THIRD UMTA R&D PRIORITIES CONFERENCE

Concurrent Sessions

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16. Abstract

This is a compilation of material that was presented at the Third UMTA R&D Priorities Conference Workshops on Bus and Paratransit Technology. Part I deals with paratransit integration and includes discussions of operational technologies (as distinct from vehicle and propulsion system development), experiences of the City of Cincinnati with their Urban Transportation Laboratory program, the Logan Airport (Boston) share-a-cab program, and the Rochester dial-a-ride program. Part II, bus technology, paratransit vehicle development, and flywheel energy storage system, contains discussions of the vehicles themselves and the flywheel energy storage program. This volume contains six resource papers which can be found summarized in Volume I of this report along with summaries of other workshops sessions. Volume I also includes the proceedings of the general sessions and a listing of conference participants.

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PREFACE

This report contains proceedings of workshop sessions of the Third Urban Mass Transportation Administration R&D Priorities Conference which was held at the U. S. Department of Transportation's Transportation Systems Center in Cambridge, Massachusetts, November 16 and 17, 1978. This volume contains the following:

<u>Bus and Paratransit Technology Workshops</u>

Part I : Paratransit Integration
Part II: Bus Technology, Paratransit Vehicle Development, Flywheel Energy Storage System

These conferences are sponsored periodically by UMTA to enable them to communicate directly with those who represent the views of transit users, operators of public transportation systems, suppliers of equipment and services, the research community, and governments at the State, local, and Federal levels. The purpose of the Third Conference was to provide a current review of UMTA's research and development plans and to solicit recommendations for improving the direction and effectiveness of its program. The conference included general sessions on research and development policy and a total of fifteen half-day workshops on research, development, and demonstrations in urban transportation systems, technologies, planning, management, and services.

The volume containing proceedings of the general sessions and summarized reports of the workshops has been published by the Urban Mass Transportation Administration. However, because of the volume of papers, presentations, and discussions, detailed proceedings of the workshops have been compiled into separate reports by subject area. All of these documents are available from:

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When ordering copies of these reports from NTIS, please refer to the list of report numbers and titles which follows.

1. Third UMTA R&D Priorities Conference, November 1978, Volume I: Proceedings of General Sessions and Summarized Reports of Workshops, DC-06-0157-79-1.

2. Third UMTA R&D Priorities Conference, November 1978, Volume II: Proceedings of Bus and Paratransit Technology Workshops, DC-06-0157-79-2.

   Part I : Paratransit Integration
   Part II: Bus Technology, Paratransit Vehicle Development, Flywheel Energy Storage System

3. Third UMTA R&D Priorities Conference, November 1978, Volume III: Proceedings of AGT and Advanced Systems Workshops, DC-06-0157-79-3.

   Part I : AGT Socio-Economic Research and AGT Applications
   Part II: AGT and Advanced Systems and Technologies

4. Third UMTA R&D Priorities Conference, November 1978, Volume IV: Proceedings of Service and Methods Demonstrations Workshops, DC-06-0157-79-4.

   Part I : Pricing Policy Innovations
   Part II: Conventional Transit and Paratransit Service Innovations

5. Third UMTA R&D Priorities Conference, November 1978, Volume V: Proceedings of UMTA Special Technology Programs Workshops, DC-06-0157-79-5.

   Part I : Safety, Qualification, and Life-Cycle Costing
   Part II: Consumer Inquiry Technology, National Cooperative Transit R&D Program, and Technology Sharing

6. Third UMTA R&D Priorities Conference, November 1978, Volume VI: Proceedings of Rail and Construction Technology Workshops, DC-06-0157-79-6.

   Part I : Railcars and Equipment
   Part II: Construction Technologies

7. Third UMTA R&D Priorities Conference, November 1978, Volume VII: Proceedings of Transit Management Workshops, DC-06-0157-79-7.

   Part I : Management Systems Developments
   Part II: Human Resources Development

8. Third UMTA R&D Priorities Conference, November 1978, Volume VIII: Proceedings of the Access for Elderly and Handicapped Persons Workshops, DC-06-0157-79-8.

   Part I : Planning and Regulation
   Part II: Demonstrations and Hardware

9. Third UMTA R&D Priorities Conference, November 1978, Volume IX: Proceedings of the Urban Transportation Planning Workshop, DC-06-0157-79-9.

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BUS AND PARATRANSIT TECHNOLOGY I

BERNARD E. BLOOD
CHIEF, TRAFFIC MANAGEMENT BRANCH, TRANSPORTATION SYSTEMS CENTER

As part of its effort to develop and apply technological improvements in bus and paratransit systems, UMTA has pursued a category of research called operational technologies--as distinct from vehicle and propulsion system development. In this R&D on operational improvements, we are concerned with the application of modern mobile-communications and computer technologies along with command and control theory to develop innovative tools for efficient management and planning in transit fleets. Through Fiscal Year 1978, about 45% of UMTA's bus and paratransit research funding was in this area; and, in FY 1979, $4.5 million or about 50% of the bus and paratransit research budget will be devoted to operational technology projects.

Bus and Paratransit Operational Technology Projects

There are two major, continuing research efforts in the FY 79 program.

The Automatic Vehicle Monitor (AVM) project is developing a system which integrates vehicle-locator, mobile-radio communication, and data processing technologies to improve the efficiency and level of service in fixed-route bus operations. The system has three major functions: (1) it enables the real-time, central control of bus movements to maintain service reliability; (2) it automatically and continuously collects fleet performance and passenger loading data for management analysis and planning; (3) it enables prompt dispatch of aid to the exact location of a vehicle with an activated silent alarm to improve passenger and driver security.

As the second major effort of our program, the Paratransit Integration Program (PTIP) represents the continuation of UMTA's developments in methods for paratransit systems planning and design, including computer aids for efficient scheduling, dispatching and routing. PTIP is concerned with all aspects of paratransit which have the potential for making operational improvements, reducing costs, increasing performance and levels of service.

The program's analyses, developments, and demonstrations are directed towards these objectives: to improve public and special-group transit where conventional services are unavailable or inadequate; to extend transit coverage through integration of fixed-route service with paratransit; to encourage private paratransit operators to the maximum extent by helping them improve productivity and operational efficiency while providing public transit at reasonable rates; to improve operational efficiency and reduce costs in paratransit services, including those for the elderly and handicapped and other special groups; to identify regulatory and institutional barriers to paratransit utilization and develop innovative approaches to overcoming them.

I would like to describe the AVM and PTIP project developments and FY 79 plans.

Automatic Vehicle Monitor System

Trial AVM systems have been deployed both in Europe and the United States, with the greatest success achieved in Zurich and Hamburg in service improvements. While the European systems are designed to improve service without consideration of cost savings, UMTA's efforts have stressed both economic and service improvements. A benefit-cost analysis performed at the Transportation Systems Center showed favorable ratios of up to 7:1 while counting only those savings provided by AVM through operational efficiency.

The first AVM deployment for transit in the United States started in 1968 with UMTA funding to the Chicago Transit Authority. This deployment was evaluated in 1973 at TSC and was found inoperative due to poor hardware-reliability and limited design scope. Since that time CTA has improved the reliability and new uses the system advantageously to conteract transit crime, making effective use of the silent alarm. The system design, however, is inadequate for systematically demonstrating or quantifying the primary AVM payoffs. The hardware and design problems in the CTA AVM are not unique; in fact, similar system developments in London and Paris have been abandoned on these grounds. The lesson learned or relearned in these experiences is that successful demonstration of relatively sophisticated electronic systems in the transit environment is critically dependent upon the use of mature, reliable hardware elements and painstaking system design with complete involvement of the transit operators.

