the installation of mercury vapor lights in stations can result in savings similar to coasting. According to the RSC, payback periods for these strategies are less than three years.

Reduced use of escalators is not a promising option, nor are performance modifications in the form of top speed limitations and reduced acceleration.

Although the results of the WMATA study are site specific, the findings can be useful to rail systems elsewhere. The flexible design of the model and its validation at WMATA suggest that it is an important management tool, and the procedures followed in the application of the model offer insights for its further application. Furthermore, the results of the study suggest general orders of magnitude for conservation that might be expected from strategies applied to other systems.

## Energy Rate Structures

Energy costs are influenced by rate structures. The RSC study carried out for the STARS Energy Cost Reduction Project surveyed rate structures for ten systems: BART, CTA, GCRTA, MARTA, MBTA, NYCTA, PATCO, PATH, SEPTA, and WMATA. Rates and charges vary widely among transit authorities, ranging from a simple charge per KWH to much more elaborate structures which include differing measures of demand, levels, and charges for a utility's fixed costs. The Washington and New York systems are of special interest because they have extensively participated in the rate-setting process. WMATA efforts resulted in a $2.7 million savings in 1979-1980. The experiences of these two systems provide useful background information for other systems.

The study suggests that transit authorities could achieve favorable readjustments in rates through knowledgeable presentations, buttressed by cost-of-service studies and the use of expert witnesses. Suggested arguments for presentation at these meetings include the acknowledgement that rapid transit is a unique energy user, and the request for a separate customer class which takes into account these special characteristics.

## Bibliography

"Cost-Effectiveness Model Development for Energy Storage Devices in Rapid Transit Systems," Carnegie-Mellon University, Final Report, September 1980, U.S. DOT Report No. UMTA-PA-06-0059-81-1, PB-82-101-163.

"Comparative Evaluation of Energy Management Models for Transit Systems," TransTech International, Inc., Final Report, February 1984, U.S. DOT Report No. UMTA-MA-06-0025-83-12, DOT-TSC-UMTA-83-52, PB-84-182-070-A18.

"Energy Cost Reduction Study of the Washington Metropolitan Area Transit Authority Metrorail System - Volume I," Carnegie-Mellon University, Final Report, May 1982, U.S. DOT Report No. UMTA-DC-06-0315-82-1, PB-83-115-378.

"Energy Cost Reduction Study of the Washington Metropolitan Area Transit Authority Metrorail System - Volume II: Appendices," Carnegie-Mellon University, Final Report, May 1982, U.S. DOT Report No. UMTA-DC-06-0315-82-2, PB-83-115-386.

"Power Rate Structure Aspects of Energy Cost for Rapid Transit Systems," Carnegie-Mellon University, Final Report, June 1982, U.S. DOT Report No. UMTA-PA-06-0059-82-1, PB-82-260-118.

"Energy Use in Ground Transportation," Booz-Allen & Hamilton, Inc., Final Report, June 1983, U.S. DOT Report No. UMTA-MA-06-0153-83-2, DOT-TSC-UMTA-83-12, PB-84-131-713.

