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# URBAN RAIL SUPPORTING TECHNOLOGY PROGRAM FISCAL YEAR 1973 YEAR END SUMMARY

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FINAL REPORT



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16. Abstract

The Urban Rail Supporting Technology Program, being conducted for the Department of Transportation Urban Mass Transportation Administration (UMTA) is described for the 1973 Fiscal Year period. Major areas covered include program management, technical support and application engineering, facilities development, test and evaluation and technology development. Specific technical discussion covers track geometry measurement, UMTA facilities development at the High Speed Ground Test Center at Pueblo, Colorado, rail car test and evaluation, especially of the State-of-the-Art-Car (SOAC) and of Boston's MBTA Green Line, instrumentation for data acquisition and processing, noise abatement methodology, and tunneling and crash-worthiness studies.

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## PREFACE

The Transportation Systems Center (TSC) has been designated as Systems Manager for the Urban Rail Supporting Technology Program by the Urban Mass Transportation Administration (UMTA) Office of Research and Development. The TSC efforts in this program contribute to advancing urban rail technology and to improving the operational capability of rail transit properties. While TSC efforts emphasize rapid transit applications, the program also provides important benefits to commuter rail and light rail systems, as well as to other forms of transportation-related activity.

This Year End Summary presents Fiscal Year 1973 accomplishments, and provides an outline of the work to be undertaken in the future. Prior accomplishments are reported in the summary for Fiscal Year 1972.

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# 1. INTRODUCTION

## 1.1 PROGRAM AND MANAGEMENT SUMMARY

The rapid, commuter, and light rail systems in operation in this country carry more than two billion passengers each year. Additionally, new systems are being planned and constructed and existing systems are being expanded. Further, large parts of existing systems are in various stages of deterioration and must be upgraded. A major portion of the cost of upgrading the existing systems and constructing new rail systems will be borne by the Federal Government through the Urban Mass Transportation Administration Capital Assistance Program. Accordingly, the UMTA Office of Research and Development, Rail Programs Branch, has undertaken a comprehensive research, development and evaluation program to provide engineering data that will permit the transit properties to make most effective use of the UMTA funds being provided. A Project Plan Agreement defines the role of TSC as Program Manager for the necessary technical support in this effort.

The Urban Rail Supporting Technology Program is a goal-oriented program of R&D directed toward the systematic improvement and evolutionary development of rail system technology. In concert with UMTA and with the cooperation of the transit industry, primary system and technology objectives have been identified and priorities established; new and existing technology and methods are being critically evaluated; and applicable new technology will be recommended for proof-of-concept.

Management of these wide ranging but related activities is accomplished by organizing the program into five subprograms, or tasks. The details of FY-73 accomplishments are described by task in Sections 2 and 3. The scope of the five tasks is summarized below:

Task I - TSC Program Management - provide the overall program technical plans, and engineering direction; establish resource requirements, industry interfaces, test and demonstration schedules; assess accomplishments and recommend implementation; report results.

Task II - Technical Support and Applications Engineering - furnish direct assistance to operating properties to establish overall operations and maintenance procedures, facilities, and equipment requirements, and to identify unique and composite transit industry problems; develop R&D projects for UMTA approval and implementation; support other UMTA system managers as directed; evaluate proposals. (In the FY-72 Year-End Summary Report, Test Vehicles and Instrumentation was reported as a major activity area. That work has reached a point of maturity such that Technical Support and Applications Engineering is a more appropriate task name.)*

Task III - Facilities Development - design, construct and operate the facilities and equipment necessary to conduct a comprehensive program of test and evaluation of urban rail cars and car subsystems, track structures and structural components, signal and power systems and train operation and control strategies; prepare associated documentation.

Task IV - Test and Evaluation - plan and conduct system testing and operational demonstrations; establish test objectives, constraints, criteria, and procedures; provide all necessary measurement instrumentation and data acquisition and processing equipment; prepare final reports and recommendations. (In the FY-72 Year-End Summary Report, this task was presented under the title Test-Program Development and Implementation. The present title more accurately reflects the full scope of the task.)

*UMTA-MA-06-0025-73-1, PB220846. Status Report Urban-Rail Supporting-Technology Program. FY72 Year End Summary.

Task V - Technology Development - carry out research, development, and evaluation tasks on UMTA-approved R&D projects directed toward the introduction of improved technology in Urban Rail System Applications. Presently-approved projects are in the areas of noise abatement and tunneling technology.

## 1.2 MAJOR ACCOMPLISHMENTS

### 1.2.1 Test Track Completion

A major milestone was reached during Fiscal Year 1973 with the completion of the 9.1 mile rail transit test track at the High Speed Ground Test Center. A double ceremony on October 12, 1972, featured the unveiling of the State-of-the-Art Cars (SOAC) at HSGTC as well as dedication of the UMTA track. The Secretary of Transportation, the Honorable John A. Volpe, was the principal speaker. Figures 1 through 3 show views of the ceremony. Figures 4 and 5 show the SOAC train. Completion of the oval represented culmination of the effort which began with one of the Urban Rail Program Group's first tasks in FY-71 -- design and construction of the first 2.4 mile section of track. The test capability at HSGTC was further improved during the past year by providing additional motive power, by the erection of a safety and security fence around the track oval, and by the completion of the Transit Maintenance Building.

The test facilities were immediately put to use for shakedown and acceptance tests, and for engineering tests on the SOAC cars. The engineering tests, based on TSC's General Vehicle Test Plan, GSP-064, were completed for the steel wheel configuration. The SOACs were then refitted with resilient wheels and further testing was initiated.

The development of the test capability at HSGTC will enhance the R&D programs of UMTA and the rail industry by facilitating test and evaluation of new and improved

Figure 1 Dedication Ceremony at the High Speed Ground Test Center: Senator Gordon Allott, Congressman Frank Evans, Secretary of Transportation John Volpe, and UMTA Administrator Carlos Villarreal.