With the recognition of the significant near-term potential in AVM, UMTA initiated the present project in 1975. The Transportation Systems Center formulated a system concept and the engineering specifications. Four candidate vehicle locator technologies, considered the most critical development item in the system; were run through comparative field tests in Philadelphia. From the results, the most mature technology was selected for the development of the complete AVM system. The Southern California Rapid Transit District (SCRTD) in Los Angeles was selected for the demonstration site. Final detailed design of the system has been completed and initial deployment on six bus routes will be accomplished by the end of FY 79. The system manufacturer, Gould Information Identification Incorporated, Ft. Worth, Texas, is under the constant guidance of TSC and SCRTD to ensure a reliable system that is fully compatible with bus operational process.

Following system deployment, a one year experimental evaluation and demonstration will be conducted under direct TSC supervision with participation of SCRTD and support from the system manufacturer. The experimental work will start with a training program for 500 drivers and 30 dispatchers and supervisors. SCRTD maintenance technicians will be trained and will assume full responsibility for the system about midway through the year. Prime objectives are to use a structured experimental design to evaluate the detailed AVM functions and to work out the associated procedures for carrying them out. The postulated benefits in real-time route control, management information and safety will be quantified. In this way it is planned that engineering design, implementation and maintenance guidelines will be established; and, also, the ways and means for the most effective use of AVM will be discovered and refined.

Paratransit Integration Program

In contrast to the specific system development of the AVM project, PTIP encompasses a diverse collection of related but not necessarily interdependent efforts all directed towards the facilitation and improvement of paratransit operations. Major early work in this program was the development of the software and computer systems for the automatic scheduling and dispatching of the vehicles in the Dial-A-Ride demonstrations in Haddonfield, N.J. and Rochester, N.Y. These demonstrations -- particularly the one in Rochester

which remains in operation under a Service and Methods grant -- have shown computer scheduling and automatic real-time dispatch is feasible and effective. In the Rochester DAR system a telephone operator inputs trip requests to the computer system which automatically selects the most appropriate vehicle, estimates the pick-up time and presents this information to the operator who relays this information to the caller. The computer then automatically transmits the trip request and address to the selected vehicle's alpha-numeric display unit. The cost, however, of the fully automatic system, as implemented in Rochester, can be high and in low demand situations may not be justified. In FY 78, under the PTIP, the Rochester DAR software was reconfigured for a newly-available mini computer. This revised system is now being implemented and the cost of computing will be substantially reduced.

In FY 76, UMTA, recognizing the proliferation of paratransit initiatives and the attendant interest in automatic operations, started a wide-ranging research effort to identify and analyze the national requirements for paratransit system planning and implementation. This effort was called Phase I of the Paratransit Integration Program to distinguish it from an anticipated Phase II. Phase II would deal with the actual development and demonstration of operational methods and technologies, identified as critical or high payoff items in Phase I.

There were five major elements in Phase II. A Benefit-Cost Analysis examined paratransit implementations on a national scale. Using a cluster analysis, seven different urban environments, as representative of the full range of U.S. city types, were selected for scenario analyses. In each scenario the relative economic, environmental and service impacts of different paratransit implementations were quantified. Macro and Micro Simulation models were developed for operation on a general purpose digital computer to provide planners and system designers with a quantitative tool for evaluating alternate paratransit implementations. Handbook for Paratransit System Design was prepared to aid system planners and designers. This is the forerunner of a comprehensive "Paratransit Handbook" and is based on a thorough review and assessment of current and past paratransit trials. Analytic techniques, rules of thumb and other planning aids are described in the document. Shared-Ride Taxi Automation requirements were determined in a study that examined market and fleet-size parameters for financially viable operations. The institution and legal barriers to shared-ride taxi implementation were also analyzed. Dial-A-Ride Computer Systems were analyzed -- particularly that in Rochester -- to determine what developments are needed to reduce costs for this type of automation. At the present time the Phase I research efforts are substantially completed and UMTA is assimilating the results in structuring a Phase II program.

The initial FY 79 plan calls for a program with four major elements. Planning and Analysis Tools and Techniques include the refinement, calibration and testing of the simulation models developed in Phase I. In addition, work on improved ways for estimating passenger demand will be initiated. Operational Techniques, Systems and Equipment will focus on the design and testing of simplified techniques and hardware for automated scheduling, routing and dispatching and management information systems. Work will include consideration of shared-ride taxi and check-point services. Paratransit Integration and

Coordination Projects will contain research on management systems, including computer aids, for the coordination of the paratransit services sponsored by social agencies and the brokerage concept for paratransit services. Technology Transfer will address the problems of paratransit technology assessment and dissemination. In particular, the preliminary handbook will be evaluated and modified in preparation for the development of a comprehensive handbook for paratransit planners and operators.

PETER E. HANNISHIN
TRANSPORTATION COORDINATOR, CITY OF CINCINNATI, OHIO

BUS AND PARATRANSIT TECHNOLOGY I

The City of Cincinnati and the Southwest Ohio Regional Transit Authority have been involved with the General Motors Corporation for over three years now, in a program known as the Urban Transportation Laboratory. This program was designed to investigate methods of applying advanced technology to the transit industry; to improve the effectiveness and efficiency of operations. The focus of attention has been a prototype Automatic Vehicle Monitoring (AVM) system, but it certainly has not been the only concern.

The Urban Transportation Laboratory started because there were two organizations, one governmental and one corporate, that had some unmet needs; and some people in these organizations with enough vision to see the possibilities inherent in a partnership between the two. We have a definite need for increased productivity in local government, because of a static or shrinking tax base, and GM needed to turn some advance technology into a marketable product - a product that could turn out to be mutually beneficial. Still the relationship was carefully structured to protect the initiative of the corporation and the pocketbook of the city.

While the original structure of the lab was strongly product oriented, a great amount of learning has occurred because of the process of working together. We have definitely learned from each other and have both benefited from the relationship. Even if the project ended today, without the installation of a full scale AYM system, the benefits derived would outweigh the costs incurred.

BUS AND PARATRANSIT TECHNOLOGY I

I see a major R & D need in the coming year for UMTA; in finding a process to encourage corporate involvement with local governments, as contrasted to proving-ground programs, that shifts some of the financial risks to the private sector while protecting the incentive of the corporations by protecting their potential for future profits. The type of relationship that we have had with GM should be fostered and encouraged with other cities and other corporations - the pay-offs are indeed worth the effort.

Now, some more detail about what we've been doing in the area of Automatic Vehicle Monitoring (AVM). We started out to evaluate the potential of AVM for both on-line, real-time applications such as dispatching and emergency location determination; and off-line, batch applications such as route planning and scheduling. The realities of the situation and the indications of potential pay-off from the off-line uses of data have caused us to shorten our horizons and our expections.

What is now called the Transit Information System, is a total system for gathering and processing ridership data; data that has traditionally been collected by drivers and traffic checkers over the last century in the transit industry. The data includes on/off loads, running time, and schedule adherance; down to the bus stop level, if desired. This data is gathered by a "black box" that consists of off-the-shelf electronic hardware; including radios, micro-processors, and computers; and what I call firmware, the programs that let all these pieces of equipment talk to and work with each other.

It's important to remember that the output from the hardware is data; data that could be collected manually if necessary. That advantages of automatic collection are:

1) it requires less manpower to collect the data
2) it provides more realiable data because of the large sample size, say 20%, versus a normal manual sample size of 1-5%
3) it is a dynamic system which can provide data more often, and on shorter notice
4) the data in its raw form is readable by automatic data processing equipment - there is no need for transcribing or keypunching.

The key advantage is the accuracy provided by a large sample size; the ability to factor out day-to-day anomolies that often distort trip level counts when only one or two trips are counted.