# STARS Automatic Train Operation (ATO) and Automatic Train Control (ATC) Project

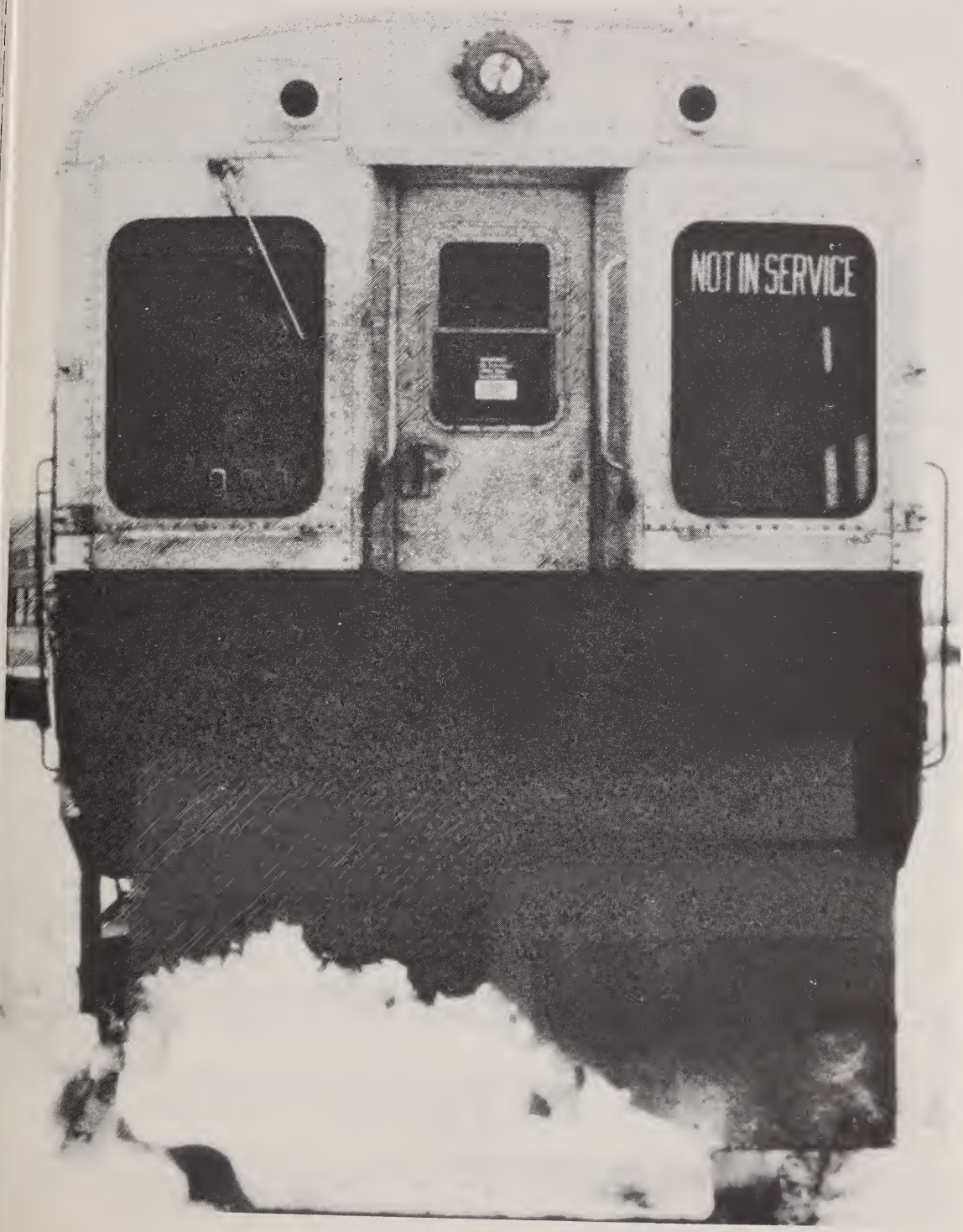
The goal of this cooperative Project between industry and government is to improve the safety and efficiency of rail transit systems by matching the level of ATO/ATC (automation) to the specific needs of a transit system. This Project is expected to produce guidelines and criteria by which transit management can evaluate different levels of automation for new transit systems or for the rehabilitation of existing systems. Efforts were initiated to assess costs, reliability, maintainability and performance of current and future signal and control systems. Concurrently, studies are underway to review the state-of-the-art of microprocessor-based ATO/ATC equipment and to study the role of human factors in control and communications including the implications of removing the operator from the train. Other studies will address safety issues related to microprocessors. Guidelines for safety analyses of microprocessor-based circuits will be produced.

# STARS Train-Line Multiplexing Project

Transit operators have identified a need to reduce the number of train-line circuits and improve the reliability of vehicle couplers by reducing the number of electrical contacts. Toward this end, UMTA has awarded a grant to Washington Metropolitan Area Transit Authority to study the feasibility of multiplexing train-line signals and recording them in real time using a solid-state, microprocessor-controlled, non-volatile memory. Only data on equipment that is operating out-of-tolerance will be recorded in the memory for future analysis to assist in improving maintenance planning. Results from the project will be applicable to all rail transit systems. The final report, to be issued in 1984, will include the technical findings of this project.