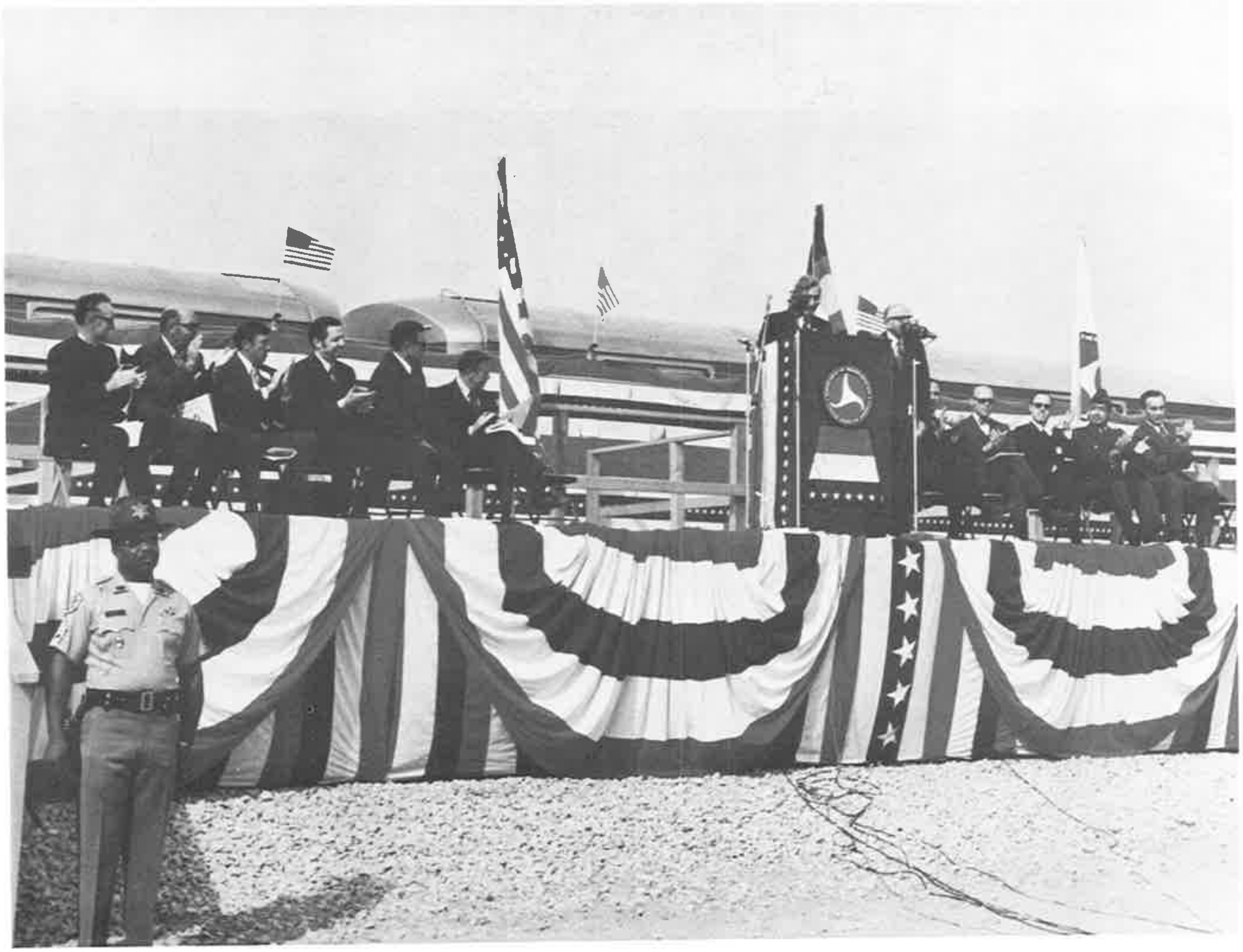


Figure 2  Dedication Ceremony at the High Speed Ground Test Center

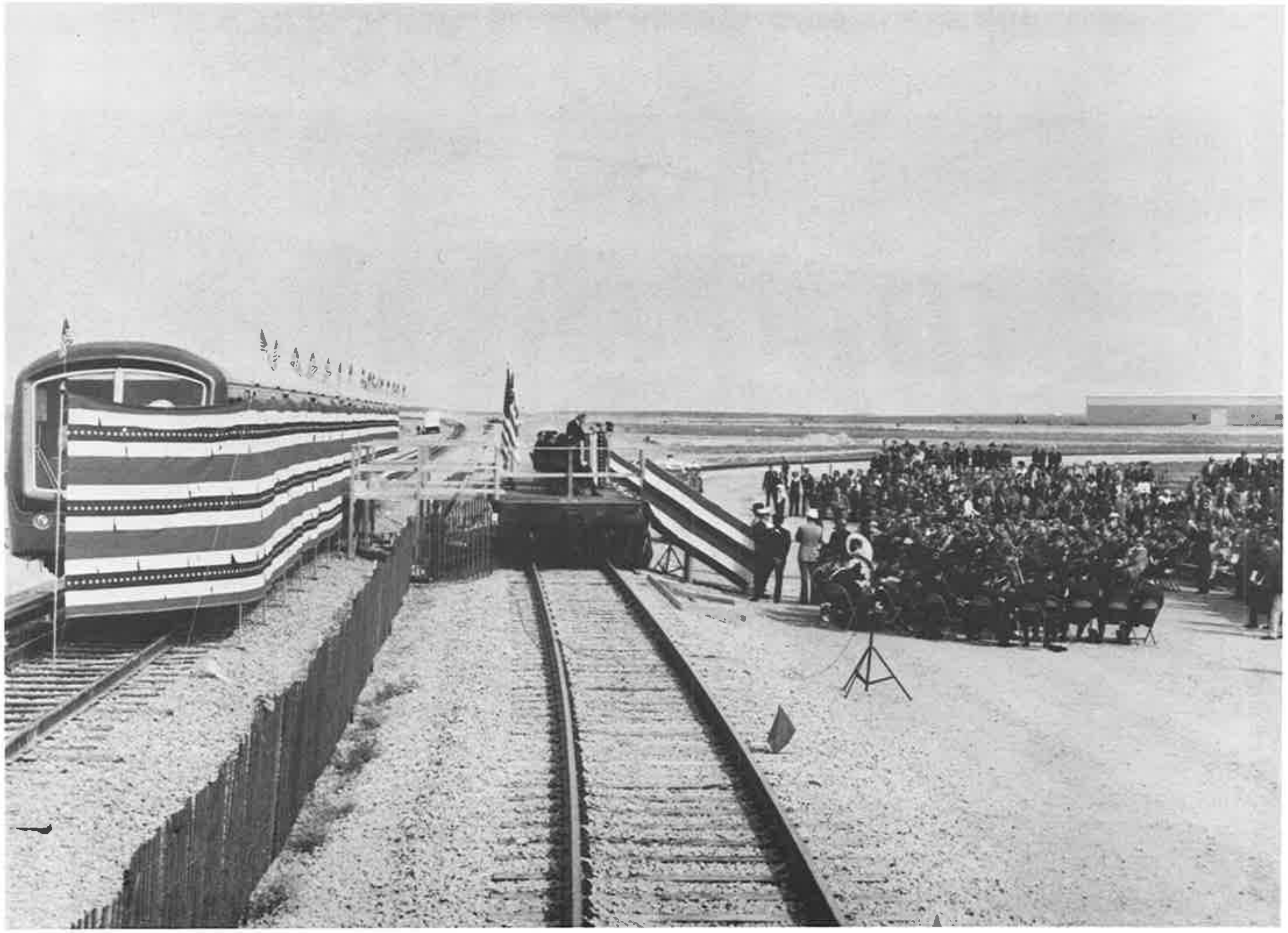


Figure 3  Dedication Ceremony at the High Speed Ground Test Center

Figure 4 State-of-the-Art Cars, Side View

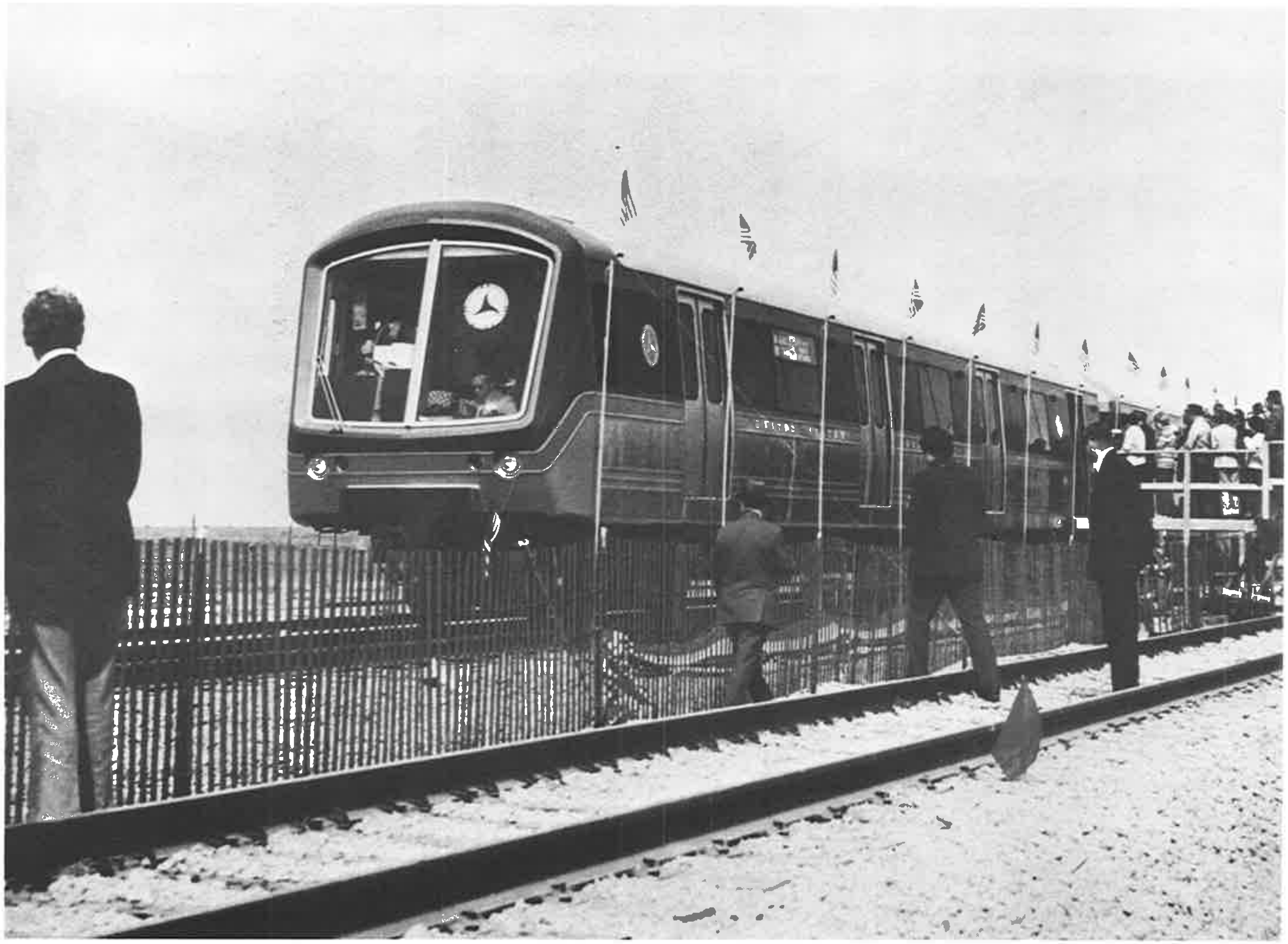


Figure 5  State-of-the-Art Cars, End View

equipment in an environment free of transit system schedules and operational problems.

In addition, the test facilities will allow more complete checkout of the initial units in each new vehicle procurement. The Standard Light Rail Vehicle, scheduled for checkout at HSGTC in late 1974, is being procured by San Francisco Muni and the Boston MBTA. The first vehicles will be evaluated at HSGTC to assure that the performance specifications are satisfied.

### 1.2.2 MBTA Track Geometry Measurement

In cooperation with the Massachusetts Bay Transportation Authority, a track geometry measurement system was installed on one truck of a PCC car. Data collected on the MBTA Green Line in Boston provided valuable information for establishing priorities in the $33 million track and roadbed rehabilitation program now underway.

### 1.2.3 Technology Improvement

Technology development programs in the areas of noise abatement and tunneling have gained momentum during the year. Program Implementation Plans have been completed. Two contracts have been awarded for work on noise abatement and three for tunneling. Noise assessment tests were conducted on the Boston MBTA lines, and plans are under way to carry out similar tests on other properties.

# 2. TECHNICAL DISCUSSION

## 2.1 TASK I - PROGRAM MANAGEMENT

The original FY-73 PPA task definitions were revised to reflect the inclusion of monitoring the State-of-the-Art Cars, the Energy Storage Cars, and the Advanced Concepts Train programs at UMTA's request, and the reduction in the contribution of FRA to the design and construction of the permanent power system for energizing the UMTA rapid transit test track. The original level of funding would have permitted the construction of one of the two substations required for the test track. Subsequently, the scope of the several tasks was reduced to reflect a lower level of funding; this new level precludes the construction of one substation with FY-73 money, but permits the initiation of procurement for the electrical hardware required.

Project Implementation Plans were submitted as follows:

| | |
|---|---|
| Noise Abatement (FY-73 - FY-77) | Dec. 1972 |
| Tunneling (FY-73 - FY-77) | Dec. 1972 |
| Safety (FY-73 - FY-77) | Dec. 1972 |
| Permanent Power | Mar. 1973 |

A draft of the FY-74 PPA was prepared, and was reviewed in June with UMTA management. As a result of these discussions, certain increases in the scope of the PPA were directed, thereby increasing the funding level. The PPA was revised to reflect these changes.

## 2.2 TASK II - TECHNICAL SUPPORT AND APPLICATIONS ENGINEERING

### 2.2.1 Track Geometry Measurement System

TSC conducted tests with prototype equipment on the New York City R-42 cars at the HSGTC at Pueblo in November 1971. This car is shown in Figure 6. Subsequent to Pueblo testing, TSC conducted tests of a prototype measurement system on the

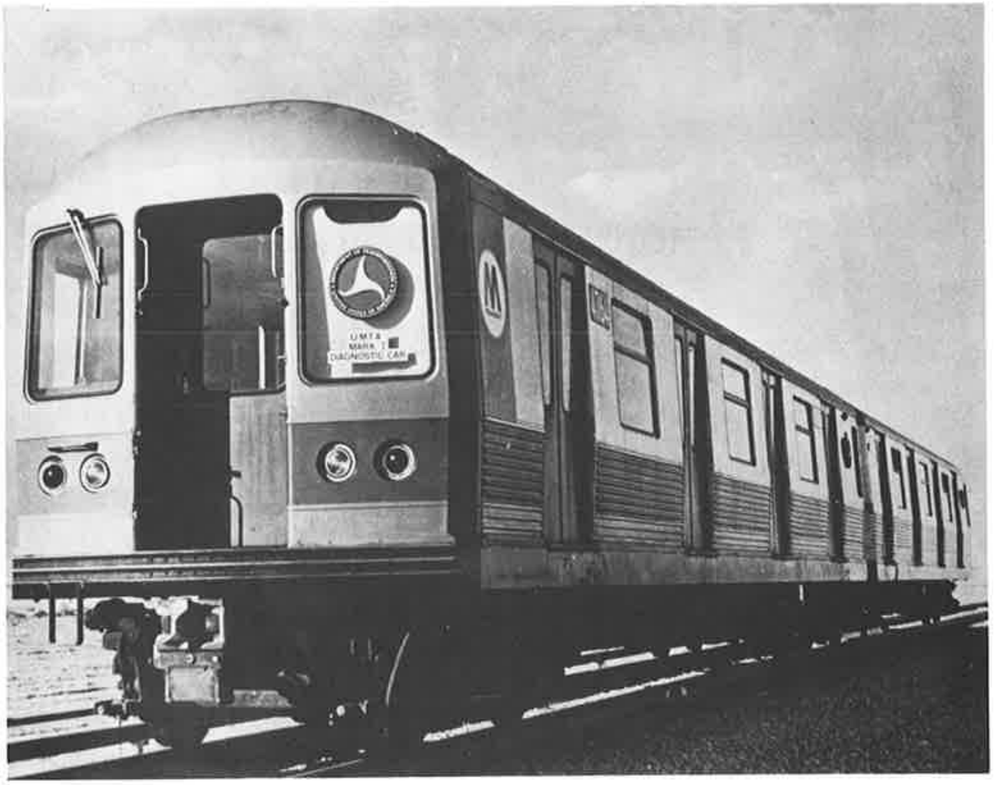


Figure 6 NYCTA R-42 Cars

Riverside Branch of the MBTA Green Line. The tests were designed to assist the MBTA in identifying critical track sections for improvement, and in addition, to provide data for the development of an advanced track geometry measurement system. Figure 7 shows the PCC truck in the TSC lab, instrumented and being readied for the tests. Figure 8 shows the instrumented truck assembled to a test car. The route tested, Riverside to Lechmere, is indicated in Figure 9.

The information gained from these tests was used to formulate the requirements and specifications for a two-step formally-advertised instrumentation system procurement, which was awarded to MB Associates, San Ramon, California in June 1973. The contract calls for delivery of two complete systems including sensors, signal conditioning equipment, and associated hardware for measuring track gage, alignment, profile, and cross level from a moving transit car. Acceptance and checkout will be accomplished at the Pueblo Test Track, using

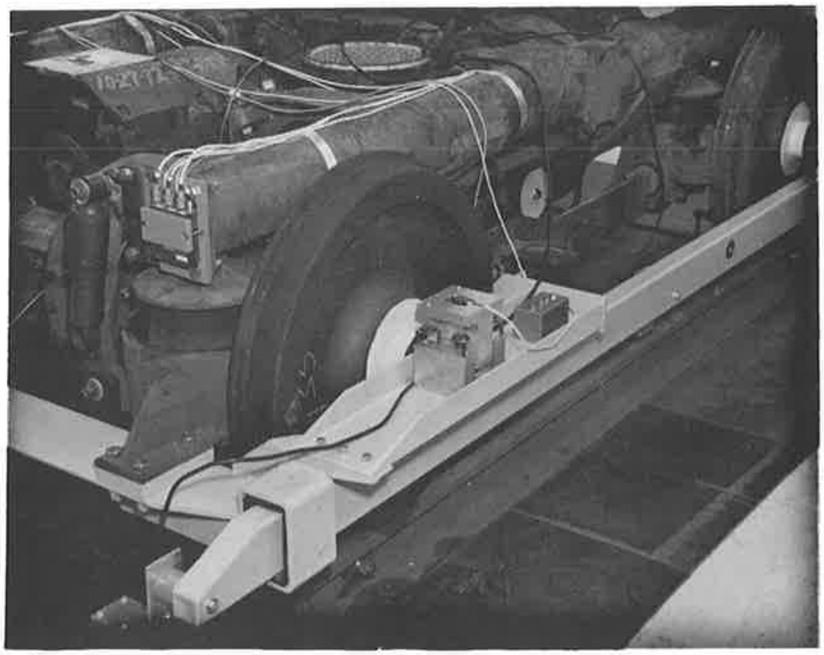


Figure 7 Instrumented Truck Used for MBTA Green Line Tests

Figure 8 Instrumented Truck Installed on MBTA Green Line Car

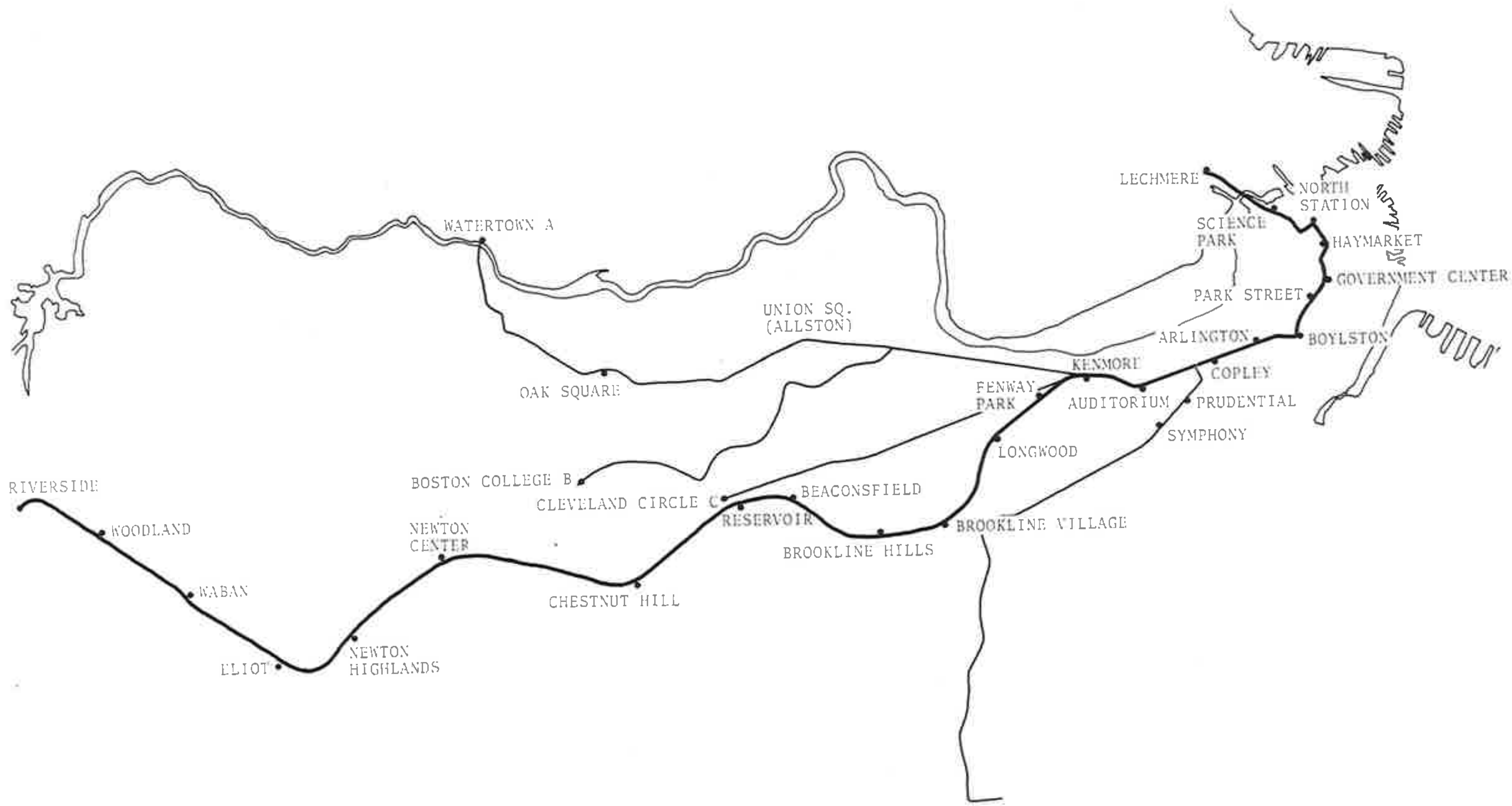



Figure 9 Map of MBTA Green Line

New York City R-42 cars and the UMTA State-of-the-Art Cars, ten months from contract initiation. After checkout, the systems will be used for demonstrations on the transit properties. The track geometry sensor project seeks to systematize the inspection of urban rail track and to derive the benefits which can result from comprehensive, orderly, and complete track inspection data.

### 2.2.2 AC Propulsion

In support of the UMTA-sponsored AC Propulsion Program with the Cleveland Transit System, TSC is preparing to evaluate the ride smoothness of the CTS/WABCO DC-AC propulsion cars presently operating on the Airport to Windermere transit line, Figure 10.