The important next step is turning this data into information; information that is usable by management and policy boards to help in making decisions. The limiting factor in use of the data is not the ability to sort it, manipulate it, or manage it; it is our ability, as operations managers or policy planners, to absorb the information that the data has to offer. This is where the software part of the system takes over. After filtering the raw data to remove extraneous values and adding certain external data; the software package sorts, merges and reformats the data to produce reports at various levels of aggragation and for various purposes.

These are the type of reports that helped us make schedule adjustments on three routes that resulted in an 8% savings in vehicle hours and an 11% savings in number of vehicles needed, without reducing the level of service. Remember, this was a first try at using the data and a first cut at new schedules; additional savings may be possible with continuing analysis of these routes. Based on our experiences with "Proposition 13" responses from voters, we feel that it is very important to follow-up on possible productivity savings of this magnitude.

Following-up on this type of new system is going to require some outside help; some help that UMTA can offer through its R & D program. Help is needed in developing appropriate reporting formats - formats that can be used, and will be used, on a day-to-day basis. Formats that must be designed by supervisors, schedulers, route-planners and upper-level managers working with the systems analysts in an interactive process. An experience based training program would logically follow this design process.

We cut our near-term expectations for AVM (or TIS) because we realize what a hard task this local system design, training, and full-scale integration is going to be. There is a future for system-wide, real-time AVM in Cincinnati; but that future must develop through evolution with the primary desire coming from the local staff. It must evolve from a proven off-line system.

Looking to the immediate future, I see one more R & D need that concerns me; and I might add, this is a very selfish need. We are now convinced that

an AVM/TIS system is cost justifiable and are cooperating with an independent evaluation by TSC to see if our reasons for justification are realistic. We are also convinced that the way to buy a packaged system is through a performance bid package, which defines the end product desired and any constraints on the techniques for producing that product. Evaluation of proposals would be based on capital and operating costs, reliability, flexibility and accuracy. This type of bid will allow fair competition between manufactures and will reduce the risk involved for us, in implementing a new technology on a large scale. Hopefully, UMTA can provide the needed technical expertise, through its R & D staff, to help in writing this type of request for proposal. Without help the process is going to be long and incomplete, because of the lack of expertise and constraints on time at the local level.

KARLA KARASH
ASSISTANT SECRETARY, OFFICE OF TRANSPORTATION AND CONSTRUCTION, COMMONWEALTH OF MASSACHUSETTS

Bus and Paratransit Technology I

MS. KARASH: I want to talk about the kind of research and development that would be very helpful to one of the paratransit programs that we have going in Massachusetts--our Share-A-Cab program at Logan Airport. Those of you from out of state who came through Logan Airport may have noticed the signs for Share-A-Cab. The Share-A-Cab program has been going on for about a year and a half now, and it provides for half-fare taxi service to all communities in the Boston Area other than the City of Boston. The service is quite labor intensive because there are four different terminals at Logan Airport, and each terminal has its own Share-A-Cab booth where a passenger can request a Share-A-Cab. There is also a central dispatch station that takes care of assigning passengers to taxis. In theory passengers are guaranteed a ride with the service within 15 minutes of the time they sign up for the service. Actually the dispatchers try to dispatch a cab to the terminals to pick up the passenger within 15 minutes after they receive the call from the booth. So the passenger may have to wait additional time for the taxi to make other pick ups and to travel to the appropriate terminal. The dispatch operation will try to match up to four passengers for the Share-A-Cab service.

One of the major problems with Share-A-Cab is that it's quite a costly service and it's costly because of the four manned booths plus the central dispatch area. It is a natural for an interactive, computerized mechanism to handle the passenger requests. I believe something like a cash machine might work where the customer pays the 50 cents and gets a little ticket that tells him or her that they will receive service by such and such a time. People are used

to using cash machines now, so that is why I suggest a similar mechanism. I think this concept is something that can easily be done given some research effort.

Along with the "cash machine" interface with passengers, we need a methodology to help us assign the best possible taxi to the customer. This should happen immediately if possible, or at least within a few minutes after the passenger registers. Right now a problem with Share-A-Cab is that there's a lot of confusion among customers after they register at the booths. Customers worry that a taxi will not be assigned to them or that it will not show up. Some customers wait a short while and them disappear. I think that we would gain much if we had an algorithm which would allow us to assign passengers immediately to a taxi.

Share-A-Cab suffers from a demand level which is too low to encourage many taxis to play the system. If the service could be made less confusing and more reliable, I believe demand would grow. Better marketing to business would help demand also, but the system would have to be made more reliable before marketing could be effective.

Finally, we need better data on the reliability of the Share-A-Cab service and on the effectiveness and efficiency of the trip scheduling. Computerized systems for assigning passengers to the taxis would give us good data as a byproduct. Right now we have to run through a week's worth of passenger slips by hand to determine if we've run a reliable service and whether the trip assignments have been proper.

Share-A-Cab represents a unique opportunity to develop an

automated dispatching system for an airport design with multiple terminals. I think this is a real challenge and I hope that Bernie Blood is thinking about doing something in this area.

JOSEPH S. SILIEN, EXECUTIVE DIRECTOR
ROCHESTER-GENESEE, N. Y., REGIONAL TRANSPORTATION AUTHORITY

BUS AND PARATRANSIT TECHNOLOGY I

Rochester and M.I.T. and UMTA go back a long way in the story of Dial-a-Ride. In the local area we started with a small rural system in Batavia, New York, without any thought that it was going to be an experiment involved in research and development.

The Batavia Bus Dial-a-Ride service was instituted to replace a faltering fixed-route bus system. The "B-Line" is dispatched manually. Its fleet of seven small buses carries nearly 90,000 passengers each year, providing a good service to the Batavia community of 18,000.

Beginning in 1973, and with the advent of the Federal grant in 1975, the project and its purposes were considerably expanded from the small Batavia service. Dial-a-Ride was viewed as a possible strategy for improving transit service in the Rochester metropolitan area. Dial-a-Ride offered the potential for integration of the fixed route urban bus service with new demand-responsive transit service in low density suburban areas, or as a substitution for the fixed route bus service at times of very low demand. The ability to accomplish these things was viewed as being made possible because of a computer dispatch system which would make optimum decisions in terms of vehicle assignment from a large fleet of vehicles operating over a considerable geographic area. The service was expanded under the grant and the computer technology was pursued vigorously with the Massachusetts Institute of Technology. The story has been filled with successes, and failures as well. On the plus side, the computer dispatch system is operating well. The system had been through a teething period. Unfortunately, there was no way to predict without actually putting it into service what would happen. Extraneous factors, such as a fire, put the computer out of business for about seven months. Nevertheless, at this point the computer is operating successfully

and is now in the process of being transferred to a locally-based machine with a tremendous potential saving in the monthly cost of operation.

Another success is the elderly and disabled special service that grew out of the experiment. The "Lift-Line" provides demand-responsive service on an advanced reservation basis. With the computer there is potential to operate in a fully demand-responsive basis as the fleet size grows. The failures were primarily in the area of service rather than software. Concepts such as subscription services, loops that connected what were thought to be major points of origin and destination, and the substitution of Dial-a-Ride for fixed route service at times of low patronage proved to be unsuccessful. On the hardware side, the most significant problem has been the vehicles, rather than the computer and attendant control input/output devices. We have not found a satisfactory small vehicle to perform this service. In an attempt to compensate, the recently added service areas are being served with Checker sedans, rather than with the small buses which have not withstood the rigors of the older established service areas.

The major problem in the whole experiment stems not from what I have outlined above, but from an unrealistic projection of the economics of providing Dial-a-Ride. There was not deployment strategy. The problem is not unique to this project and has emerged as a theme at UMTA R&D conferences over the years. In the case of this particular experiment, the inescapable fact that became clear to us was that no matter how good the project or the service was, we could not afford to keep it once the demonstration grant was concluded.