## Bibliography

"Maintenance/Diagnostic Train-Line Multiplexing System," Washington Metropolitan Area Transit Authority, Project No. DC-06-0443, Final Report, (Forthcoming).


NOT IN SERVICE

# STARS Winterization Project

Cold weather problems arise in a random fashion. The severe winters of 1977-1979, for example, caused major operating problems and shut-downs for many transit systems. In response, the United States Congress authorized the Cold Weather Transit Technology (CWTT) Program to improve transit operations under the severe weather conditions of ice, snow and cold. UMTA implemented this Program through a grant to the University of Notre Dame with the Vought Corporation as the principal contractor.

The 26 volumes produced under the CWTT Program present analyses of the problems of cold weather operations and the development of countermeasures. The problems addressed include loss of vehicle traction, loss of communication and/or power, and system malfunction through vehicle and wayside equipment freeze up. The countermeasures developed include new technologies and contingency plans, with special attention focused on deicing and snow removal.

## Bibliography


"Rail Transit Winterization Technology and Systems Operations Study," Alexander Kusko, Inc., Final Report, September 1980, U.S. DOT Report No. UMTA-MA-06-0025-80-9, DOT-TSC-UMTA-80-34, PB-81-122-905.

"Specification Guide for Snow Removal Vehicles for Rail Transit Systems," Alexander Kusko, Inc., Final Report, November 1983, PB-84-146-398-A08.

"Cold Weather Transit Technology Program, Volume 1: Executive Summary," Vought Corporation, Final Report, 1982, U.S. DOT Report No. UMTA-IN-06-0009-82-1, PB-83-785-33.

"Cold Weather Transit Technology Program, Volume 2: Physics of Ice and Snow at the Interface with Transitway Surface," Vought Corporation, Final Report, 1982, U.S. DOT Report No. UMTA-IN-06-0009-82-2, PB-83-162-438.

"Cold Weather Transit Technology Program, Volume 3: Characteristics of Ice and Snow at the Interface with Transit Vehicle Surfaces," Vought Corporation, Final Report, 1982, U.S. DOT Report No. UMTA-IN-06-0009-82-3, PB-83-159-871.

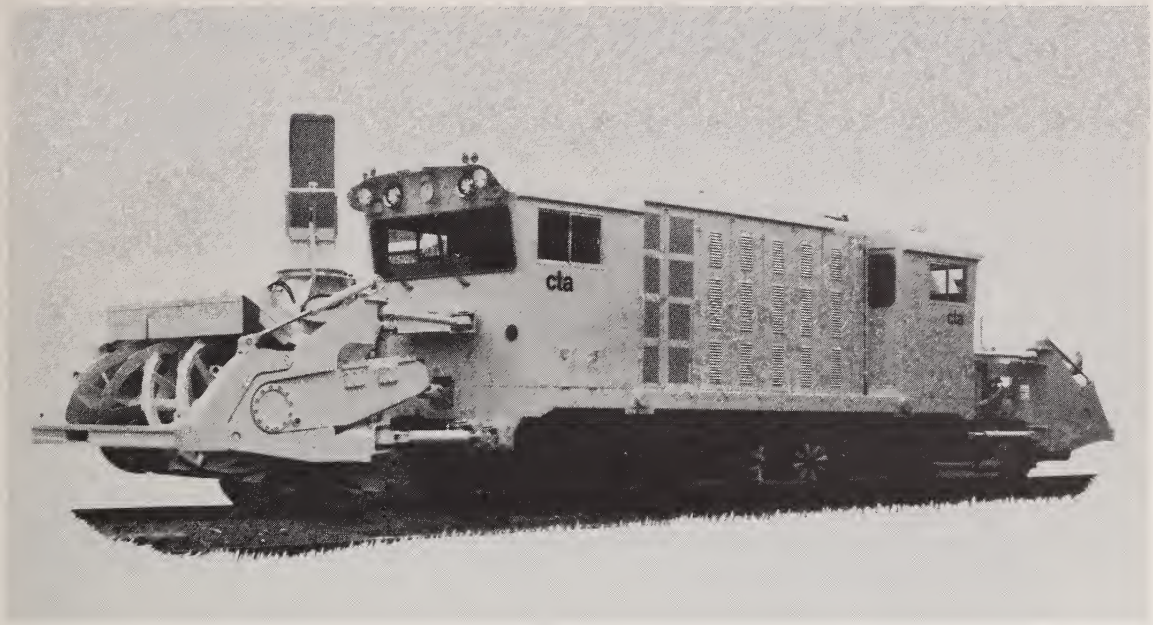
"Cold Weather Transit Technology Program, Volume 4: Advanced Countermeasures for Combatting Ice and Snow Problems," Vought Corporation, Final Report, 1982, U.S. DOT Report No. UMTA-IN-06-0009-82-4, PB-83-162-099.