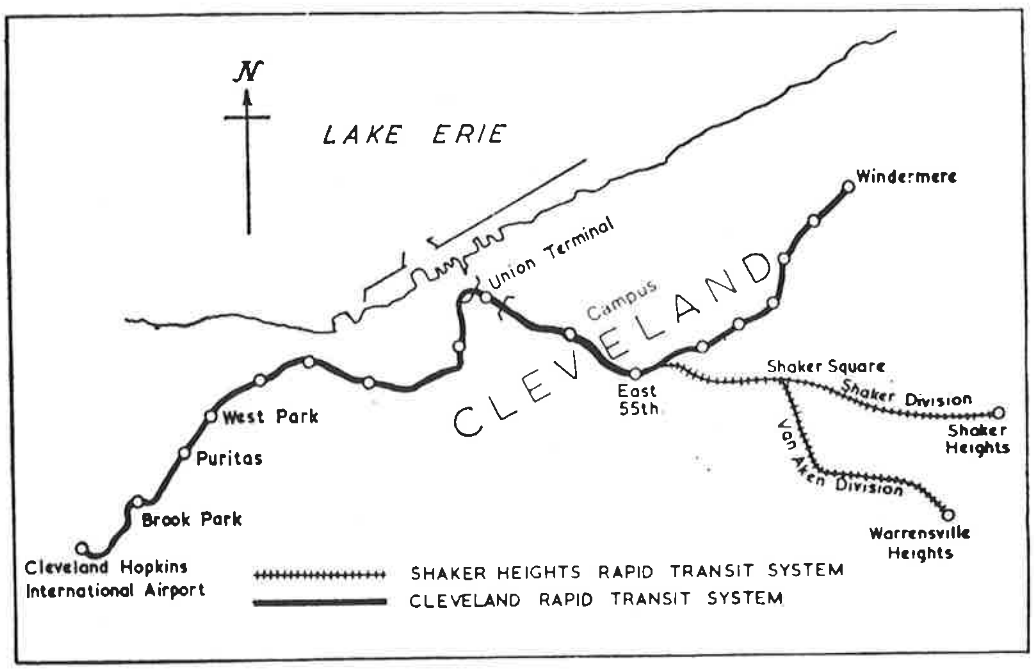



Figure 10 Map of the Cleveland Transit System Airport Line

The test procedures are described in DOT/TSC document GSP-064, General Vehicle Test Plans for Urban Rapid Transit Cars. A detailed test plan and system calibration procedure has been developed in preparation for the test program. Figure 11 shows the instrumentation that will be used on the Cleveland Car this coming September.

The objective is to obtain data which will allow for the determination of differences, if any, in ride smoothness between a regular CTS transit car and a recently refurbished car with a DC to AC converter system. The overall experimental test plan includes several tasks (i.e., determination of cost savings, reduced maintenance, passenger acceptance, etc.)

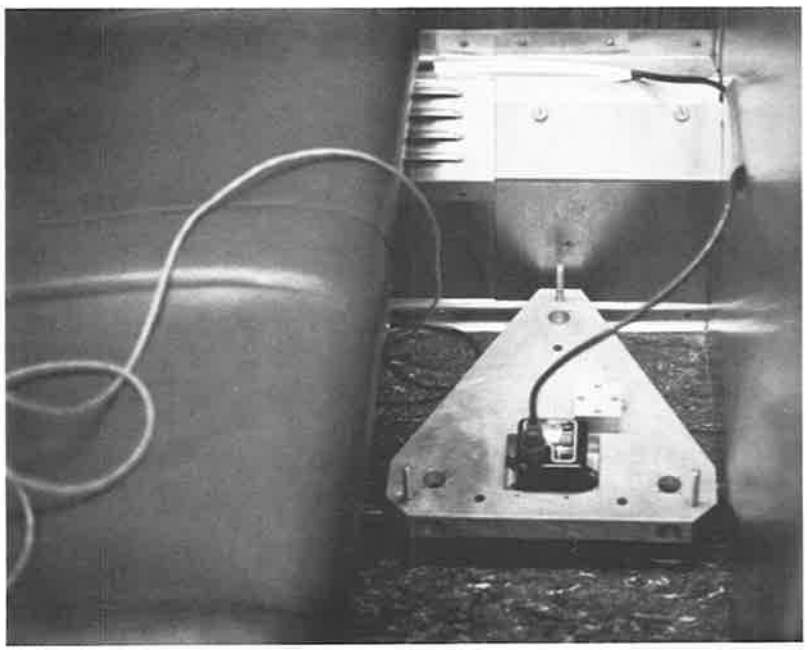
### 2.2.3 Energy Storage Car

In support of the Pueblo test phase for the Energy Storage Car Program, developed under an UMTA R&D grant, TSC has been coordinating activities between the New York Metropolitan Transportation Authority (MTA) (prime contractor) and Garrett AiResearch (sub-contractor).

To date, all hardware has been manufactured and laboratory half-car systems tests are being performed at the Torrance facility. The ESC testing is divided into three phases:

1. Torrance Phase
2. Pueblo Phase
3. N. Y. City Phase

Torrance Phase: This period consists of the developmental component tests performed by Garrett per their own specifications, and laboratory half-car systems tests. Static stress levels will be investigated by applying strain gages to certain areas of the car structure and equipment supports. The strain gages will be left on the cars for further testing at Pueblo.



Sensor Plate on Car Floor

Recording Equipment on Seat

Figure 11 Cleveland Ride Roughness Test Instrumentation Setup

NYCTA will inspect the equipment and the R-32 vehicles prior to installation of the equipment at Torrance.

Pueblo Phase: The track testing of the Energy Storage Cars will be divided into four parts:

1. Performance - Performance measurement of the ES Cars as conventional R-32 cars so as to assure that the ES Cars match the relevent performance of the R-32 against which they will be compared. Also, check trainline functions using the two NYCTA R-42 cars presently at HSGTC.

2. UMTA Baseline Tests - Contribute information to the data file on urban rail cars that are tested at Pueblo. Conduct tests consistent with GSP 064.

3. Duty Cycle - Compare performance (primarily energy consumption) with predictions from the computer simulation.

4. Auxiliary Tests -
   Noise and Vibration
   Operation with dead third rail
   Failure modes
   Stress levels

NYCTA Phase: NYCTA will perform shakedown and preliminary tests of the ES Cars as a two-car train, and will then join the two ES Cars to a conventional R-32 pair to conduct comparative testing as a four car train. Sensors in the draft gear will assure that all propulsion loads are being shared equally within the train. This measurement phase will be followed by a six-month period of testing in revenue service with consists of up to ten cars.

Present target dates are:

a. Shipment of the vehicles from Torrance to Pueblo - Fall 1973.

b. Six to nine weeks of testing at Pueblo.

c. Two months testing in New York.

d. Six months revenue evaluation testing in New York.

2.2.4 Safety - Crashworthiness, Existing Transit Vehicles

TSC is conducting analytical and experimental studies directed toward improved urban rail system safety.

One specific goal is to reduce the number of injuries that may result from the collision of two trains. Calspan Corporation (formerly Cornell Aeronautical Laboratory, Inc.) under contract to TSC, is conducting an 11-month study for assessment of the crashworthiness of existing urban rail vehicles.

The contract negotiations were completed just prior to the end of the fiscal year. The initial efforts will be focused on the analysis of existing rail vehicle crashworthiness.

These efforts will include:

1. Development of analytical tools to predict the passenger threat environment during collision.
2. Development of criteria for predicting passenger injury due to train collision.
3. Application of injury criteria and analytic models to predict passenger injuries resulting from collision of trains of existing car designs.
4. Definition of the applicability of existing static and dynamic testing to demonstration of vehicle crashworthiness (e.g., compression tests).
5. Preliminary design of impact absorption devices for urban rail vehicles.

6. Design studies of car structural configuration for improved impact energy management.

7. Development of engineering standards for urban rail car crashworthiness.

The contractural effort consists of 10 tasks. Figure 12 summarizes the major tasks of the Calspan program and indicates the flow of effort and the interactions between the individual tasks. The final product will be new engineering standards which will lead to new car designs that offer increased crash damage protection to the rider.

### 2.2.5 Technical Monitoring

Technical monitoring was performed on the Transit Development Corporation (TDC), Inc. subway ventilation study and for UMTA's engineering requirements for the utilization of the HSGTC Wheel/Rail Laboratory.

## 2.3 TASK III - FACILITIES DEVELOPMENT

The urban rail test facilities at HSGTC comprise the following: (a) the electrified urban rail test track, (b) the power system for energizing that track, (c) repair, maintenance and modification facilities, (d) the Rail Dynamics Laboratory, and (e) supporting services. Each of these five items is described in more detail in the following paragraphs.

### 2.3.1 UMTA Rail Transit Test Track

The remaining 6.71 miles of the 9.12 mile oval Rail Transit Test Track were completed, with the exception of rail grinding, in September 1972. Checkout of the track was accomplished on September 8, using locomotive DOT-001 and the two NYCTA R-42 subway cars. The track was dedicated on October 12, together with the unveiling of the two SOAC's, in public ceremonies attended by numerous dignitaries. Grinding of the running rails was accomplished on December 11. The track which

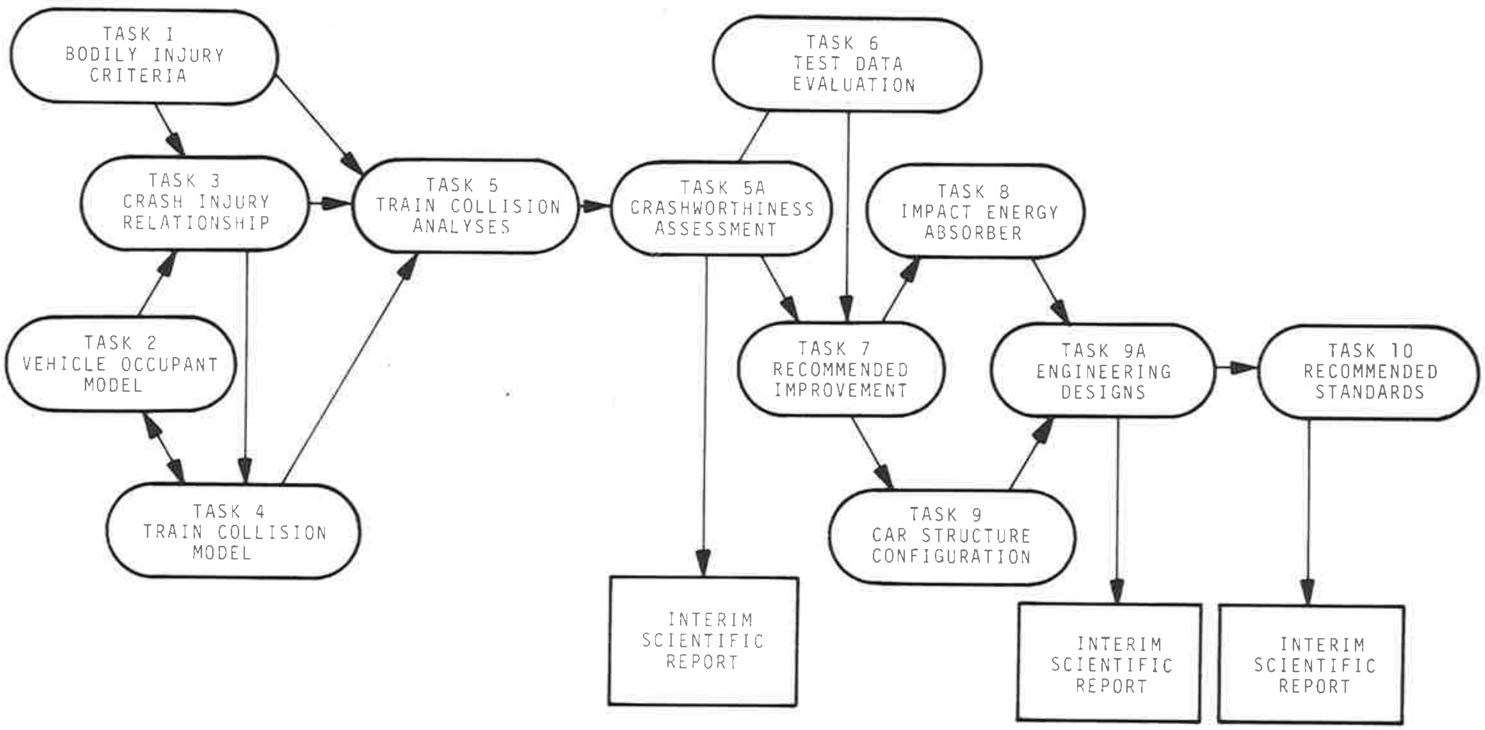



Figure 12 Crashworthiness Study Task Structure

is designed for continuous 80 mph operation, has been in almost constant use since September. The track exceeds the standards for FRA Class 6 and IRT Class 4 track.

The primary purpose of this facility is to serve as a reference track for the test and evaluation of urban rail vehicles - light, rapid, and commuter rail cars. A secondary purpose is the development, test, and evaluation of state-of-the-art and advanced track structures.

The track is comprised of six sections, each representative of a type of transit track currently in use, or being built, by operating properties. Each section is long enough so that meaningful data on vehicle characteristics such as noise, vibration, and ride comfort can be obtained within the section. A plan of the track is shown in Figure 13; the grade is shown in Figure 14. All wood ties and switch timbers are hardwood, A.R.E.A. Group Ta, size 5 (7"x9"). The concrete ties are Gerwick pre-stressed monolithic concrete ties, model RT-7-M-38, made by the Santa Fe - Pomeroy Company, and adapted to receive contact rail supporting brackets.

As shown in Figures 13 and 14, the test track comprises three tangent and three curved sections. The westerly tangent section, 11,000 feet in length, contains 4000 feet at zero grade and 7000 feet at 0.69 percent grade. The easterly portion contains approximately 4200 feet at 1.47% grade, part on tangent and part on the wide curve. At other places, grade has been matched to terrain. The curves at the north and south ends of the loop are 1°-30' curves (3,820 foot radius) with 4.5 inches of superelevation. This configuration is balanced for 65 mph and has about 2.2 inches of unbalance at 80 mph. The curve near the middle of the easterly side is a 0°-50' curve (6876 foot radius), has 2 inches of superelevation, and is also balanced for 65 mph operation.