In an effort to deal with this, the project was re-structured with a new

emphasis on the economics, and what to do when the demonstration ended. We attacked the problem in two ways. First, the vendor was competitively selected to provide service in two new areas, while service in the two existing areas was continued under the fixed route operator. The vendor in the new areas is a taxi operator. The resulting savings in operating cost is approximately 50 percent in favor of the private operator versus the public provider.

The second aspect upon which the project was restructured involved the finding of a local share commitment in advance from the communities where the new service would be offered, such that if the service is successful, the towns themselves will at least consider funding the 50 percent local share required to keep it running.

The lesson learned is that it is as important to plan for what happens after research and development as it is to plan for experiments being conducted during the project itself. As for continuing R&D needs, answers must be found to the questions of when is the computer really cost effective? Can the computer be cost effective even for a small system by taking the guesswork out of the dispatcher's work? Finally, there remains a compelling need to develop a satisfactory small vehicle for operating these services.
Thank you.

BUS AND PARATRANSIT TECHNOLOGY II

Chairperson: *Anthony Carrano,* Chief Bus Engineer, New York City Transit Authority

UMTA's BUS TECHNOLOGY AND PARATRANSIT VEHICLE DEVELOPMENT PROGRAM: *Bernard Vierling,* Director, Office of Bus and Paratransit Technology, UMTA

UMTA's FLYWHEEL ENERGY STORAGE SYSTEM PROGRAM: *Frank Raposa,* Chief, Electric Power and Propulsion Branch, Transportation Systems Center

Panel: *Frank Venezia,* Superintendent, Vehicles and Industrial Equipment Design, Chicago Transit Authority

Edward Tanski, Vice President, Maintenance and Equipment, Niagara Frontier Transit Metro System, Buffalo, N.Y.

Daniel Morrill, Assistant General Manager and Director of Operations, Southeastern Michigan Transit Authority, Detroit, Mich.

Richard J. John, Chief, Energy Programs Division, Transportation Systems Center

Reporter: *Frederick M. Seekell,* Transit Systems Branch, Transportation Systems Center

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BUS AND PARATRANSIT TECHNOLOGY II

BERNARD VIERLING
DIRECTOR, OFFICE OF BUS AND PARATRANSIT TECHNOLOGY
URBAN MASS TRANSPORTATION ADMINISTRATION

Bus and paratransit services provide the majority of public transportation in the United States today. These services are composed of three elements: The vehicles, with their propulsion systems; the roadways and passenger stops; and the operational systems.

Vehicles range in size from taxis, which are used in paratransit service up to articulated buses. The roadways in most communities are available for operation of the buses and paratransit vehicles, and bus stops or station stops are generally provided along the curb areas adjacent to the streets used by the vehicles.

Operational systems to insure an efficient level of service to the traveller are presently limited in scope and generally do not entail much more than two-way voice radio systems to insure on-time operation.

Looking to the future, a great deal of work remains to be done in the area of vehicles and operational systems, which will increase the efficiency of bus and paratransit services. Future operations may well require substantial efforts on roadways and passenger stops, if bus and paratransit services are pushed to their ultimate capabilities.

In the vehicles currently used in bus and paratransit service which have been designed for their particular usage and are standard -- the standard bus, the three prototype transbuses,

the high capacity bus, and the small bus.

You will notice that I don't have the high capacity bus or the small bus here, but show instead the transbus prototypes, and that's because up until now, we have not really had an effective program on the small bus or the articulated bus, the high capacity bus.

Primary attention in the United States has been directed to standard size 35- or 40-foot bus with a lesser effort having been spent on the articulated and small transit bus. A possible scenario in the future where energy conservation dictates better usage of public transit is a requirement for development efforts in all vehicles from the paratransit vehicles -- up to the articulated bus capable of being operated in bus-trains, and in dual mode-type operations.

The standard size bus, the transbus, will be a low floor vehicle which will permit increased operating efficiency in that the lower floor will reduce the dwell time necessary for boarding the deboarding passengers. This feature will also permit the use of a ramp or a lift at the front door to accommodate wheelchair passengers.

A consortium of operators, Los Angeles, Miami, and Philadelphia, is presently seeking bids for the purchase of 530 production transbuses.

A second consortium intending to purchase 525 additional transbuses is well underway. The low floor feature of the transbus should also be incorporated in other buses and the paratransit vehicles to be used in urban transportation.

Much of our fiscal year 1979 R&D funds will support the transbus development in the form of component testing. Plans are also underway to push for the development of a United States built articulated transbus after suitable transbus designs have been established and put into production. Funding will probably be provided to manufacturers of transbus for the development of an articulated design from the basic transbus design.

The high capacity bus. UMTA's efforts in the development of the high capacity bus have been limited in the past to the determination that an articulated-type large bus can be more universally utilized in the United States than a double decker bus because of restrictive height limitations in many of our cities where buses must operate under bridges and overpasses.

Two important features of an articulated bus are the hinge which provides the appropriate positioning of the rear section of the bus relative to the forward section and the location of the propulsion system within the bus. Most articulated buses have the propulsion system at the rear of the forward section which makes it virtually impossible to have a low floor.

UMTA is currently testing a low floor articulated VO-V2 bus from Germany and this is in the prototype stage. It combines a new hinge design with a propulsion system located at the rear of the trailer section and driving the trailer wheels. If our tests confirm the viability of this design approach, we will have achieved a major breakthrough in the development of a low floor articulated bus. That bus is currently in Detroit. It will be put on a test track in Ohio. It will go from there to

Pittsburgh for demonstration; from there to Baltimore, and then back to Germany.

During this month's stay in this country, we have invited all of the manufacturers of buses, the operators of buses who have in the past indicated an interest and been part of the bus technology, high capacity bus group, to come and witness this bus at any of these particular locations and also to hold a meeting at the test track in Ohio.

It is possible that a low floor, small bus down to thirty feet in length can also be built on transbus tooling. These buses would have the same inherent transit qualities and characteristics necessary for the heavy duty operation required in public transit. The market for small buses at the present time has not been sufficient to encourage the major manufacturers to enter the market.

It is probable, therefore, that the development of a bus less than thirty feet in length may require some special effort on the part of the government to encourage development. I've been very happy in the last couple of weeks to see the activity in small bus manufacture. In the previous session to this one, indications were that there are companies that are now beginning to build heavy duty small buses and that would delight me because I think that the job of designing these buses certainly should be spearheaded by the manufacturing group and not by a government agency.

If we can participate in testing and in helping in the development of that bus, then that certainly is a job that we

would want to take on.

Paratransit vehicles. Here again, the market for such vehicles is unknown at the present time. One would think that the taxi industry which buys somewhere between 30,000 and 50,000 vehicles a year would provide an adequate incentive for a major manufacturer to develop a vehicle meeting the specific requirements of these operators.

Unfortunately, this has not been the case, and at the present time paratransit services have been provided with converted sedans, station wagons, limousines, vans, and in some instances, small buses. An increasing number of transit services in the paratransit field are being aimed at the elderly and handicapped groups.

Presently available vehicles must be adapted to fulfill these requirements and in many instances are not really satisfactory. UMTA has attempted to encourage major manufacturers to build such a vehicle which would meet most of the paratransit needs with a single, multi-payload vehicle, rather than a multi-vehicle fleet. This would certainly reduce the logistics problem of the paratransit operator by reducing to one-type vehicle his needs for spare parts, training, tooling and so forth.

It is entirely possible, due to market conditions under the federal requirement for fuel economy that will shape the design of future passenger cars, that UMTA will have to underwrite to a greater degree than hoped for the development of a specific paratransit vehicle if only to accommodate the elderly and handicapped.

One of the areas in which we are working now with NHTSA is in the area of this corporate average fuel economy requirement which tends to downsize the vehicle at the same time that we at UMTA are trying to encourage more people per vehicle by van pooling and shared-ride taxis. So, we have had a number of discussions with NHTSA. We are working with them toward the possibility of some special legislation which might be necessary to insure that we will have a vehicle that would not be illegal and that would accommodate the requirements of the paratransit field.