"Cold Weather Transit Technology Program, Volume 5: Transitway Design Concepts for Improving System Performance Under Cold Weather Conditions," Vought Corporation, Final Report, 1982, U.S. DOT Report No. UMTA-IN-06-0009-82-5, PB-83-128-736.

"Cold Weather Transit Technology Program, Volume 6: Planning for a National CWTT Research Center," Vought Corporation, Final Report, 1982, U.S. DOT Report No. UMTA-IN-06-0009-82-6, PB-83-134-684.

"Cold Weather Transit Technology Program, Volume 7: Lightweight Transit Vehicle Traction Performance on Ice and Snow," Vought Corporation, Final Report, 1982, U.S. DOT Report No. UMTA-IN-06-0009-82-7, PB-82-256-488.

"Cold Weather Transit Technology Program, Volume 8: Development of Transitway Countermeasures for Combatting Ice and Snow Problems," Vought Corporation, Final Report, April 1982, U.S. DOT Report No. UMTA-IN-06-0009-82-8, PB-82-256-496.




"Cold Weather Transit Technology Program, Volume 9: Development of Vehicle Countermeasures for Combatting Ice and Snow," Vought Corporation, Final Report, 1982, U.S. DOT Report No. UMTA-IN-06-0009-82-9, PB-82-257-387.

"Cold Weather Transit Technology Program, Volume 1: Executive Summary," University of Notre Dame, Final Report, 1984, U.S. DOT Report No. UMTA-IN-06-0009-83-1, PB-84-191-618-A04.

"Cold Weather Transit Technology Program, Volume 2: Transit Systems Survey," University of Notre Dame, Final Report, 1983, U.S. DOT Report No. UMTA-IN-06-0009-83-2, PB-83-219-527.

"Cold Weather Transit Technology Program, Volume 3: Investigation of the High Incidence of Rail Pull Apart on Continuous Welded Rail," University of Notre Dame, Final Report, 1983, U.S. DOT Report No. UMTA-IN-06-0009-83-3, PB-83-118-263.

"Cold Weather Transit Technology Program, Volume 4: Investigation of Rail Heater Reliability," University of Notre Dame, Final Report, 1983, U.S. DOT Report No. UMTA-IN-06-0009-83-4, PB-84-155-381.

"Cold Weather Transit Technology Program, Volume 5: Third Rail Deicing System Research," University of Notre Dame, Final Report, 1983, U.S. DOT Report No. UMTA-IN-06-0009-83-5, PB-84-159-987.

"Cold Weather Transit Technology Program, Volume 6: Winterization of Self-Ventilated Traction Motors on Rail Transit Vehicles," University of Notre Dame, Final Report, 1983, U.S. DOT Report No. UMTA-IN-06-0009-83-6, PB-84-136-753.

"Cold Weather Transit Technology Program, Volume 7: Track Switch Deicing System Research," University of Notre Dame, Final Report, 1983, U.S. DOT Report No. UMTA-IN-06-0009-83-7, PB-84-155-407.

"Cold Weather Transit Technology Program, Volume 8: Bus Wheel Housing Deicing Project," University of Notre Dame, Final Report, 1983, U.S. DOT Report No. UMTA-IN-06-0009-83-8, PB-84-137-462.

"Cold Weather Transit Technology Program, Volume 9: Ice Formation Precursor Research," University of Notre Dame, Final Report, 1983, U.S. DOT Report No. UMTA-IN-06-0009-83-9.