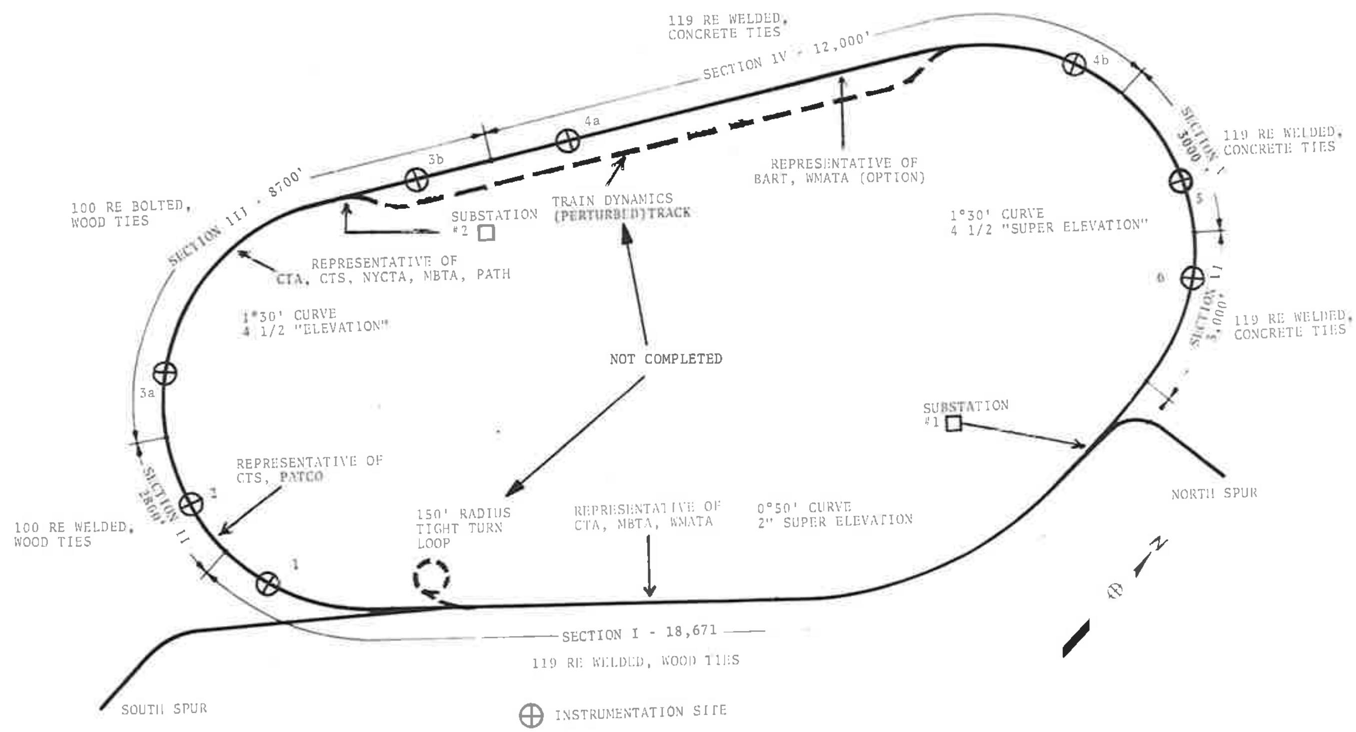



Figure 13 Plan of the High Speed Ground Test Center Track

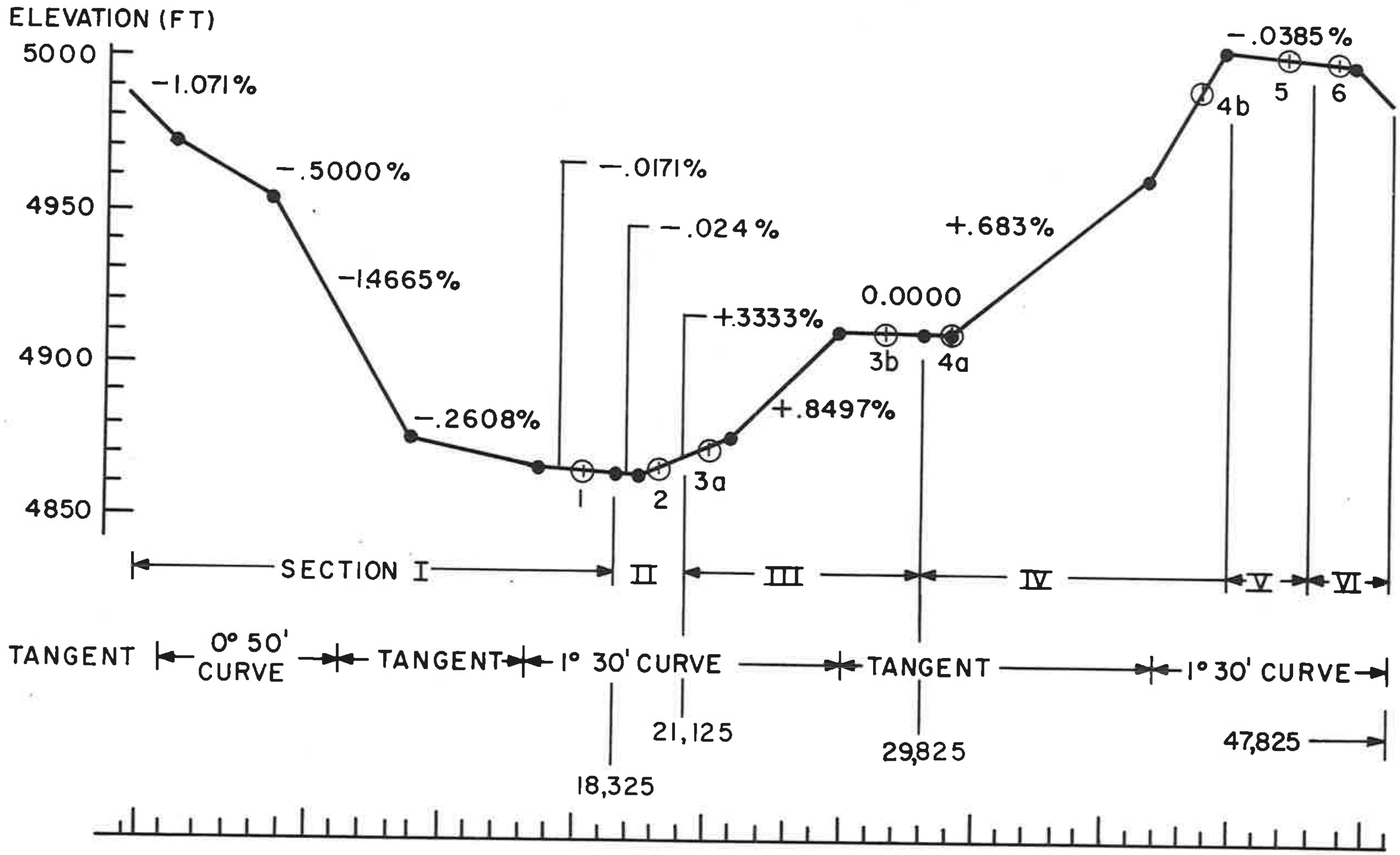



Figure 14 Track Profile at HSGTC Showing Grades

The track has been instrumented for the measurement of forces and deflections in the structure and trackbed. Sections I, II, V and VI have one location each with embedded instrumentation. Sections III and IV have two such locations each, one on tangent and one on curved track. The locations are shown on Figure 13.

Electrification around the entire test track is provided by an overrunning contact or third rail on the inside of the oval, leaving the outside free for future development work in electrification. The contact rail used is Bethlehem 150 lb. type NMC, used by many transit properties .

All transit properties were examined to determine the optimum placement of the contact rail. The placement chosen is compatible with all the properties considered. It is essentially that of the New York City Transit Authority IND and BMT divisions, the Port Authority Transit Corporation Lindenwold Line, the Long Island Rail Road, and Washington Metropolitan Area Transit Authority. The contact shoes of cars of other properties can be adjusted to ride on the contact rail. Both running rails are used as the negative power return, and are connected together at several points by cross track bonds.

Design work was initiated in January 1973 on the 150-foot radius tight turn loop. Drawings were given to FHWA Region 8, Denver, Colorado, on May 15 for the preparation of an IFB to be released in July. Drawings for a train dynamics (perturbed) track are being finished, and will be given to FHWA Region 8 early in July. Both additions will be built under a single construction contract, if possible.

The tight turn loop is a closed circular loop of 150-foot radius, very near the minimum radius curve that can be traversed by 75-foot long cars. This loop is joined to the main oval by 488 feet of connector track at a radius of 326 feet. Both the connector track and the tight turn loop will be used in the investigation of car performance in such areas as wheel squeal (wheel screech), internal noise and vibration, and suspension system stability. The train dynamics (perturbed) track will contain known perturbations in alignment, profile, cross level, and gage, and will be used for the dual purposes of evaluating vehicle suspension system performance and calibrating track geometry measuring systems. Running rail will be 119 pound welded rail on wood ties. Electrification will use the same construction techniques and materials as the main part of the test oval. The locations of these additions are shown in Figure 13.

In addition to the conventional contact (third) rail electrification, UMTA plans call for construction of a catenary over part of the westerly portion of the track. This section will be used for test and evaluation of urban rail vehicles equipped with overhead power collection systems, such as pantograph-equipped light rail vehicles and commuter cars. The catenary will be designed to operate at voltages up to 25KV AC.

Requirements for a fence to protect the electrified rapid transit test track from trespassers were discussed with representatives of FRA responsible for safety at HSGTC. The requirements were given to FHWA Region 8 in August 1972, a contract was awarded in November, and the fence, a four strand barbed wire cattle fence with warning signs, was completed in April 1973.

A contract was awarded to Battelle Columbus Laboratories in February 1972, for the development of design criteria applicable to the design of track for urban rail systems. Particular emphasis is being placed upon track laid on concrete slab. The final reports are due in December 1973. They will delineate areas of concern in track construction, and make recommendations for future research and development in at-grade urban track construction.

### 2.3.2 Power System for Energizing the Rail Transit Test Track

Design of the permanent power system for energizing the rapid transit test track at HSGTC, a high priority item, was initiated on February 1973, following agreement with representatives of FRA's Test Center and Demonstrations Division on allocation of costs between FRA and UMTA/TSC. Laramore, Douglass and Popham of Chicago, Ill., was selected to do the design work. A Program Implementation Plan was prepared and submitted March 20, defining the steps to be taken, costs, and schedules. Several meetings have been held between representatives of LDP and TSC concerning the design. Discussions with representatives of industry clearly indicated that the unique design requirements could be met within the established schedule and budget. Two substations, placed approximately as indicated in Figure 13, will be required. Present plans call for construction of Substation #1 in FY-74, and Substation #2 in FY-75.

A draft of the specification for the electrical equipment for Substation #1 was received for comments on June 18, 1973. Procurement action on this electrical equipment was initiated June 29. Completion of Substation #1 by March, 1975, is dependent upon expedited handling at each stage noted in the PIP and delivery of electrical equipment within one year.

The power system thus will permit testing of two modes: one, with constant voltage at the vehicle so that performance can be measured and compared to specified values, or two, as a vehicle on a transit system where the voltage at the vehicle depends on its position with respect to the nearest substation (operating at constant output voltage). The power system will be capable of maintaining at the test vehicle any preset voltage in the range between 400 volts and 1500 volts DC. This is accomplished by a series of trackside sensors which supply voltage data to the regulating system in the first substation; the second substation is slaved to the first. In addition, the substations can supply the test track with any regulated voltage in the range of 400 to 1600 volts DC, with the voltage at the output of the substation being controlled to the preset value (as in normal transit system operation).

Both substations are being designed for unattended operation, with provision for the later addition of supervisory control from a future test control center. The design will accommodate up to three additional substations, to be added as needed. The additional substations would permit testing of 10-car trains, or multi-train operation.

Temporary power sources are being provided for energizing the rapid transit test track pending the completion of the permanent power system. These sources comprise the 3000 HP diesel electric locomotive DOT-001 operated in the standby power mode, and two 500 KW 600 volt DC engine-alternator-rectifier units, operated in parallel to supply the SOAC and other transit car power needs. The preload capacity of DOT-001 was increased from two to five steps to increase its ability to handle the sudden loads imposed by starting transit cars. These modifications were completed on October 4, 1972, under a contract with General Electric. The two 500 KW units were leased from the O'Brien Machinery Company and were made operational on September 27, 1972. These units are strategically placed around the track so as to provide additional power to minimize voltage drops around the track. Operational problems have been experienced with this temporary power system, particularly in very cold weather, emphasizing the need for the permanent power system at the earliest practicable date. The permanent power system will be capable of energizing both the contact (third) rail and the catenary system.

### 2.3.3 Maintenance and Service Facilities

#### Transit Maintenance Building

The SOAC test program required that a service and maintenance facility be readily available to support the testing. Since the permanent facilities were not available, plans and specifications for a simple Transit Maintenance Building were prepared in April, 1972. A construction contract was awarded to the Gustafson Construction Company on July 28, 1972, and the building was ready for occupancy on October 13, 1972.

This Transit Maintenance Building provides a minimum service and repair capability for urban rail vehicles. It is a pre-engineered steel structure, 40 feet wide by 192 feet long, with a service pit 100 feet long. The building has been supplied with water, sanitary facilities, 90 KVA of 120/208 volt three phase AC power, and 120 KW of 600 volt DC power. Power is presently obtained from diesel engine generator sets; these will be shortly replaced by permanent power derived from the 115KV switchyard. The facility includes four 35 ton jacks, air compressor, battery charger, hand tools, and electrical and electronic test equipment. The building is located adjacent to one leg of the wye track at the north spur. The exterior and interior of this building are shown, respectively, in Figures 15 and 16.

Technical Services Facility

This building, the major maintenance and repair center for HSGTC, is a comprehensive facility for the servicing and modification of all vehicles - rail, research, and automotive - as well as the installation and repair of test equipment and instrumentation in the vehicles. A construction contract was awarded by FRA in April, 1973 with construction scheduled for completion in mid 1974. The facility will be made fully operational in late 1974. While primary responsibility for construction of this building rests with FRA, TSC has been heavily involved in its design, and in the selection of repair and maintenance equipment for it, in order to ensure that all requirements of UMTA are met.