The threatened limitation on adequate petroleum fuels in the future and the need for reducing exhaust noise and emissions in the urban area require that we explore propulsion systems that do not have to rely on petroleum fuel. It is safe to say that electric energy which can be developed from many of the basic fuels should be available in the urban areas well into the future. For this reason, long range planning for propulsion systems within UMTA is being aimed at the ultimate use of electric energy for the propulsion of all vehicles in the bus and paratransit service.

UMTA's flywheel energy storage system program is one that offers a potential, long-range solution to the petroleum problem while at the same time reducing noise and emissions in the urban area. This program will be discussed in detail at this meeting by Frank Raposa of TSC.

Interim propulsion systems are being developed for the purpose of reducing noise and emission problems inherent in

otto-cycle and diesel engines. One such system presently under joint development with the Department of Energy is the gas turbine. A turbine engine developed for DOE will be installed in a number of advanced design buses for service tests and evaluation at a selected property.

At the same time a similarly equipped advanced design bus and a standard powered advanced design bus will be endurance tested on a test track. Although the turbine can be operated with a wider range of fuels, has less vibration and better emissions characteristics than the current diesels, it is considered only an interim solution to the urban bus problem.

TSC is monitoring our propulsion system development program and that is being discussed in another session.

Roadways and passenger stops. At the present time roadways for the bus and paratransit vehicles are already available and serve the private automobile as well as the bus and paratransit service. This is one of the reasons that bus service has suffered over the years as the number of vehicles on the road have expanded, causing congestion.

Bus stops, on the other hand, have been rather spartan in their accommodation of passengers and should be upgraded in the future to provide greater protection, comfort, safety and information to the passengers.

There was a beautiful picture that I tried to get for a slide to show here of one of the Metro stations -- air conditioned, beautiful accommodations inside, with escalators - the passenger then comes out and gets on the bus, and when he leaves that

beautiful building, he's right out in the wind and the weather. This is an area in which we will have to spend time and effort in the future.

This will be particularly true when real time transit information can be made known to the passenger and available to him at the local bus stop. Work is being done to this end in the current multi-user automatic vehicle monitoring system for areawide coverage scheduled to be tested in the Los Angeles area in 1979 to 1980 period. This is being described in detail by Bernie Blood of TSC in another session.

In the future it is probable that work will need to be done on the roadways, freeways, and busways to provide automation for buses similar to the automation currently being developed for the downtown people movers. An automatic guideway transit system for bus operations should benefit from the current development of this AGT equipment.

It is conceivable that dual mode involving trains of buses and/or articulated buses may be operated much like current rail systems, only such operations will be conducted on freeways and expressways and, perhaps, even busways which are separated appropriately from other traffic.

As the development of automated guidance systems and controls reach maturity in the automated guideway transit field, these equipments can be incorporated in buses to serve a similar purpose. They should be far less expensive than the full development of a separated guideway system presently envisioned for most DPM and AGT systems.

The operational efficiency of transit bus systems has lagged behind that of transit rail systems primarily because buses share the same roadway as all other traffic, but probably due partially also to the inherent flexibility of the bus system which do not require the regulated schedule operations so necessary in rail systems just for the insurance of safety. There is no reason, however, with the current state of the art of location and communication systems why the bus cannot be operated on an exclusive right of way on as reliable a schedule as rail services.

At the present time, UMTA is sponsoring the development of a multi-user areawide automatic vehicle monitoring system which will be installed in the Los Angeles area for an exhaustive test program. This system will permit the dispatch office to know at all times, on a real time basis, the location and general status of each vehicle in its fleet.

The location information and display will be done automatically without any requirement being placed on the driver.

Transmissions of location information will be done by digital communications. In a normal operation the computer will determine the optimum action that the driver should take to keep on schedule and will automatically transmit specific instructions to him without dispatcher intervention.

They have the capability of flagging each bus, of identifying automatically if the bus is ahead of schedule, behind schedule, or if he has an emergency.

Although the system being developed for Los Angeles is rather sophisticated, it is anticipated that simpler, less

sophisticated systems can be developed and made available to smaller communities where high level service is equally important, but the problem can be solved with a less complex location and communication system. An AVM system should have a broad application not only in scheduled and paratransit public transportation services, but also in private industry where continuous monitoring of vehicle location is extremely important where companies are shipping highly valuable or critical material.

Although the system being planned for Los Angeles should have a positive cost benefit impact, there is still a considerable amount of effort that should be made to simplify and reduce the cost of providing this type of service information.

One of the areas to be tested in Los Angeles is the provision of information to the passengers at designated bus stops. This will be current, real time information indicating to the waiting passenger when his bus will be available, its route, and current location. This kind of information is important to the passenger if he is going to be able to depend upon public service in the future.

Another area of extremely important development is in the integration of paratransit service with scheduled transit service. In the American city which is developed around the private automobile where the driver has complete freedom to establish his route and schedule at all times, the population densities don't lend themselves to fixed route transit systems which were originally very popular and very successful earlier in the century.

As a result, many communities are comprised of multi-car

families and the population density will not support these scheduled operations even though the service level that is provided is rather inadequate. It's a loss leader for the operator. It's a lack of service for the user, and another way has to be found to solve these problems.

In these communities, some form of paratransit probably will be more efficient and economical and should be integrated into the scheduled transit system at appropriate points to reduce the total transportation cost to the passenger and the operators.

Furthermore, with paratransit service feeding a fixed route bus system, the bus operator will be getting the maximum benefit in revenues available to him. If the paratransit operation is conducted by a taxi operator, the paratransit service should augment his income and provide an expanded operating base not presently available to him.

Paratransit integration is currently being tested in Rochester, New York, and will be tested elsewhere in the country shortly.

In all of its efforts, UMTA is developing the necessary tools required to meet the broad spectrum of transportation requirements that exist throughout the country. It will be up to each local community to orchestrate the use of these tools to meet its particular needs. In some cities the full spectrum of vehicles, control systems, roadways and stops will come into play. In others, only the simplest and barest of vehicles and systems will be required.

At the present time there are over two thousand cities in

the United States whose sole public transit is in the form of taxi cabs. It is therefore apparent that our efforts in developing paratransit vehicles and simple operational systems are equally important as that of developing the most sophisticated systems which we know will be required.

An example would be the Shirley Highway express bus service operation which you've been hearing about from time to time over the years. During the rush hour approximately 60,000 people are currently using that corridor. There are about 22,300 vehicles involved in moving those 60,000 people, and if you were to carry the same level of passengers which is 32 people per vehicle that are currently using the bus service, you could meet all of that requirement with 1800 buses. It gives you something to think about and certainly in the event we had a great emergency, I take great comfort in the fact that I think our bus and paratransit industry could move in and take over and meet that emergency.

FRANK RAPOSA
CHIEF, ELECTRIC POWER AND PROPULSION BRANCH
TRANSPORTATION SYSTEMS CENTER

The flywheel energy storage program is an element of the jointly sponsored DOE/DOT urban transit motor vehicle energy conservation and propulsion technology program. The program is sponsored by the UMTA Office of Bus and Paratransit Technology, and by two DOE organizations: the Division of Energy Storage, and the Division of Transportation and Energy Conservation.

The managing organization of that program is the Transportation Systems Center and the Electrical Power and Propulsion Branch, the organization that I am the manager of.

The program resources being applied are 12 million dollars of DOT money, 1.5 million dollars of DOE energy storage money, and .8 million dollars of DOE transportation and energy conservation money, for a total program resource of 14.3 million dollars.