"Cold Weather Transit Technology Program, Volume 10: Composite Rail and Associated Surface Phenomenon," University of Notre Dame, Final Report, 1983, U.S. DOT Report No. UMTA-IN-06-0009-83-10.

"Cold Weather Transit Technology Program, Volume 11: Prediction of Ice Formation," University of Notre Dame, Final Report, 1983, U.S. DOT Report No. UMTA-IN-06-0009-83-11, PB-84-159-995.

"Cold Weather Transit Technology Program, Volume 12: Study of Laser Deicing," University of Notre Dame, Final Report, 1984, U.S. DOT Report No. UMTA-IN-06-0009-83-12, PB-84-192-400-A04.

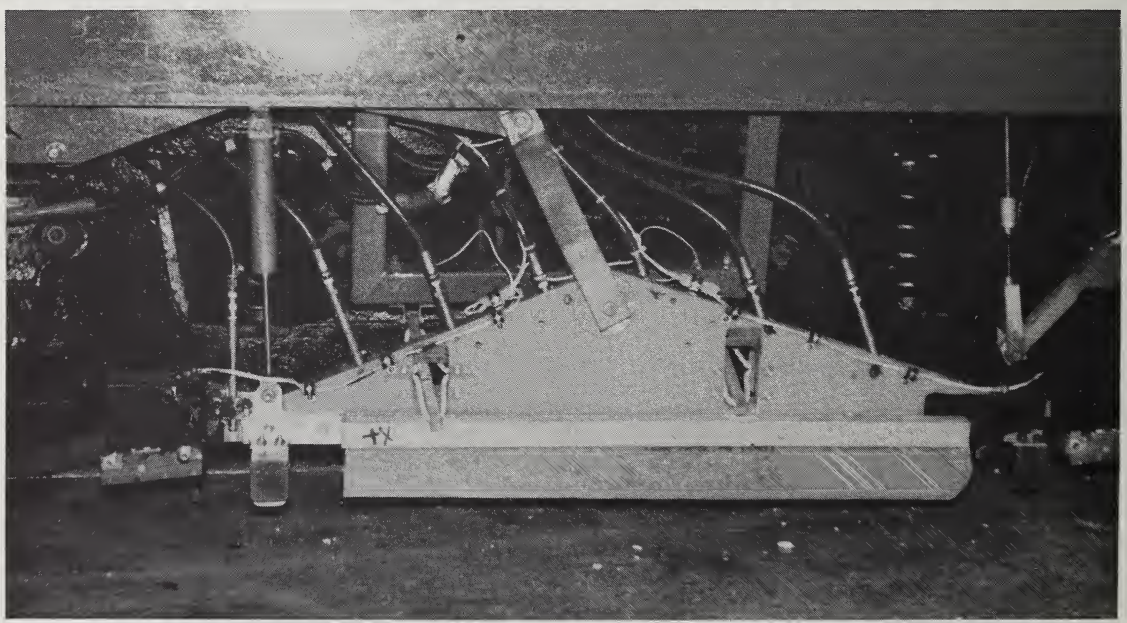
"Cold Weather Transit Technology Program, Volume 13: Microwave Coupling to Ice/Metal Structures," University of Notre Dame, Final Report, August 1983, U.S. DOT Report No. UMTA-IN-06-0009-83-13, PB-83-263-178.

"Cold Weather Transit Technology Program, Volume 14: RF Coupling to Complex Geometric Shapes," University of Notre Dame, Final Report, 1983, U.S. DOT Report No. UMTA-IN-06-0009-83-14.

"Cold Weather Transit Technology Program, Volume 15: Modelling and Analyses of Thermal Conduction in Severe Ice Melting Problems," University of Notre Dame, Final Report, 1983, U.S. DOT Report No. UMTA-IN-06-0009-83-15, PB-84-138-957.

"Cold Weather Transit Technology Program, Volume 16: Modelling of Ice Fracture," University of Notre Dame, Final Report, 1983, U.S. DOT Report No. UMTA-IN-06-0009-83-16, PB-84-155-399.