The 400 foot long building is divided longitudinally into two sections. A high bay area, which will be used for servicing rail and research vehicles, is served by two 30 ton bridge cranes with a clear hook height of approximately 30

Figure 15  Exterior View of the Maintenance Building at HSGTC

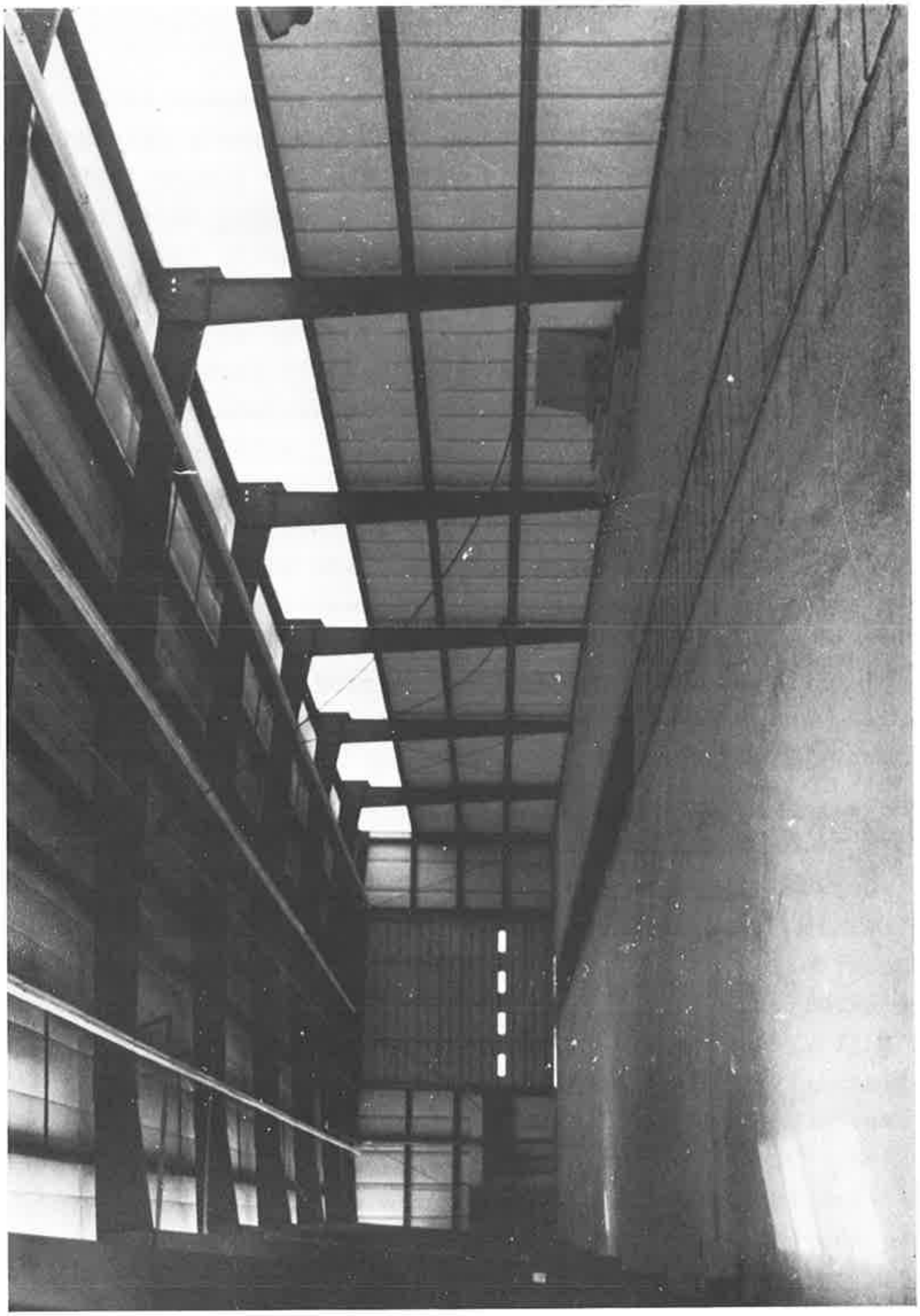


Figure 16 Interior View of the Maintenance Building at HSGTC

feet. Four tracks enter the building from an access track from the west. The northerly track runs completely through the building, over work pits and a pit for the future installation of a wheel trueing machine. The remaining three tracks run half way through the building. The northerly track of these three is also provided with a service pit. Except over the pits, the floor is flush with the top of the rail. The pits are provided with service facilities such as air, light, and power. The low bay area includes automotive, machine, electrical, electronic, carpentry, welding, and paint shops, as well as storage, assembly, and office areas. It also houses the ambulance and fire engine. The facility is, however, not designed for major repairs and overhauls, such as locomotive rebuilding and replacement of wheels on axles by pressing; it will handle the majority of work generated in research, test, and evaluation programs. Plan, elevation, and sectional views of this facility are shown in Figures 17, 18, and 19.

### 2.3.4 Rail Dynamics Laboratory

The Rail Dynamics Laboratory, a joint project of FRA and UMTA, is intended to permit the testing of rail vehicles under controlled laboratory conditions, with specific emphasis on the wheel/rail interaction and the vehicle suspension system. Full scale vehicles will be tested by supporting them on roller drives, with each supporting roller capable of being moved by hydraulic actuators under control of a suitably programmed computer. Runs can be made on a vehicle with simulated track irregularities to determine wheel/rail forces and vehicle suspension system performance. Extreme conditions can be simulated without risk of derailments, which might otherwise occur in a "real world" situation.

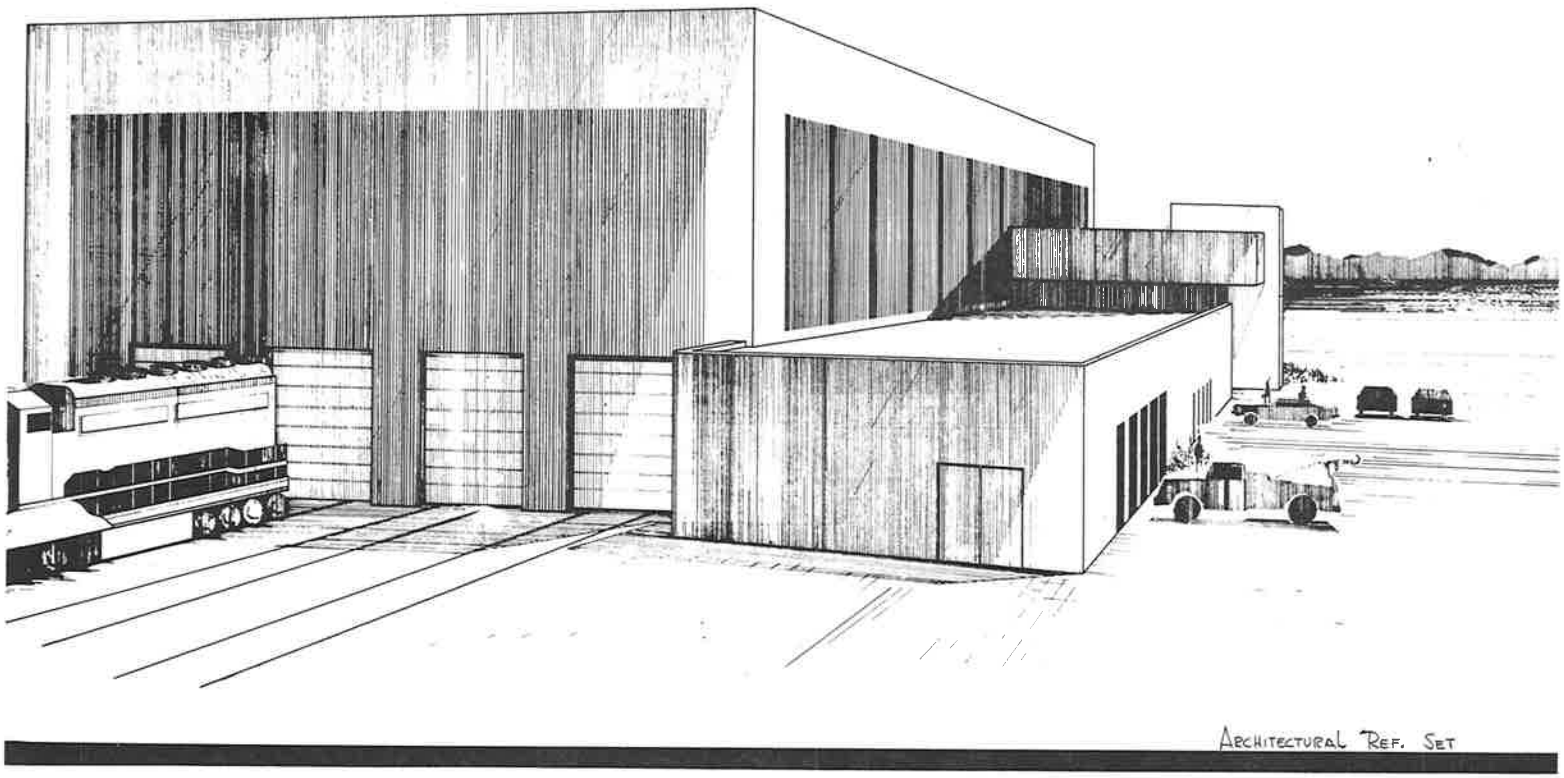



Figure 17 Front Elevation of the Technical Services Building at HSGTC

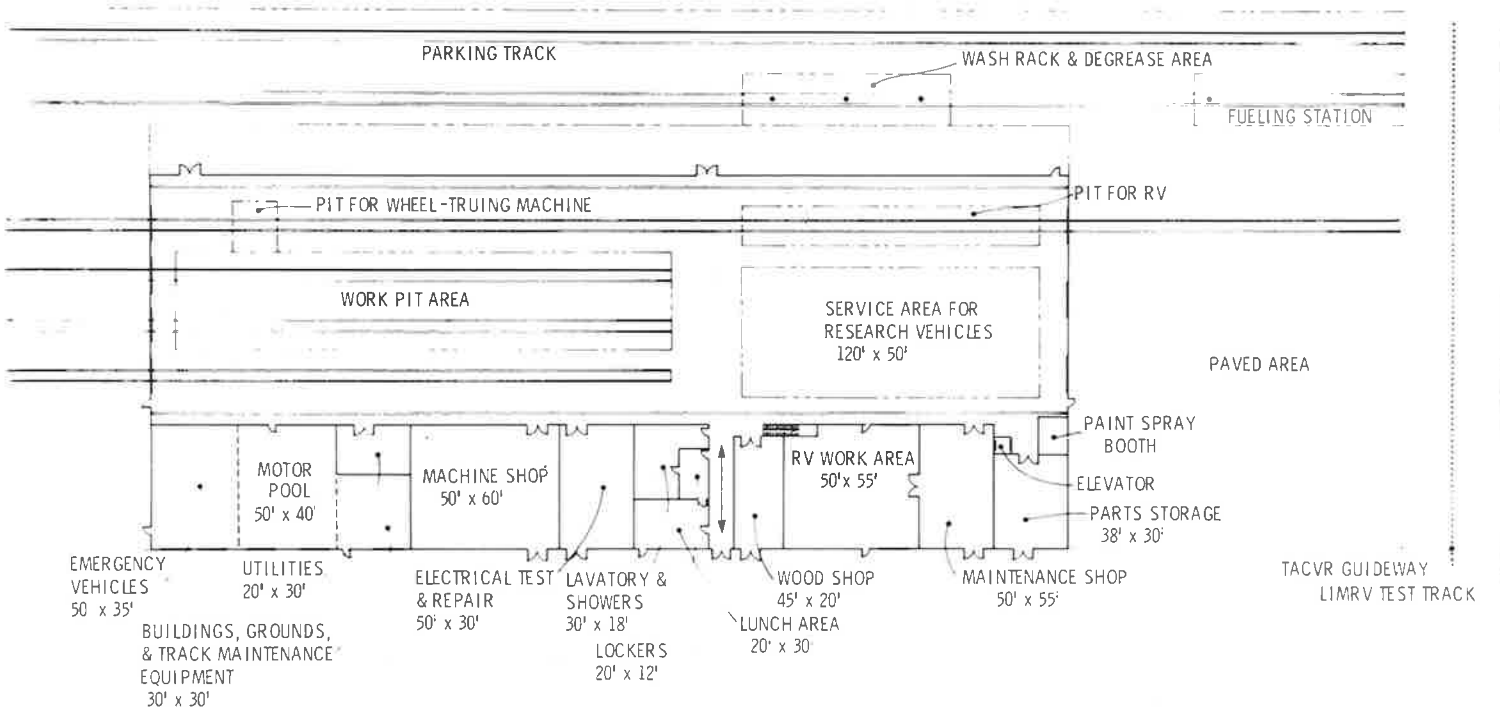



Figure 18 Plan View of the Technical Services Building at HSGTC

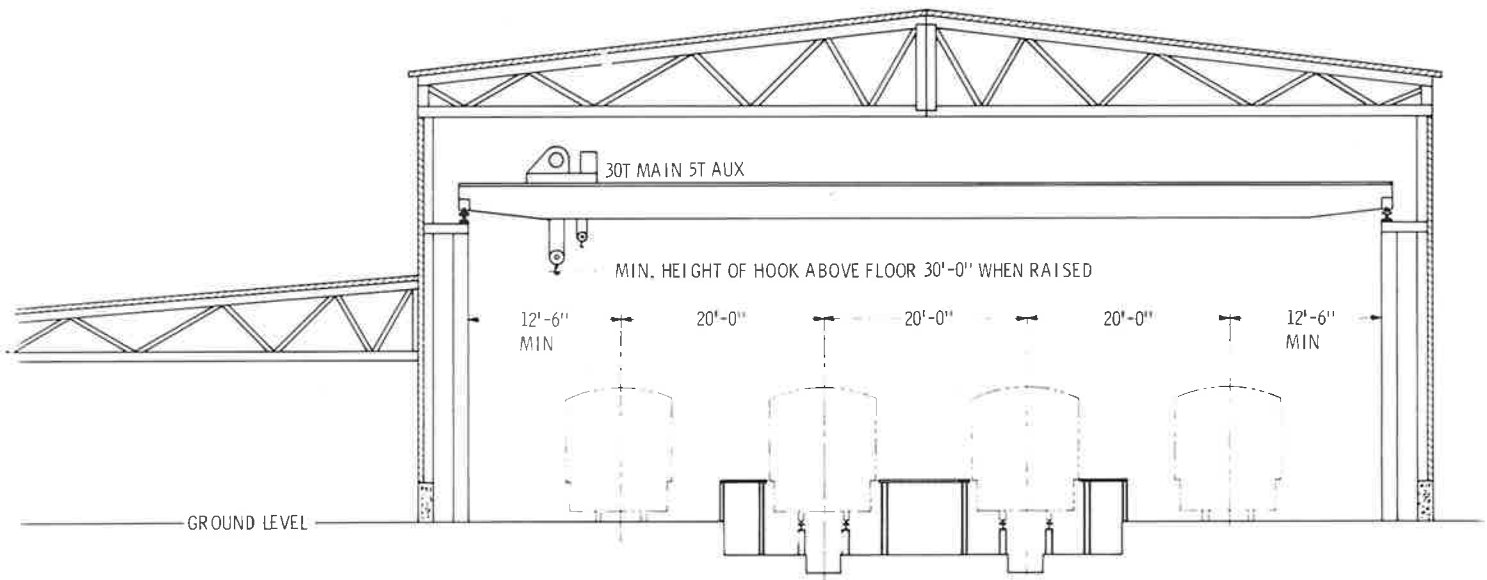



Figure 19 Sectional View of the Technical Services Building at HSGTC

Construction of the Rail Dynamics Laboratory was started in July, 1972. Completion is expected in 1974. FRA is responsible for the construction of the facility. Engineering support and analyses have been provided to FRA to ensure that the needs of UMTA are met.