The program's goals and objectives are to reduce dependency on petroleum fuels, to increase fuel energy efficiency, to minimize the impact of noise and pollution on the environment, to decrease life cycle costs, and to stimulate development of cost competitive urban transit motor vehicle propulsion systems.

The overall program plan is to review and assess the applicability of new propulsion technologies, looking at heat engines, heat engine hybrids, wayside electric systems, electric hybrids, and the flywheel. We will assess the deployment potential for these new propulsion systems. We will fabricate, test and

evaluate flywheel energy storage system engineering prototypes, and we will then transfer that technology to industry.

I'm going to concentrate the rest of this presentation to the flywheel energy storage activity element of the program. Our objective is to assess the applicability of flywheel energy storage technology to urban transit motor vehicles. It is a multi-phased program -- phase one being a feasibility study which was completed in 1977. Phase two is development of experimental vehicles, which we are about to launch off into. Phase three will be demonstration of those experimental vehicles. Phase four will be a production and deployment phase.

I'd like to spend about five minutes reviewing the results of the phase one program, the feasibility study program. It was a program conducted by the General Electric Company as one contractor, and by the AiResearch Manufacturing Company of California as the second contractor. These contracts were competitively awarded in 1976.

The primary work tasks were to establish propulsion system requirements. This was accomplished with close cooperation with several transit authorities. Flywheel propulsion concepts were derived, baseline vehicle concepts were defined, comparative analyses activities were conducted of the flywheel propulsion concepts compared to the baseline vehicles, concepts were finalized on the flywheel, design studies were conducted, life cycle-costs analyses were performed, and phase two planning activities were conducted. The final reports were published in October of 1977.

An APTA task force monitored this program, and there were two APTA reviews, one in December, 1976, and another one in May of 1977. The performance characteristics of the flywheel bus are shown on Table I.

In the component selection process, first priority has been given to cost, not only in the initial cost, but in the supporting facility maintenance costs necessary to support this concept.

Performance -- it had to be equivalent to a contemporary diesel engine bus. Weight is a consideration, particularly with respect to energy consumption and axle load limits. It has to fit in an existing bus and it had to be compatible with the low floor profile.

The concept that was selected is as shown in Figure 1. It is a flywheel package, coupled to an inductor alternator which are packaged in an evacuated housing to minimize power losses and maximize energy storage capability. The flywheel-alternator output power is then processed by a dual converter which controls the power to a traction motor.

We take power off the flywheel-alternator to supply the vehicle auxillary loads which we identify as vehicle hotel loads. The system has a total weight of approximately 7,000 pounds. This compares to approximately 5,500 pounds of a V-8 diesel enginer power plant in a 40 foot diesel bus.

The flywheel package is shown in Figure 2.

The flywheel package assembly has both the flywheel and the inductor alternator in a single housing, with the inductor alternator being on the top, and the flywheel itself being on

the bottom. The flywheel is constructed of steel and it is constructed of multiple discs. There is a containment system built into the flywheel housing which has the requirement to contain a burst section of the flywheel.

One of the requirements of the phase one program was to look at modularity for obtaining various flywheel hybrid systems. Figure 3 depicts three of them. The upper one shows a flywheel propulsion system that you would apply to a trolley coach to get extended off-wire operation of the trolley coach. The middle figure depicts a flywheel battery hybrid system wherein you would augment the battery system with a flywheel and, as a consequence, greatly reduce the size of the battery pack that is required for this kind of system. The impact of adding the flywheel is to significantly increase the range of the vehicle.

The bottom chart depicts a flywheel diesel hybrid where the flywheel augments the diesel engine and uses a much smaller diesel engine than you would normally require. You are able to recuperate breaking energy into the flywheel, and accomplish such things as a significant decrease in your fuel consumption -- and to minimize the impact of smoke when accelerating, wherein the flywheel is used for the accelerating power and not the engine.

I'll go through some of the results of the phase one study. Figure 4 depicts the energy requirement comparisons. In the far righthand column, we get the fuel consumption of each of these vehicles in common dimensions; namely, in BTU's per mile. On the diesel bus, we currently are experiencing about 41,000 BTU's

per mile. Comparing that to the pure flywheel bus, we see that there is a potential savings of about 25 percent. This is derived principally from being able to recover the breaking energy of the vehicle, storing it back in the flywheel, and reusing that energy for acceleration. Although contemporary battery buses do utilize regeneration, the amount of weight for the batteries results in significantly higher fuel consumption of a battery bus when compared to a diesel bus. Again, in the hybrid configurations with the flywheel, you can accomplish significant reductions in battery weight and get fuel consumption numbers, again competitive with conventional diesel buses.

Table II shows life cycle cost estimates. In looking at life cycle cost estimates of these various vehicles, this table makes a one-to-one correspondence between a baseline vehicle and the appropriate flywheel vehicle. In comparing flywheel energy storage to conventional trolley coaches, we see that we are quite competitive. When we look at flywheel diesel hybrids as compared to pure diesels, again we see a very cost competitive situation. Looking at pure flywheels compared to pure diesels, you again see a cost competitive situation.

Summarizing the phase one conclusions, these systems can be competitive in life cycle costs. They can meet or exceed transit property maintenance requirements, and they do require less energy and can be independent of petroleum. They do offer substantial noise reduction compared to the diesel bus, and do eliminate or minimize emissions in the local environment. The modularity concept is available, and the system is compatible

with installation in low floor buses.

Let me now talk about the phase two program. The phase two program will concentrate on the development, test, and evaluation of engineering prototype vehicles. We will continue with the contractors of phase one; namely, the General Electric Company and AiResearch Manufacturing Company of California. The contract costs are approximately five million dollars per contract. The estimated contract awards are February-March 1979. Contract completion dates will be the end of January, 1983. The schedule that will take us through system engineering, component design, component test and evaluation, testing at the contractors' sites in late 1982, and in 1983 a test activity which would take place in Cambridge. Critical program reviews will occur at twelve months, twenty-four months, and thirty-six months into the program.

Figure 5 shows the installation of the engineering prototype in the vehicle. The entire package would be packaged in the existing engine compartment of the diesel bus.

The technical risks that we see in the phase two program are the integrity of that flywheel rotor over its projected life span, the ability of the flywheel containment system to protect against a ruptured flywheel disc, the homopolar inductor alternator design, the bearing design, lubrication and cooling of high speed rotating machinery operating in a vacuum and the performance and reliability of the power electronics equipment.

The flywheel package must have a life time of one million charge/discharge cycles to obtain a thirty-year life time. That

has yet to be demonstrated in any flywheel activities that have been done to date. So, we look at that as a technical risk. The ability of the flywheel containment system to protect against the ruptured flywheel will be demonstrated by testing to destruction at least one flywheel package to verify the integrity of the containment system.

The inductor alternator design has never been done before at the power levels required and we look at that as a risk as well as the operation of the system in a vacuum, the bearing design and lubrication system against the thirty-year projected life time. The final risk that we have identified is the performance and reliability of the power electronics equipment. When you look at applications like LRV and BART, there is a whole history of learning experience in the application of power electronics.

The challenges that we see in the program include designing to cost, which is a critical element in the life cycle cost analysis; and to preserve the component modularity, not only for the various kinds of hybrids but for applying the concept itself to a spectrum of vehicles from the full size transit bus to the smaller sized buses, schools buses and vans. Another technical challenge is to verify the acceptability of the gyroscopic effects of the flywheel. The flywheel is mounted in the vehicle so that its axis is in the vertical plane with gyroscopic effects minimized. We still want to run a series of tests such as the bus bouncing in and out of potholes, bouncing up and down twelve-inch curbs, to measure the effects on the installation system

and on the suspension system of the bus.

The results we expect to achieve in the phase two program will be to have demonstrated performance in a full-sized bus. We will have developed realistic bases for estimating production costs. We will have demonstrated it on two buses of competitive designs. We will have verified the energy economy of the system, and we will have done some simulated transit operations testing here in Cambridge.