"Cold Weather Transit Technology Program, Volume 17: Tasks Status and Continuation Recommendations," University of Notre Dame, Final Report, 1983, U.S. DOT Report No. UMTA-IN-06-0009-83-17.



# STARS Escalator Design and Maintenance Project

The convenience provided by rail transit escalators is not inexpensive. In 1979 prices, capital costs were $5,000/foot of escalator length. Transit authorities have experienced equipment failures which are major contributors to an annual maintenance cost of approximately $6,000 (1979 prices) per escalator. The high failure rates are in part a reflection of the fact that the escalators in use by most transit authorities were not designed to meet the severe demands of public transit environments.

The California Institute of Technology's Jet Propulsion Laboratory conducted two studies on escalators under the STARS Program. The first study examined recent innovations in escalator design including the modular design concept. This type of construction reduces capital costs where high-rise escalators are required, although maintenance requirements may be higher. The study recommended long-term maintenance contracts both to control costs and to stimulate design improvements.

The second study examined three design features: mat operation, which provides service on demand; two-speed operation; and extended flat steps. In addition to costs, traffic flow and safety were considered in the conclusions. Mat operation was shown to save energy, and dual-speed systems were found to be effective in handling peak loads.

Both investigations developed suggestions for research and development ahd have useful reference lists.

## Bibliography

"Escalator Design Features Evaluation," Jet Propulsion Laboratory, Final Report, May 1982, U.S. DOT Report No. UMTA-MA-06-0025-81-3, DOT-TSC-UMTA-81-66, PB-82-258-716.

"Overview of Escalator Applications in Rail Transit," Jet Propulsion Laboratory, Final Report, July 1980, U.S. DOT Report No. UMTA-CA-06-0116-80-2, PB-81-128-720.

"Escalator Reliability Evaluation: A Comparison of Several Transit Properties," Alexander Kusko, Inc., Final Report, February 1979, U.S. DOT Report No. DOT-TSC-1180-76.

# National Technical Information Service

Many of the reports listed in the bibliographies in this Digest can be obtained from the National Technical Information Service (NTIS). NTIS is the central source for the public sale of U.S. Government-sponsored research reports, including research sponsored by the U.S. Department of Transportation.

Documents available from NTIS are issued a "PB" number for ordering purposes. Where available, NTIS PB numbers have been provided for the documents included in the bibliographies of this Digest.

An NTIS Order Form is provided at the end of this document. Additional information on the products and services available through NTIS can be obtained by writing:

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161

NTIS will fill orders for publications in stock within three days. Documents which must be reprinted will be mailed within two weeks. Rush order service is available with an additional surcharge on each document ordered. Most NTIS reports are also available on microfiche. Orders can be placed by calling (703)487-4650 for regular orders, or (703)487-4700 for rush orders. Orders can also be placed in writing.

The easiest way to order documents is to establish an NTIS Deposit Account with a minimum deposit of $25. The purchase price of documents ordered is deducted from the deposit account. Deposit Account Statements are provided by NTIS to indicate activity on the account on a monthly basis.

# Transit Research Information Center

The Transit Research Information Center (TRIC) is another repository for UMTA reports. TRIC is located within UMTA's Office of Technical Assistance. TRIC maintains a full collection of all UMTA-sponsored reports and provides, upon request, a one-page technical abstract of any report. It is also possible to request abstracts of all UMTA reports related to a specific topic.

Through 1980, TRIC published annual compendiums of reports pertaining to work performed under UMTA R&D grants and contracts, technical studies grants, and university research and training grants in a document entitled, "Urban Mass Transportation Abstracts." These Abstracts include condensed descriptions of UMTA reports available for purchase through NTIS. Each volume is indexed by title, individual and corporate author, geographic area, project number and subject. Volume I (1972) through Volume VII (1980) of these reports are available from NTIS.

Since 1980 this information has been transmitted to the Urban Mass Transportation Information System (UMTRIS) database, administered by the Transportation Research Board (TRB).

