U.S. Department of
Transportation

MEDIUM- AND HEAVY-DUTY VEHICLE R&D: STRATEGIC PLAN

April, 2000

MEDIUM- AND HEAVY-DUTY VEHICLE R&D:

STRATEGIC PLAN

U.S. Department of Transportation

April, 2000

Prepared by:

United States Department of Transportation
Research and Special Programs Administration
John A. Volpe National Transportation Systems Center
Transportation Strategic Planning and Analysis Office
55 Broadway
Cambridge, Massachusetts, 02142-1093

This document is available on the World Wide Web at http://scitech.dot.gov

TABLE OF CONTENTS

LIST OF FIGURES

Figure **Page**

LIST OF TABLES

Table **Page**

1. INTRODUCTION

This plan addresses Department of Transportation (DOT) research and development activities that support improvements in the environmental characteristics and energy efficiency of medium- and heavy-duty vehicles[1] and, by increasing the long-term capability of domestic companies to produce clean and efficient vehicles, also foster future economic growth and productivity. This plan documents the early stages of what is expected to be an ongoing strategic planning process specific to research and development (R&D) in these areas. This R&D complements, and is coordinated with, efforts focused on other strategic goals for transportation, including transportation safety—the Department's most important goal.

DOT's medium- and heavy-duty vehicle programs are distinct in at least three important respects. First, in the case of the Advanced Vehicle Technologies Program (AVP), federal resources are being focused on truly revolutionary technologies—electric and hybrid-electric propulsion—for medium- and heavy-duty vehicles. In contrast, heavy vehicle research supported by the Department of Energy (DOE) is focused primarily on making improvements to the diesel engine—a technology upon which these vehicles have relied for many years. In addition, the AVP addresses multiple vehicle types—examples include buses, trucks, locomotives, and marine vessels—unlike the Partnership for a New Generation of Vehicles (PNGV), which is focused on automobiles. AVP projects are coordinated with the Intelligent Vehicle Initiative (IVI) and other departmental safety programs—in particular, those of the National Highway Traffic Safety Administration (NHTSA) and the Federal Motor Carrier Safety Administration (FMCSA)—in order to ensure that next-generation medium- and heavy-duty vehicles will meet future safety standards.

Second, DOT's R&D programs, in particular the AVP, benefit from innovative contracting and management processes, reduced overhead, and collaborative efforts which maximize the impact of the funding. AVP funds are cost-shared, and are allocated through a competitive team-based peer review process in which concept papers based on broad performance guidance are first solicited from the eligible regional consortia and then full proposals—the basis for awarding funds—are requested for those ranked highly. Funding is awarded through "other transactions" authority, a non-procurement instrument that involves payments based on cost-shared accomplishment of agreed-upon milestone objectives and operates outside a number of acquisition regulations. Other transaction agreements are used in lieu of standard contracting mechanisms to expedite and streamline project development and to enhance participation by the private sector. This non-traditional, industry-driven, cost-shared approach to Federal contracting for research and development increases the commitment of the partners, leverages valuable research funding, strengthens the likelihood for success, and reduces risk to the Federal investment.

Third, DOT manages two R&D programs that focus specifically on the development of advanced technologies to improve publicly supported passenger transportation. Through the Federal Transit Administration's (FTA's) Equipment and Infrastructure R&D, DOT is pursuing

[1] For purposes of this plan, medium- and heavy-duty vehicles are defined as transportation vehicles, other than motorcycles and aircraft, that are not currently subject to federal fuel economy standards. These standards currently apply to cars and trucks that weigh at most 8,500 pounds.

important advancements in both transit buses and transit rail systems. Also, through the Federal Railroad Administration's (FRA's) High-Speed Ground Transportation (HSGT) program, DOT is promoting the development of intercity passenger transportation systems that will provide a time-competitive alternative to air and/or automobiles for medium-distance trips. These activities are both distinct in their focus on improving the performance of transportation systems in which scarce public resources play a particularly important role.

DOT is involved in a number of additional programs that support the advancement of technology for medium- and heavy-duty vehicles. The Maritime Administration (MARAD) and Coast Guard (CG) are involved in partnerships to develop fuel cells for marine vessels. The Intelligent Transportation Systems (ITS) Joint Program Office (JPO) manages the Department's multimodal ITS Program, including applications for commercial vehicles. DOT also manages funding for the University of Alabama's Center for Advanced Vehicle Technologies (CAVT), which was established in September of 1998 and focuses on new vehicle technologies, computer-based modeling tools teaching advanced technology, and partnering with regional industry.