### 2.3.5 Supporting Services

Miscellaneous supporting services during the fiscal year include (a) the repair of one traction motor and several flat wheels on the R-42 subway cars; (b) the extension of the loan agreement with NYCTA on these cars from June 30, 1972 to December 31, 1973; (c) technical assistance to FRA in the evaluation of proposals for track impedance measurement equipment; and (d) attendance at coordination meetings to represent UMTA's interests in the gradual development of HSGTC.

## 2.4 TASK IV - TEST AND EVALUATION

### 2.4.1 Test Plans and Requirements

The "General Vehicle Test Plan", GSP-064, which was initially published in FY-72, provides the basis for standardized vehicle testing at HSGTC. Experience gained in the application of these test procedures to the SOAC program during FY-73 will be incorporated in an expanded version of GSP-064 to be published in February, 1974. This version will include test sets in the categories of power consumption, power system interactions, and structures dynamics. Figure 20 shows the test sets that are planned for this version.

The SOAC test results will also be used as basis for updating Section 17 of the Guideline Specification for Urban Rail Cars. The initial version of this document was prepared for UMTA by Boeing Vertol and published in March, 1973. A draft of the Section 17 revision will be available in January 1974.

PERFORMANCE
- Acceleration
- Deceleration-Blended Braking
- Deceleration-Service Friction
- Deceleration-Dynamic Only
- Deceleration-Emergency
- Drift Test
- Friction Brake-Duty Cycles
- Spin/Slide-Acceleration
- Spin/Slide-Deceleration

POWER CONSUMPTION
- Power Consumption

ADHESION
- Adhesion-Deceleration

COMMUNITY NOISE
- Equipment Noise Survey-Wayside
- Effect of Car Speed-Wayside
- Screech Loop Survey-Wayside

PASSENGER NOISE
- Effect of Car Speed-On Car
- Effect of Track Section-On Car
- Screech Loop Survey-On Car
- Interior Noise Survey
- Acceleration Effect-On Car
- Deceleration Effect-On Car

RIDE ROUGHNESS
- Dynamic Shake Test-Vertical
- Dynamic Shake Test-Lateral
- Dynamic Shake Test-Longitudinal
- Component Induced Vibration
- Ride Roughness-Worst Speeds
- Ride Roughness-Acceleration
- Ride Roughness-Deceleration

POWER SYSTEM INTERACTION
- Radio Frequency Interference

STRUCTURE DYNAMICS
- Constant Speed
- Acceleration
- Deceleration

Figure 20 List of Test Sets for Revised General Vehicle Test Plan

In addition to general vehicle testing, requirements for more specific types of tests to be performed on vehicles are being investigated. A contract was awarded to General Electric for a study to determine the "Analytical and Experimental Techniques for the Evaluation of the Dynamic Characteristics of Rail Vehicles".

A Ways and Structures test plan that was scheduled for completion during FY-73 has been deferred pending resolution of resources available. The effort in this area has been limited to date, but additional planning effort will be required to assure a balanced test program.

### 2.4.2 Test Program Implementation

#### SOAC Engineering Tests

Boeing Vertol was awarded a contract in February, 1973 to conduct engineering tests on the State-of-the-Art Cars (SOAC) at HSGTC. Garrett AiResearch Corporation is a subcontractor to Boeing for test support. The instrumentation and data acquisition equipment, provided by AiResearch, has been delivered, installed and checked out. The engineering tests are based on GSP-064.

The phase of the tests using solid steel wheels has been completed. A sample of the results of wayside noise tests is shown in Figure 21. The higher noise levels on Section I may be caused by the heavier traffic that section experiences. Acoustiflex resilient wheels have been installed and additional tests will be performed at HSGTC during July 1973.

The five-city test and evaluation tour of the SOAC's is scheduled to begin after completion of a simulated revenue exercise at HSGTC. The test contract includes one week of testing on each of five demonstration properties.

#### Green Line Tests

Tests were conducted on the Boston MBTA Green Line in December 1972 in support of the Applications Engineering Task.

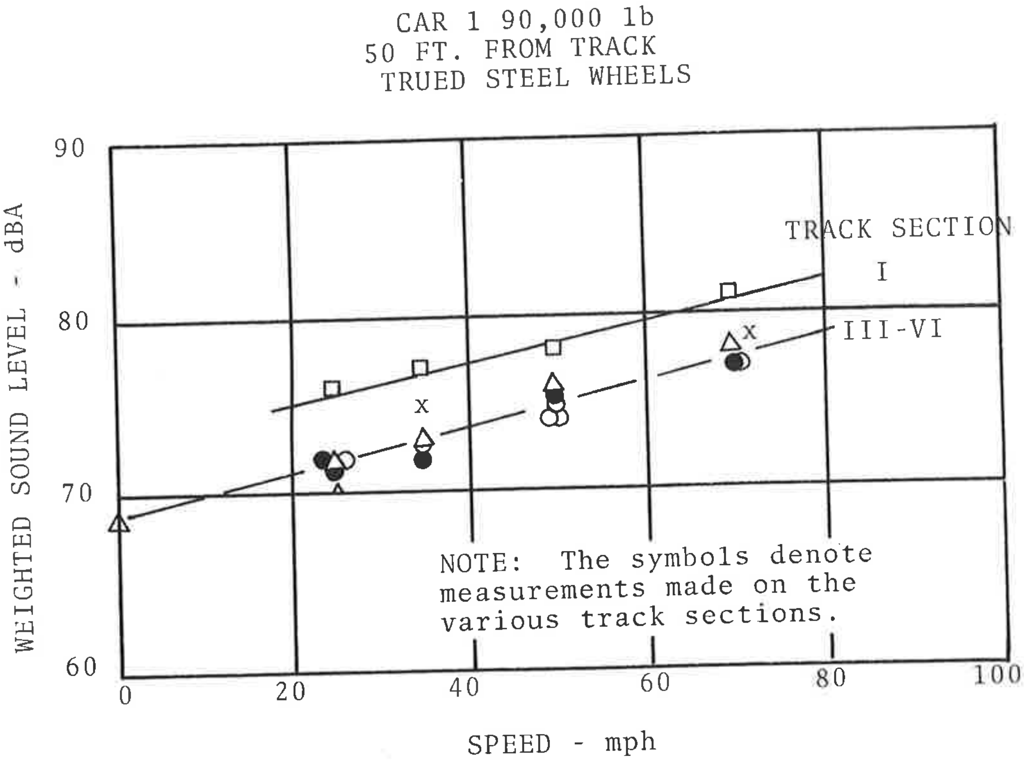



Figure 21 Effect of Track Section on SOAC Wayside Noise

Track geometry measurements were made (gage and midchord profile) to establish sections which should be given top priority in the Gree Line refurbishment program. Ride roughness and noise data were recorded in the first step of an effort to evaluate the benefits of the three-year improvement program. A series of test reports, MBTA Green Line Tests--Riverside Line, December 1972, Vols. I-V, DOT-TSC-UMTA-74-1, I-V, PB 224207(I) and PB 225093 (II-V), were published in September and October 1973. Additional tests will be conducted over a three-year period to complete this test program.

The instrumentation was installed and operated by TSC personnel. A sample of the summary printout of track gage is shown in Figure 22. This printout shows the percentage of track in the test section that satisfied the IRT classifications.

FROM - KENMORE
TO - AUDITORIUM
GAGE



| ZONE | UPPER LIMIT | LOWER LIMIT | % OF TOTAL | NO. OCCURANCES | TOTAL FT. |
|---|---|---|---|---|---|
| 6 | 99.00 | 57.75 | 0.02 | 1 | 0.5 |
| 4 | 57.75 | 57.25 | 10.23 | 24 | 286.5 |
| 2 | 57.25 | 57.00 | 14.45 | 70 | 404.5 |
| 0 | 57.00 | 56.25 | 70.32 | 80 | 1969.0 |
| 1 | 56.25 | 56.00 | 4.98 | 30 | 139.5 |
| 3 | 56.00 | -99.00 | 0.00 | 0 | 0.0 |

| ZONES | IRT CLASS | TIGHT | WIDE | % OF TOTAL |
|---|---|---|---|---|
| 0+1+2+4 | 1+2 | 56.00 | 57.75 | 99.98 |
| 0+1+2 | 3 | 56.00 | 57.25 | 89.75 |
| 0+1 | 4 | 56.00 | 57.00 | 75.30 |
| 6+3 | BELOW STNDRD | 56.00 | 57.75 | 0.02 |

Figure 22 Sample Computer Summary Printout for Track Gage, December MBTA Green Line Tests

R-42 Tests

Track construction and SOAC test activity at HSGTC precluded any major test activity using the R-42 vehicles during the past Fiscal year. The R-42's were used to conduct tests evaluating the power capabilities of DOT-001 in preparation for the SOAC tests. They were also used to checkout the newly completed oval, prior to the arrival of the SOAC's. It is planned to use the R-42's for checkout and acceptance of new test equipment scheduled for delivery during FY-74. This will include the digital data acquisition system and the Mk II track geometry measurement system. The R-42 cars will also be used as part of the Energy Storage Car Test Program.

Test reports for R-42 tests conducted during FY-72 have been prepared. The report for track geometry tests conducted in November, 1971 and the report for instrumentation tests conducted in August 1971 and in March and June 1972 are in publication. Figure 23 shows the measured footprints of the R-42 vehicle and the DOT locomotive. These data were obtained in June 1972.

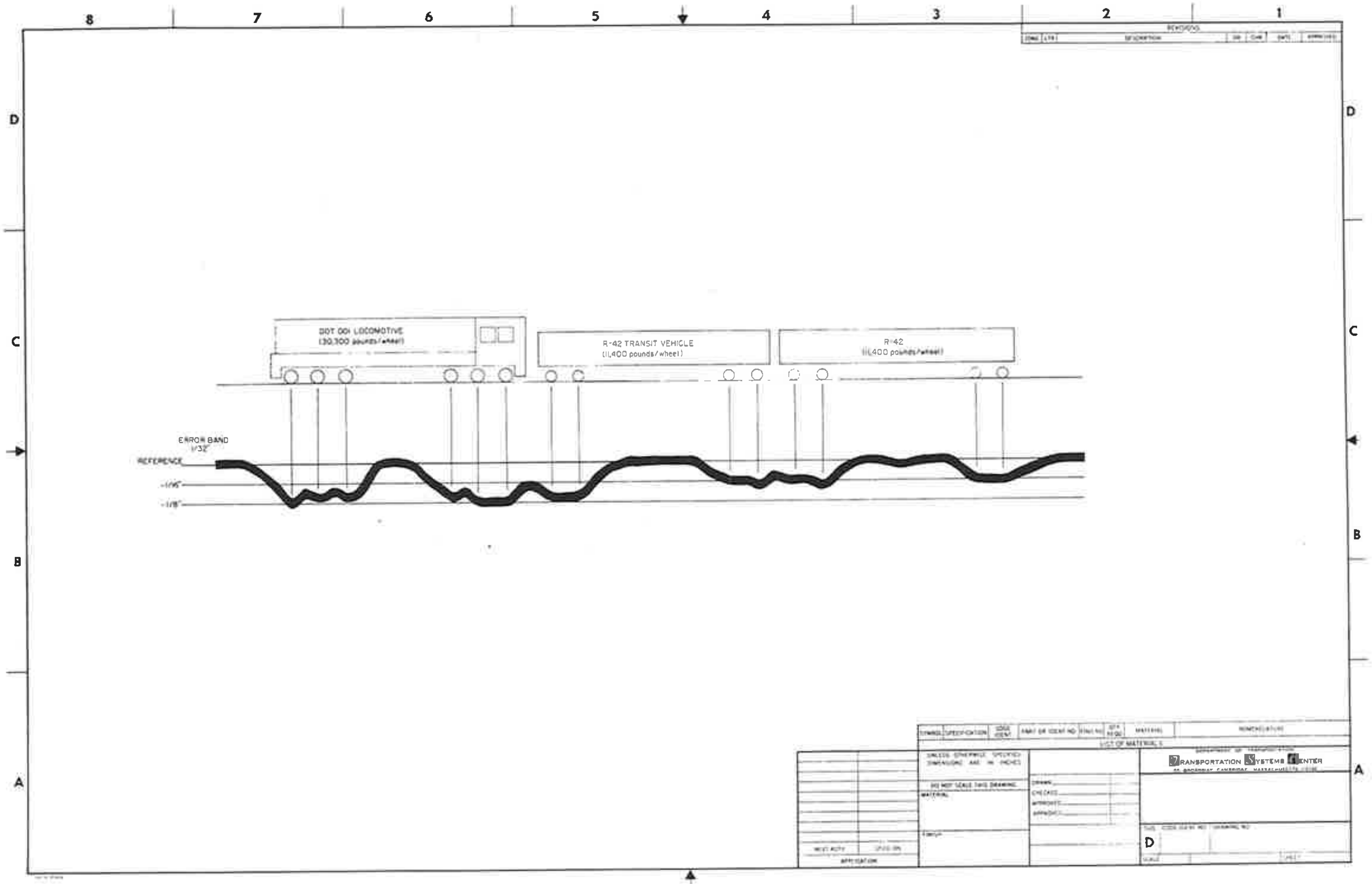



Figure 23 Vehicle Footprints Obtained From June 1972 Tests

### 2.4.3 Data Acquisition and Processing

All testing to date has utilized magnetic analog tape recorders for data collection, but in most instances, the data is processed digitally at TSC. Thus the requirement for digital data collection evolved and specifications were developed. Procurement of a digital system was initiated and the Data Acquisition Systems (DAS) contract awarded to Sperry Univac in March. The contract calls for delivery of three digital systems which have the capability for data processing, both on-line and off-line, as well as data collection. The necessary UNIVAC computer training is also provided.

The first system, DAS 1 will be delivered to TSC in September 1973 for checkout. DAS 2, which is planned for collecting data at the wayside instrumentation stations on the UMTA test loop, and DAS 3 which will be used for data collection on board the transit vehicle, will be delivered to HSGTC, Pueblo in October and November. DAS 1 and DAS 3 are identical and will be used for vehicle testing and for track geometry data collection and processing. A simplified block diagram of DAS is given in Figure 24 to show system components and the input/output capability.

Analog data acquisition will continue to be used for some specific applications to complement the digital capability. Two Honeywell 5600 analog magnetic tape recorders with TRI-COM constant bandwidth multiplex hardware were procured for analog data acquisition to replace the Leach MTR 3200A analog magnetic tape recorder. Checkout of this Honeywell/TRI-COM equipment was completed in September, 1972 and it was used for data collection and playback on the Green Line tests.