UMTRIS first published the "Urban Mass Transportation Abstracts - Cumulative Bibliography 1974-1980" in April 1982. It includes the UMTA reports submitted by TRIC as well as research reports from other sources. Installments of the bibliography, available from TRB, are published semi-annually. For information pertaining to the UMTRIS database, contact:

Transportation Research Board
2101 Constitution Avenue, N.W.
Washington, DC 20418
(202)334-3263

The bimonthly edition of UMTA Abstracts, listing the most recent UMTA reports, is still issued through TRIC. A cumulative retrieval term index appears at the end of every third bimonthly abstract. These documents may be obtained from:

U.S. Department of Transportation
Urban Mass Transportation Administration
Office of Technical Assistance
Transit Research Information Center
400 Seventh Street, S.W.
Washington, DC 20590
(202)426-9157

# Transportation Systems Center

Reports prepared for UMTA by the Transportation Systems Center (TSC) in Cambridge, Massachusetts, are free upon request while copies are available. When supplies are exhausted, reprints may be ordered through NTIS, or in some cases from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

TSC has two toll-free numbers to call for current information. These are:

(800)842-1151 (within Massachusetts)
(800)225-1612 (outside Massachusetts)

Documents may be ordered by title from:

U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, MA 02142

# UMTA Public Information Service

UMTA's Office of Public Affairs conducts an active public information program. Press releases and brochures describing various UMTA programs and policies are available upon request from:

U.S. Department of Transportation
Urban Mass Transportation Administration
Office of Public Affairs
400 Seventh Street, S.W.
Washington, DC 20590

**MAIL ORDER TO:**

NTIS®

**National Technical Information Service**
**U.S. DEPARTMENT OF COMMERCE**
Springfield, Va. 22161
(703) 487-4650 TELEX 89-9405

**For DDC Users Only**

DDC User Code _____

Contract Number _____

(last 6 characters only) _____

**Treasury Agency Location Code**
For Government Users
(who report on SF-224)
(8 digit)

☐☐ ☐☐ ☐☐☐☐

Date _____

**SHIP TO:**

Name _____

Organization _____

Address _____

City, State, ZIP _____

Attention: _____

**METHOD OF PAYMENT**

☐ Charge my NTIS deposit account no. _____

☐ Purchase order no. _____

☐ Check enclosed for $ _____

☐ Charge to my American Express ☐ Visa ☐ Master Charge ☐

Account no. _____

Card expiration date _____

Signature _____

(Required to validate order)

| ITEM NUMBER | Quantity | | | UNIT** PRICE | PRIORITY* MAIL SERVICES | TOTAL PRICE |
|---|---|---|---|---|---|---|
| | Paper Copy | Micro-fiche | Other (specify) | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

* Add $3 per item for First Class Delivery in North America;
Add $4 for each paper copy Airmail Delivery outside North America.
** ALL PRICES SUBJECT TO CHANGE.

**Enter Grand Total** $

NTIS®

# DEPOSIT ACCOUNT APPLICATION

☐ Here is my check to NTIS for $ _____

Charge to my ☐ American Express ☐ VISA ☐ MasterCard.

Account No. _____

Expiration Date _____ Interbank no. _____ (if applicable)

Signature _____ (required to validate order)

FOR NTIS USE ONLY

DA No. _____ Code _____

Cert. No. _____

Check No. _____

Schedule No. _____

Certifier _____

Order Cards _____

Name _____

Company _____

Street _____

City, State, ZIP _____

Date _____ Signature _____

Telephone Number _____

NTIS®

DEPOSIT ACCOUNT APPLICATION

☐ Here is my check to NTIS for $ _____

Charge to my ☐ American Express ☐ VISA ☐ MasterCard.

Account No. _____

Expiration Date _____ Interbank no. _____ (if applicable)

Signature _____ (required to validate order)

FOR NTIS USE ONLY

DA No. _____ Code _____

Cert. No. _____

Check No. _____

Schedule No. _____

Certifier _____

Order Cards _____

Name _____

Company _____

Street _____

City, State, ZIP _____

Date _____ Signature _____

Telephone Number _____

U.S. Department
of Transportation

**Urban Mass
Transportation
Administration**

400 Seventh St., S. W.
Washington, DC 20590

Official Business
Penalty for Private Use $300

Postage and Fees Paid
Urban Mass Transportation
Administration
DOT 511