The follow-on activities to the phase two program would be a preliminary operational deployment and demonstration phase where we would utilize the services of up to six transit authorities to retrofit up to six coaches in each authority with flywheel energy storage propulsion systems. We will then attempt to get 50,000 miles of operation on those thirty-six vehicles. The exact number of vehicles and transit authorities that we would be able to interact with depends a great deal on the funding resources that would be available in that phase of the program. I should emphasize that at the beginning of the phase three program, we envision a complete redesign phase to utilize the experience of phase two.

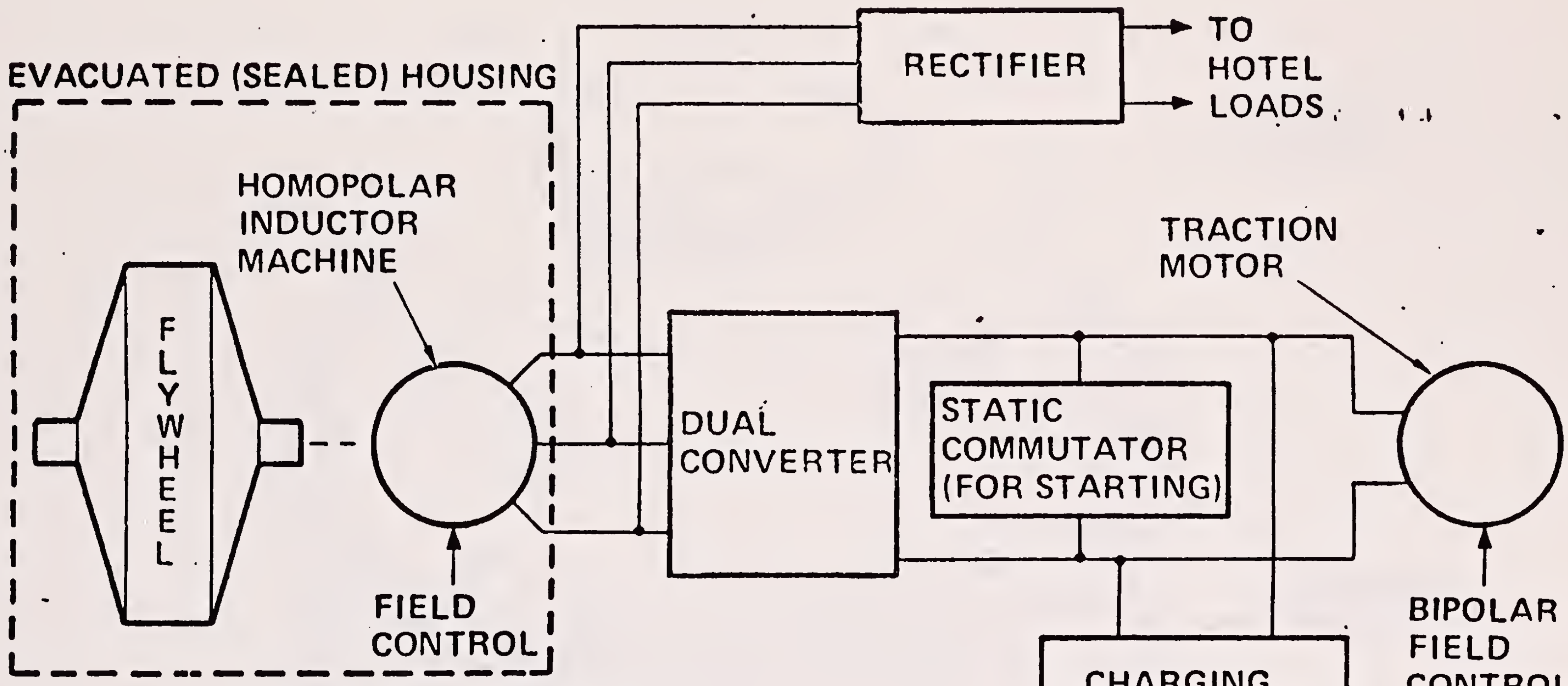
The phase four program is procurement for operational deployment which would again be proceeded by a redesign phase to take the benefits of the phase three testing.

TABLE I

FLYWHEEL BUS PERFORMANCE

(BASED ON INSTALLATION IN TRANSBUS)

O MAXIMUM SPEED: 55MPH	
O MAXIMUM ACCELERATION:	3.5 MPHPS(JERK LIMITED)
O ACCELERATION TO SPEED:	30 MPH IN 10 SEC. 55 MPH IN 26 SEC.
O GRADE PERFORMANCE:	3.0 MILES AT 55 MPH ON 5 PERCENT GRADE
O FREEWAY PERFORMANCE:	8.9 MILES AT 55 MPH ON LEVEL
O RANGE BETWEEN CHARGES (MI):	
	3.8 (CYCLE B, FULL HOTEL LOAD)
	4.5 (CYCLE C, FULL HOTEL LOAD)
	4.9 (CYCLE B, MIN. HOTEL LOAD)
	6.4 (CYCLE C, MIN. HOTEL LOAD)



- TOTAL WEIGHT 7600 LB
- QUIET CLEAN PROPULSION
- COMPLETE ROUTE FLEXIBILITY BETWEEN CHARGES
- EXCELLENT ENERGY EFFICIENCY