In the current mode of operation, analog data is digitized at TSC on the Honeywell 516 computer. The sampled data, stored on disc, is then processed on the Honeywell 632

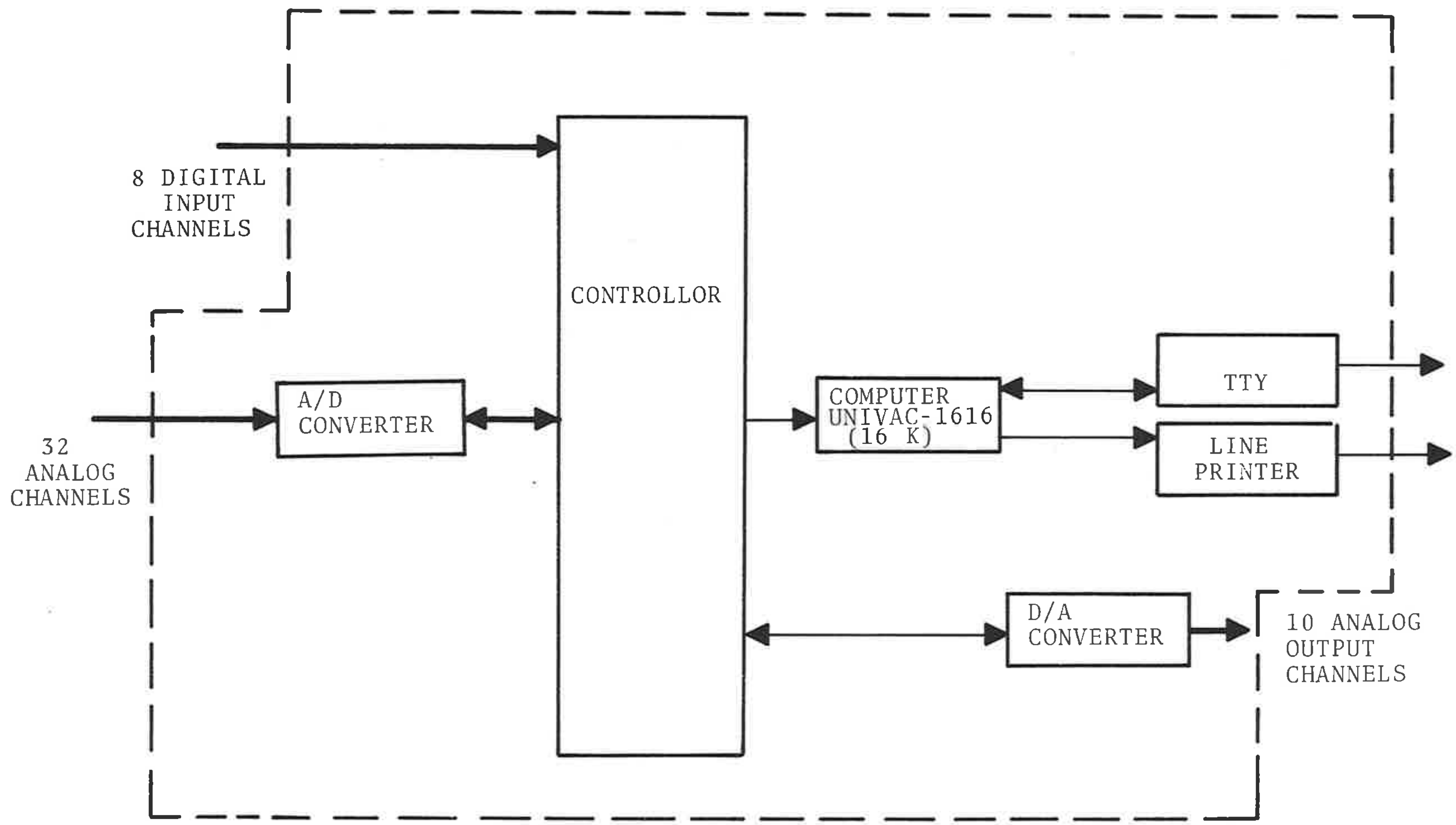



Figure 24 Digital Data Acquisition System (DAS)

computer. Analog filters and new digitizing hardware have been implemented to minimize errors and to provide better control over sampling rates.

The software development effort includes the following:

1. Real time high speed data acquisition
2. Real time rail geometry program
3. Signal processing and data reduction

Software has been developed in support of the ongoing requirement for processing test data. It was developed for processing the track geometry test data of the November test, and was further refined for processing the Green Line test data. Software for general vehicle tests is still being developed. Computation of true profile using double integration of an accelerometer is currently being evaluated.

Software developed for processing data at TSC will also be used where practicable for application to the on-board processing which will be possible with the new DAS systems.

### 2.4.4 Instrumentation and Equipment

TSC instrumentation for track geometry, ride roughness, and noise measurements were adapted for the MBTA Green Line tests. Clearances were established to assure that test hardware would clear all protuberances in the tunnels. Adapting beams and bracketry were designed, manufactured, and installed on a truck of a PCC car. Test data was collected over a period of one week in December, 1972. (See Section 2.2.1)

Procurements for analog and supporting equipment to interface with the digital data acquisition system have been initiated. The relationship of this equipment is illustrated in the block diagram of Figure 25. For vehicle tests and track geometry measurements, this equipment will be mounted in the rail car. For wayside tests, all but the sensors will be mounted in the mobile van. The status of this equipment is as follows:

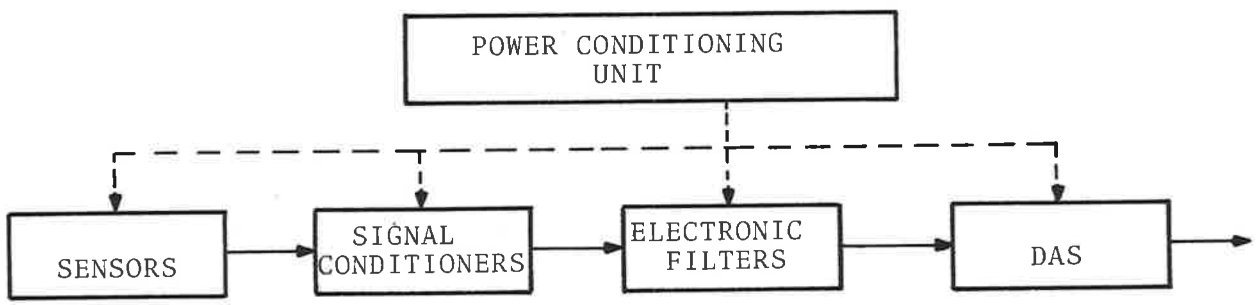



Figure 25  Complete Data Collection System

1. Mobile Test Van - a contract was awarded to the Pickwick Company in Cedar Rapids, Iowa to build a rubber tired vehicle for Ways and Structures test data collection. It will include a 12 KW portable generator and will house the DAS 2 hardware and required signal conditioning equipment. (Spec GSP-059). The mobile van will be capable of collecting up to 30 channels of data at any of the wayside test stations on the rail transit test track.

2. Power Conditioning System - A contract was awarded to Avtel Corp. for two power conditioning systems to be used on board urban rapid rail vehicles in conjunction with DAS 1 and 3. They will provide an uninterruptable power source for operating the test equipment even during loss of third rail power for periods up to ten minutes. (Spec. No. GSP-094). These 15 KVA power systems will convert the 600 volt DC third rail power to 110 volt AC for operation of the instrumentation and test equipment. Both systems will be used on board rail vehicles. One will be used with DAS 1 for vehicle testing. The other will be used on board the rail vehicle used for measuring track geometry. Power will be provided for the Mk II track geometry system as well as for the DAS.

3. Signal Conditioning Equipment - Procurement has been initiated for a universal signal conditioning system which will provide analog processing for a range of instruments applicable to the test program. The 30 channels of signal conditioners being procured will be sufficient for extensive testing on rail vehicles at Pueblo or for wayside testing with the mobile van. Additional channels will be procured but the 30 channels will be sufficient initially for both vehicle and wayside tests.

4. Variable Electronic Filter System - Procurement has been initiated for a variable filter system to be used in conjunction with the digital data acquisition system. The four-pole variable filters will also be sufficient for 30 channels.

A draft of a speed and distance measurement study has been prepared and is currently being reviewed. Definition of the long range calibration requirements for the program is in preparation.

## 2.5 TASK V - TECHNOLOGY DEVELOPMENT

### 2.5.1 Noise Abatement

2.5.1.1 Assessment. The noise abatement program is directed toward reduction of acoustic noise in urban rail systems, thereby contributing to improved environmental quality for users and the community. The program will make available, in a form useable in present and planned urban rail systems, the technology for control of acoustic noise and will provide UMTA with the tools required to evaluate and recommend noise abatement measures for urban rail systems.

Initially this effort is being directed toward an assessment of the current acoustic noise climate of urban rail systems and of the technology available for reducing this climate to acceptable levels. In order to establish and demonstrate the methodology for conducting this assessment, a pilot study of the Massachusetts Bay Transit Authority (MBTA) rapid transit system was conducted (DOT-TSC-UMTA-74-13, UMTA-MA-06-0025-74-8).

The study was conducted by TSC personnel with the cooperation of MBTA between October 10 and November 20. The study involved the following steps: definition of noise and vibration climates for the rider, operator and community; identification of the important contributors to these climates; identification of commercially available remedies and options for abatement; cost of abatement options (parts, installation and maintenance), and additional information concerning compatibility of abatement procedures with other aspects of rapid transit operations.

The methodology developed is described in the subject report. Figure 26 shows a sample time history for station noise. Figure 27 depicts a measurement summary of the in-car, in-station and community noise levels for the Harvard to Quincy Center Red Line. Figure 28 indicates the noise levels and locations of site-specific in-car noise.

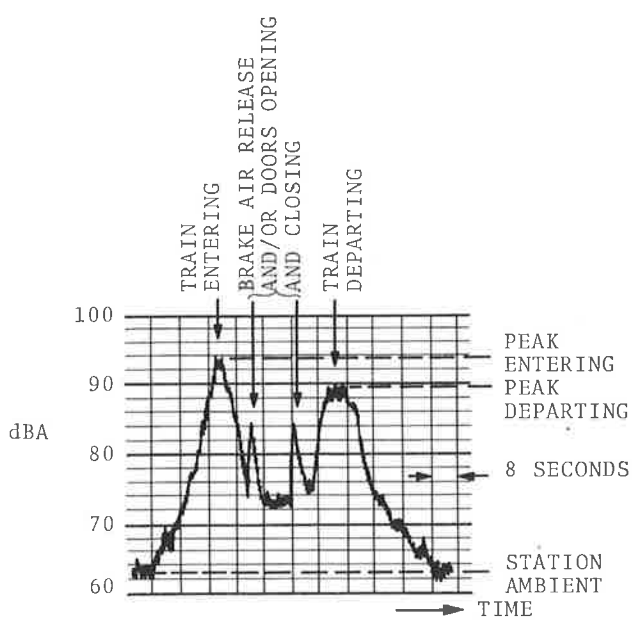



Figure 26 Sample Time History of In-Station Platform Noise Levels

This measurement program will be applied in Chicago, New York, Cleveland, Philadelphia, and San Francisco during FY-74.

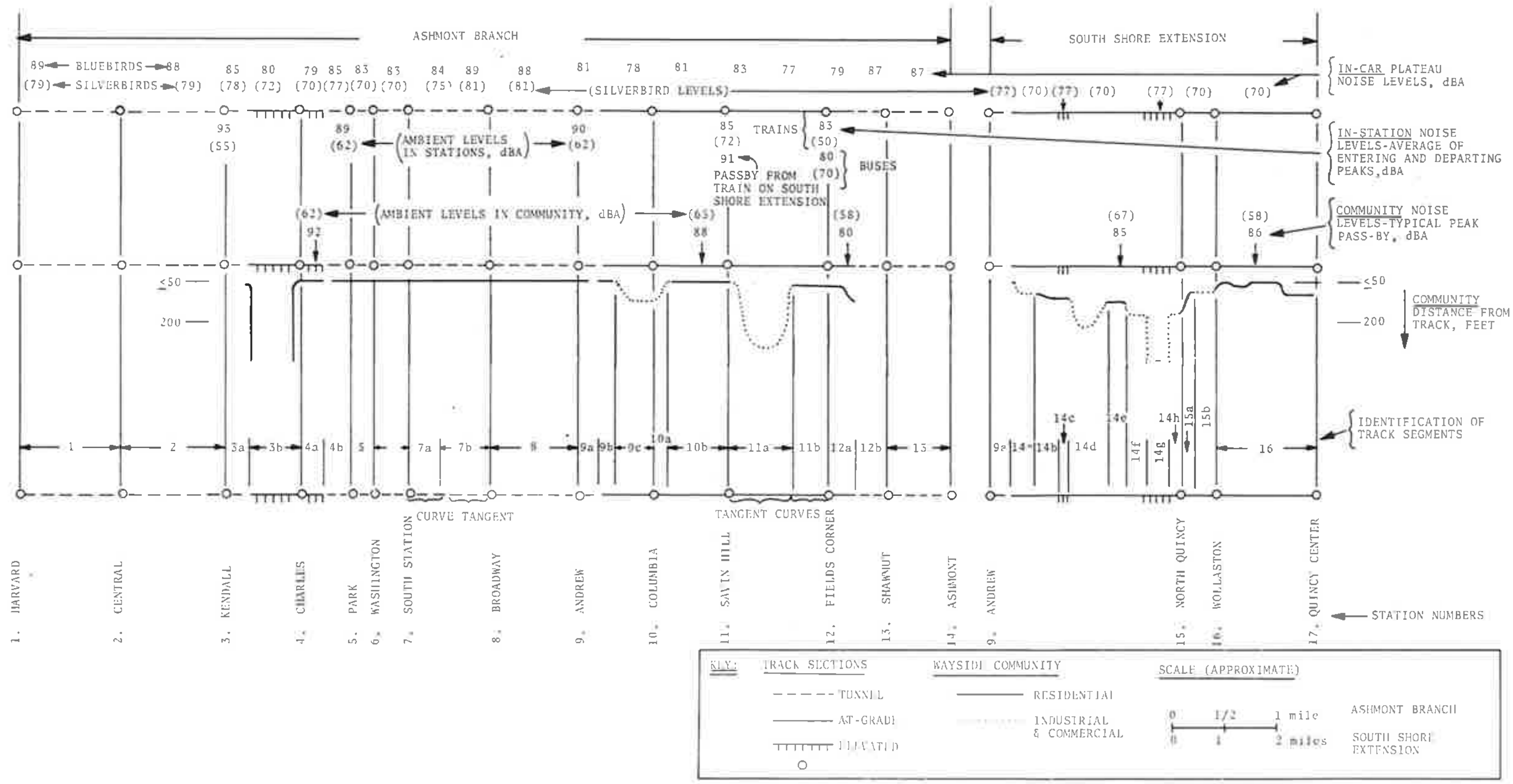



Figure 27 MBTA Red Line Noise Measurement Summary

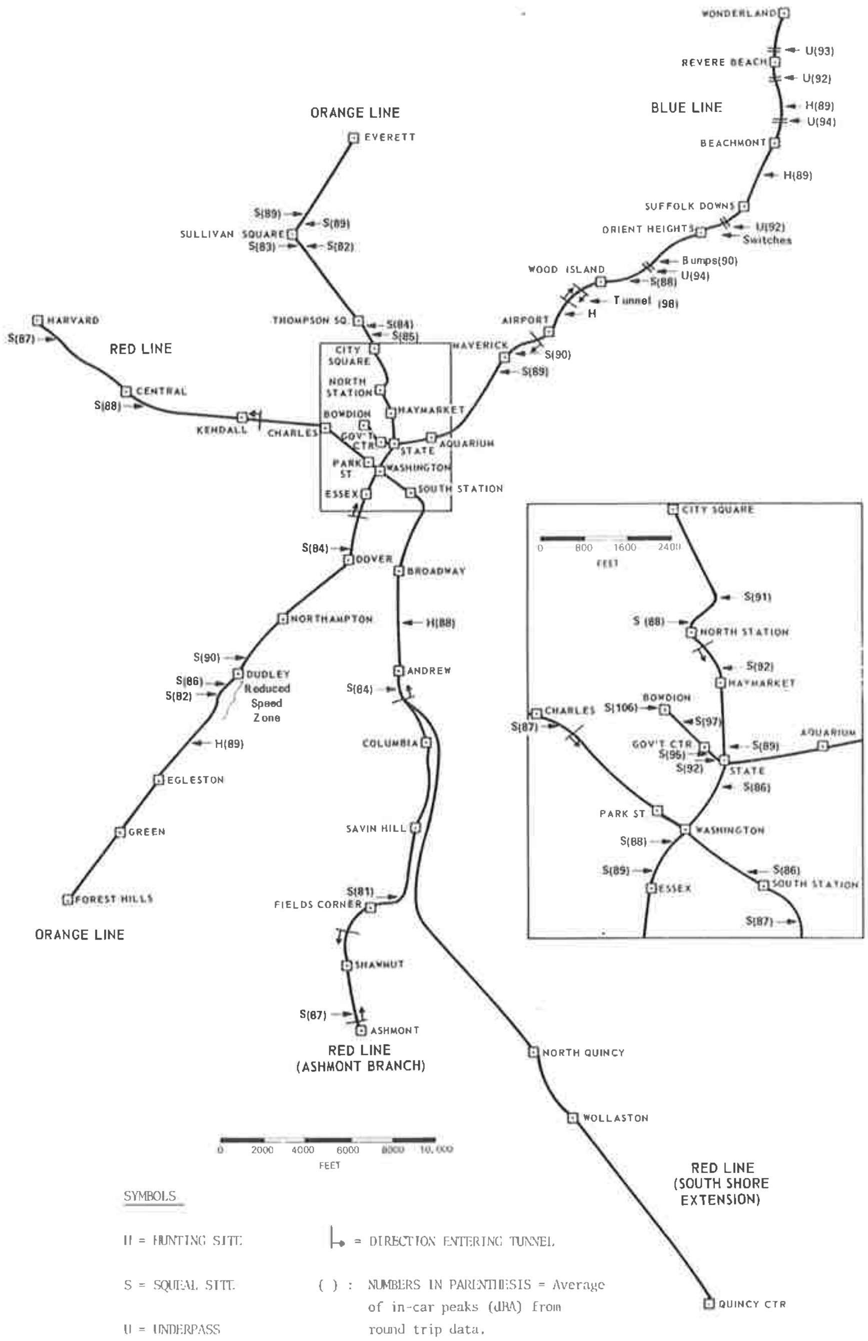



Figure 28 Site-Specific In-Car Noise Problems

2.5.1.2 Existing Technology. In terms of existing technology, a plan has been developed for FY-74 in-service test and evaluation of commercially available equipment. Resilient wheels, acoustic treatment of stations, damping of elevated structures, and sound barriers will be evaluated. All of the mentioned activities are programmed toward the eventual promulgation of a noise and vibration handbook for design engineers (approximately April 1977). Figure 29 depicts the overall flow of events of the noise program.

2.5.1.3 New Technology. In the area of new technology, two efforts were initiated with the objective being to assess and develop analytical prediction and design tools for the abatement of noise in urban rail systems. The emphasis is being placed on two parallel and interrelated paths. The first is the prediction and control of vibration transmission away from the wheel/rail interface and secondary radiation effects, viz., track and elevated structures. The second is the demonstration of improved devices and design methods for reduction of acoustic noise due to metal railroad-type wheels rolling on metal rails. These efforts are scheduled for completion by September 1974. Fabrication of hardware and evaluation of prototype models will follow these activities. Two procurements address these efforts. Contracts were awarded during the last week of June 1973 to:

Bolt, Beranek & Newman - Wheel/Rail Noise
Cambridge Collaborative - Track & Elevated Structures

2.5.2 Tunneling

The overall objective of the UMTA tunneling program is to bring about a substantial reduction of the cost and time required in the urban rail tunneling process, compatible with minimal environmental impact and minimal environmental risks.

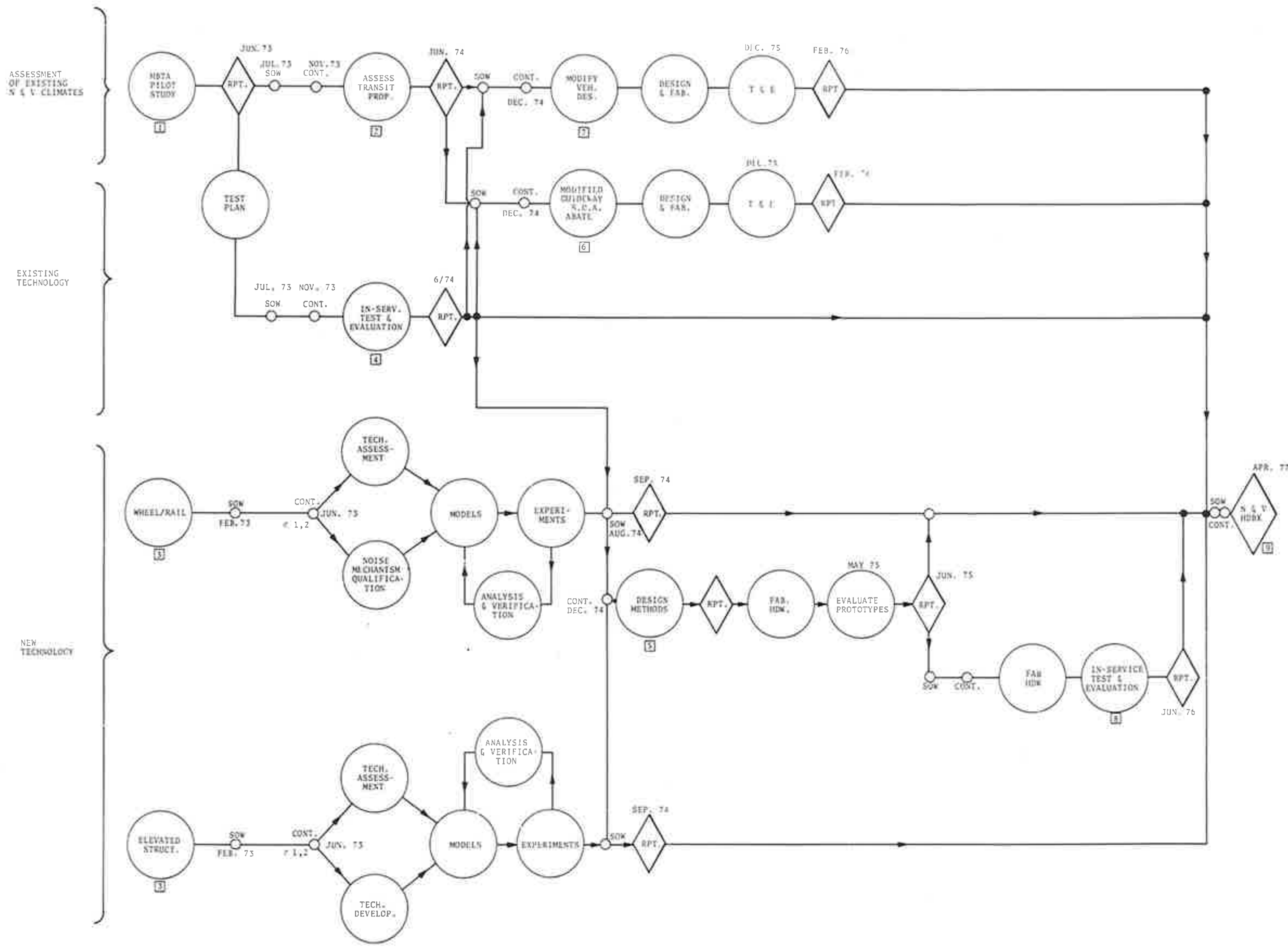



Figure 29 Noise Program Flow of Events

In support of UMTA, and consistent with GSP-0072 (A Plan for UMTA Tunneling R&D) and the FY-73 to FY-77 Project Implementation Plan, three interrelated R&D starts were initiated during FY-73 viz.

1. <u>Rapid Transit Tunneling, Systems Analysis Modeling and Optimization</u>

   The objectives of this activity are to identify and quantitatively describe, based on case histories, the process by which urban rapid transit tunnel and station systems are implemented; to structure the processes within a modeling framework; to collect and analyze cost data within this framework; to identify and quantify safety and environmental considerations and constraints within the framework; to analyze contractual arrangements used in urban tunneling; to identify and describe the technologies and tools employed, and to formulate an analysis for determination of system sensitivities and optimization of the rapid transit tunneling process.

   Bechtel Corp., San Francisco, was awarded the contract for this effort in June 1973. The final report is expected by September 1974.

2. <u>Subsurface Instrumentation Study</u>

   The objective of this task is to develop, with available technology, devices and methods which, in combination with existing conventional methods and improved in-situ testing methods, will improve the knowledge of subsurface conditions. This includes the nature and variability of the soil, rock, groundwater, and the presence of buried obstructions such as utilities and abandoned remains of prior construction activities. The effort will also document the requirements, justify the need, and determine feasibility for the development of methodologies and data interpretation techniques as well as estimate the cost of the instrumentation development effort.

Parsons, Brinkerhoff, Quade and Douglas, New York City, was awarded the contract for this task. The final report is expected in July 1974.

3. Stress-Strain Instrumentation

   The task includes the development of improved instruments, techniques, methods and data handling for the monitoring of stresses, forces, pore pressures, soil movements and other relevent parameters during tunnel and station construction.

   The objective of the proposed study contract is to establish the requirements for reliable monitoring instrumentation and software that will aid in the reduction of cost and environmental impact and enhance safety of rapid transit tunneling.

   A final report on this activity is scheduled for July, 1974.

Follow-on activities from items 2 and 3 above will be prototype instrumentation development and evaluation.

New starts for FY-74 include Soft Ground Excavation Techniques, Ground Support Linings, and Environmental and Safety Requirements for the Urban Tunneling process.

TSC is coordinating closely with the Interagency Committee on Excavation Technology (I.C.E.T.) in this work.

# 3. MILESTONES

## 3.1 TASK I - PROGRAM MANAGEMENT

| | |
|---|---|
| Completed Preparation of PPA UM-404 | JUNE 1973 |

## 3.2 TASK II - TECHNICAL SUPPORT AND APPLICATIONS ENGINEERING

| | |
|---|---|
| Completed Specifications for Track Geometry Sensor System, GSP-075 | NOV 1972 |
| Awarded Manufacturing Contract for Track Geometry Sensor System, DOT-TSC-616 | JUNE 1973 |
| Prepared Test Plan for Cleveland AC Propulsion Test Program | JUNE 1973 |
| Transit Vehicle Crashworthiness Study | |
| Completed Specification TMO-0141 | FEB 1973 |
| Award Contract ------- | FY-74 |
| IRT - Environmental Control Work | (Technical Monitoring) |
| Wheel/Rail Dynamics Research Facility | (Technical Monitoring) |

## 3.3 TASK III - FACILITIES DEVELOPMENT

| | |
|---|---|
| Completed 9.12 Mile Test Track | SEP 1972 |
| Completed Transit Maintenance Building (TMB) | OCT 1972 |
| Provided Heat, Water, and Sanitary Facilities in TMB | MAY 1973 |
| Completed Engineering Design of Tight Turn Loop | MAY 1973 |
| Initiated Design of Perturbed Track Section | FEB 1973 |
| Awarded Contract for Permanent Power System Design | FEB 1973 |
| Received Draft of Power Equipment Specification for Substations | JUNE 1973 |
| Dedication Ceremonies for Test Track | OCT 1972 |
| Completed Fence Around Test Track | APR 1973 |
| Completed Modification to Locomotive DOT-001 | OCT 1973 |
| Provided Supplementary Power from Engine-Generator Sets | SEP 1972 |
| Awarded Contract on Design Tools and Criteria | Feb 1973 |

## 3.4 TASK IV - TEST AND EVALUATION

| | |
|---|---|
| Conducted Tests on MBTA Green Line | DEC 1972 |
| Released Test Report "MBTA Green Line Tests, Riverside Line - December 1972", DOT-TSC-UMTA-73-5 | JUNE 1973 |
| Awarded Contract for Conducting Engineering Tests on SOAC and Updating General Vehicle Test Procedures and Guideline Specifications for Urban Rail Cars | FEB 1973 |
| Conducted Engineering Tests on SOAC Vehicles at HSGTC. (Steel wheel configuration completed) | JUNE 1973 |
| Awarded Contract for Three Digital Data Acquisition Systems (DAS) | MAR 1973 |
| Awarded Contract for Mobile Test Van for Ways and Structures Testing | JUNE 1973 |
| Awarded Contract for Two Power Conditioning Systems to be Used on Board Rail Vehicles for Test Equipment | JUNE 1973 |
| Released Specifications for Signal Conditioning System | MAY 1973 |
| Released Specifications for Variable Electronic Filters | JUNE 1973 |
| Completed Drafts of Test Reports for Remainder of R-42 Car Test Activity at HSGTC | JUNE 1973 |

## 3.5 TASK V - TECHNOLOGY DEVELOPMENT

| | |
|---|---|
| Wheel/Rail Noise Abatement Study | |
| Completed Specifications, TMP-122 | NOV 1972 |
| Awarded Contract, CONT-TSC-644 | JUNE 1973 |
| Track and Elevated Structures Study | |
| Completed Specifications, TMP-125 | NOV 1972 |
| Awarded Contract, CONT-TSC-643 | JUNE 1973 |
| Rapid Transit Noise Abatement Assessment Study (MBTA Pilot Study), DOT-TSC-UMTA-73-6 | JUNE 1973 |
| Tunneling Systems Modeling and Optimization Study | |
| Completed Specifications, TMP-124 | JAN 1973 |
| Awarded Contract, CONT-TSC-601 | JUNE 1973 |
| Subsurface Instrumentation Study | |
| Completed Specifications, TMP-126 | JAN 1973 |
| Awarded Contract, CONT-TSC-654 | JUNE 1973 |
| Stress-Strain Instrumentation Study | |
| Completed Specifications, TMP-129 | JAN 1973 |
| Awarded Contract, CONT-TSC-661 | JUNE 1973 |