S-18003

FIGURE 1 - FLYWHEEL ENERGY STORAGE CONCEPT

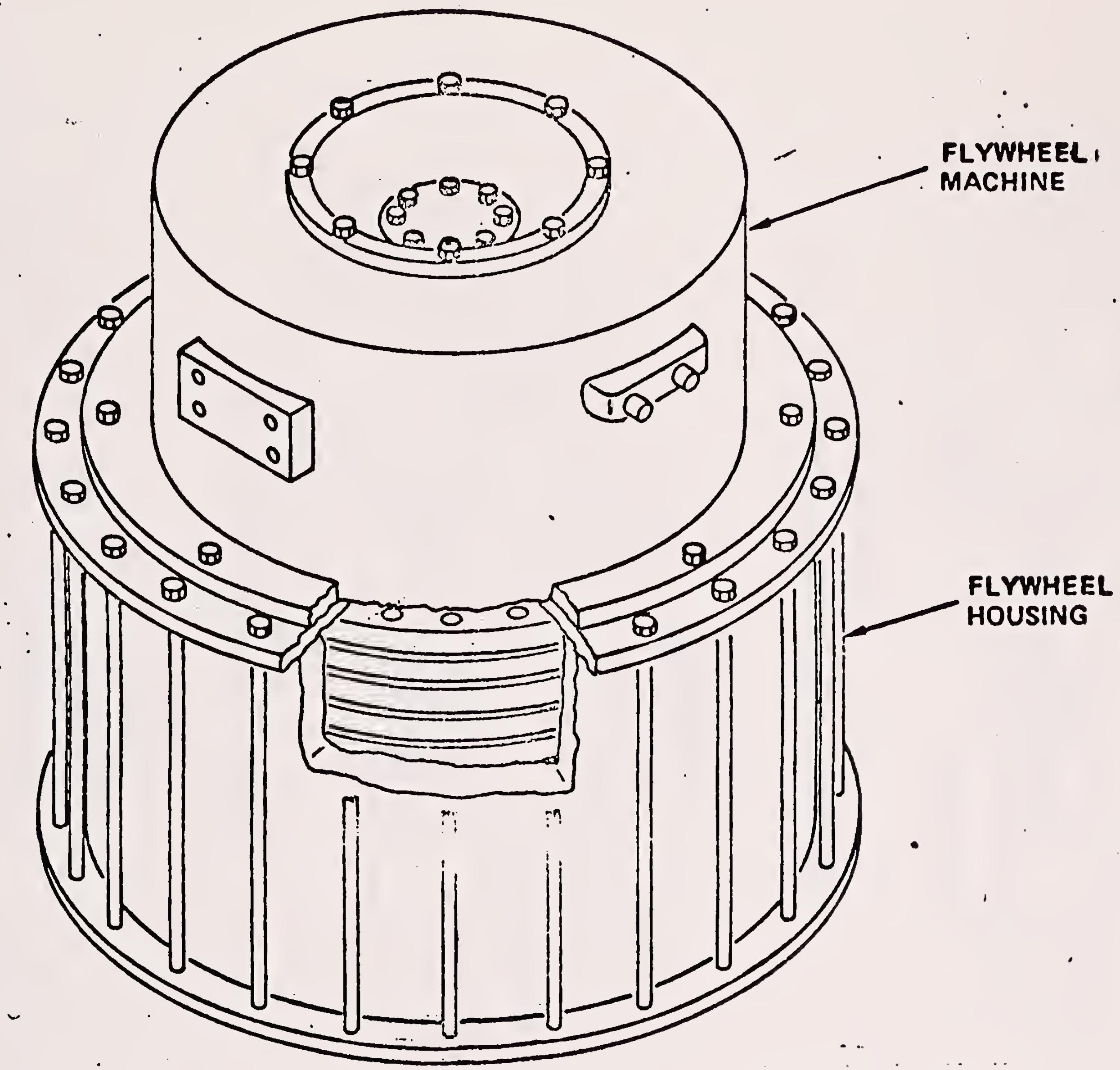
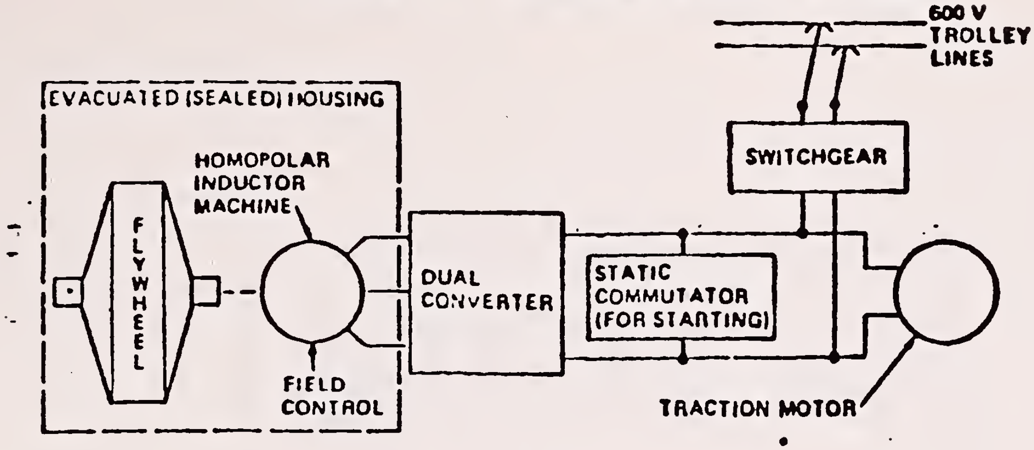


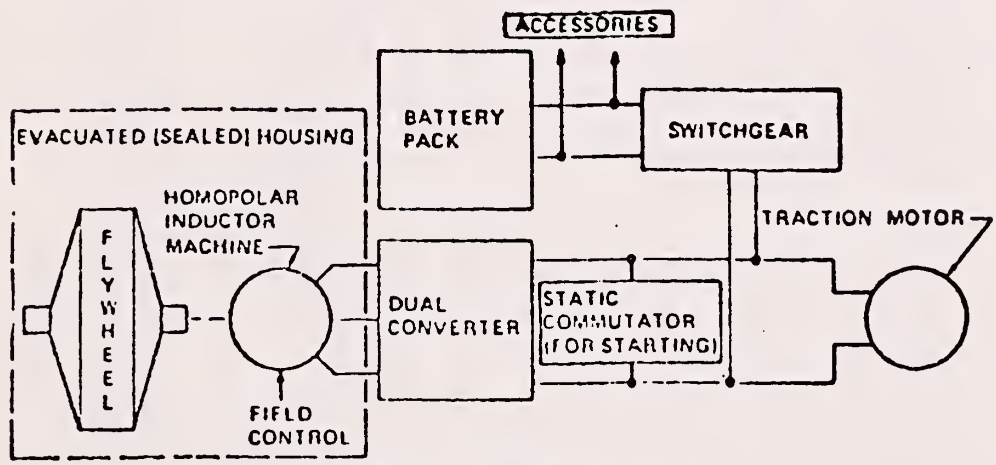
FIGURE 2 - FLYWHEEL PACKAGE ASSEMBLY

FIGURE 3 - FLYWHEEL HYBRID SYSTEMS



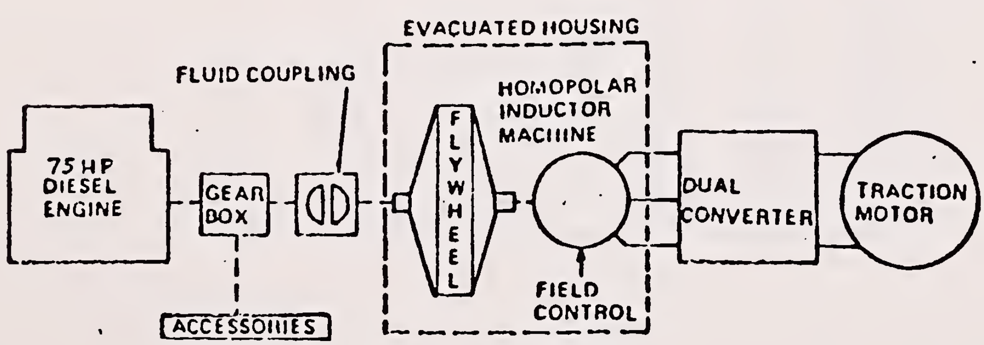
• TOTAL WEIGHT 2600 LB

(A) FLYWHEEL/TROLLEY COACH



• TOTAL WEIGHT 17,700 LB

(B) FLYWHEEL/BATTERY



• TOTAL WEIGHT 5300 LB

(C) FLYWHEEL/DIESEL ENGINE

FIGURE 4

ENERGY REQUIREMENT COMPARISON
(BASED ON COMPUTED VALUES FOR DRIVING CYCLE C)

Vehicle	Computed Energy Consumption		Equivalent Btu/mi
	At Vehicle	At Source	
Diesel bus	0.272 gal/mi	0.302 gal/mi	40,599
Trolley coach	4.08 kW-hr/mi	4.56 kW-hr/mi	38,800
Battery bus	5.27 kW-hr/mi	5.60 kW-hr/mi	47,610
Pure flywheel bus	3.31 kW-hr/mi	3.51 kW-hr/mi	29,900
Flywheel/battery hybrid	4.46 kW-hr/mi	4.74 kW-hr/mi	40,300
Flywheel/diesel hybrid	0.240 gal/mi	0.267 gal/mi	35,820
Flywheel-augmented trolley coach	3.23 kW-hr/mi	3.43 kW-hr/mi	29,180

TABLE II

LIFE CYCLE COST ESTIMATES

Basic System	Base Line Standard		Contractor Estimates: AiResearch	Contractor Estimates: General Electric
I. Continuous Wayside Electric:				
LLC(cents/mile	114	PURE FLYWHEEL	97	103
II. Diesel:				
LLC(cents/mile)	97	FLYWHEEL/DIESEL	94	NA
III. Trolley Coach (T/C)				
LLC(cents/mile)	114	T/C AUGMENTED	99	104
IV. Battery Bus				
LLC(cents/mile)	147	FLYWHEEL BATTERY	129	127