2. BACKGROUND

2.1 Previous Strategic Planning

In 1997, the National Science and Technology Council (NSTC) Committee on Transportation Research and Development—with members from DOT, DOE, EPA, NASA, and the Departments of Defense (DoD) and Commerce (DoC)—completed the *Transportation Science and Technology Strategy*, which offers a framework for meeting our national transportation goals of safety, security, energy efficiency, global competitiveness, environmental quality, and accessibility to transportation for all Americans. The *Strategy* identifies twelve strategic partnership initiatives, including one focused on next-generation motor vehicles and ships.

In April, 1999, the NSTC Subcommittee on Transportation Research and Development[2] broadened the 1997 *Strategy,* incorporating an even greater role for the larger transportation community. Further development in close collaboration with State, local, and tribal government agencies; academic institutions; and industry led to the completion of the *National Transportation Science and Technology Strategy*, which identifies national goals and desired outcomes for the transportation system. The 1999 *Strategy* refines the partnerships identified in 1997, including the *Partnership on Next-Generation Motor Vehicles and Ships*, which was expanded into the *Partnership on Next-Generation Transportation Vehicles*. The vision of the partnership for Next-Generation Transportation Vehicles is a far more sustainable transportation system with fewer harmful environmental impacts and reduced dependence on fossil fuels. The goal is to develop internationally competitive, domestically produced transportation vehicles that achieve unprecedented gains in fuel efficiency and in both environmental and operational performance, including reduced greenhouse gas emissions.

2.2 Emissions and Energy Trends

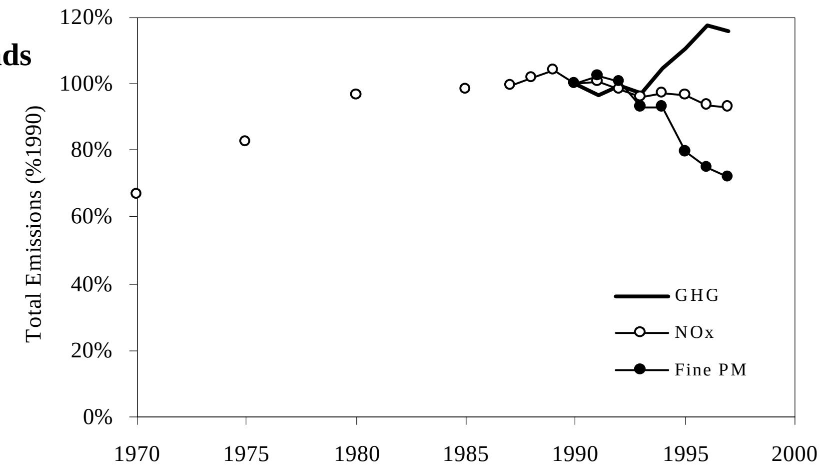


Figure 1. U.S. Emissions of Greenhouse Gases (GHG), Nitrogen Oxides (NOx), and Fine Particulate Matter (PM) from Medium- and Heavy-Duty Vehicles

In considering medium- and heavy-duty vehicle R&D, three general trends are of particular interest. First, the U.S. has made significant progress toward the reduction of regional and urban air pollutants such as lead, tropospheric ozone, carbon monoxide (CO), and fine particulate matter (PM). Medium and heavy-duty vehicles, many of which rely on efficient diesel engines, are especially important as emitters of both fine PM and ozone-forming nitrogen oxides (NO_X). As shown in Figure 1, fine PM emissions from these

[2] Under a 1998 reorganization of the NSTC, the Committee on Transportation Research and Development became a subcommittee under a new NSTC Committee on Technology.

vehicles have fallen dramatically since 1990 and NO_X emissions are falling gradually from a period of relative stability between 1980 and 1990. This reflects the regulation of both the quality of highway diesel fuel and the emission rates of engines used in medium- and heavy-duty highway vehicles. New standards for locomotives and marine vessels and forthcoming increases in the stringency of NO_X standards for heavy-duty highway vehicle engines should contribute to a continuation of these trends.

Second, although the world will never run out[3] of oil, the price of petroleum in constant 1997 dollars is projected to increase from about $17 per barrel in 1995 to as much as $30 per barrel in 2020.[4] Further, petroleum supplies are already geographically concentrated—particularly in the Persian Gulf—and are projected to become even more so in the future. The U.S. spent $61 billion on petroleum imports in 1997, and is projected to spend between $100 and $158 billion (in 1997 dollars) on petroleum imports by 2020. Most of the underlying projected increase in consumption occurs in the transportation sector, which accounted for about 65 percent of U.S. petroleum use in 1997. That share is projected to grow to 69-72 percent by 2020. As shown in Figure 2, energy demand for medium- and heavy-duty vehicles, after dipping in the early 1980s, has resumed a steady upward trend and has more than doubled since 1970.

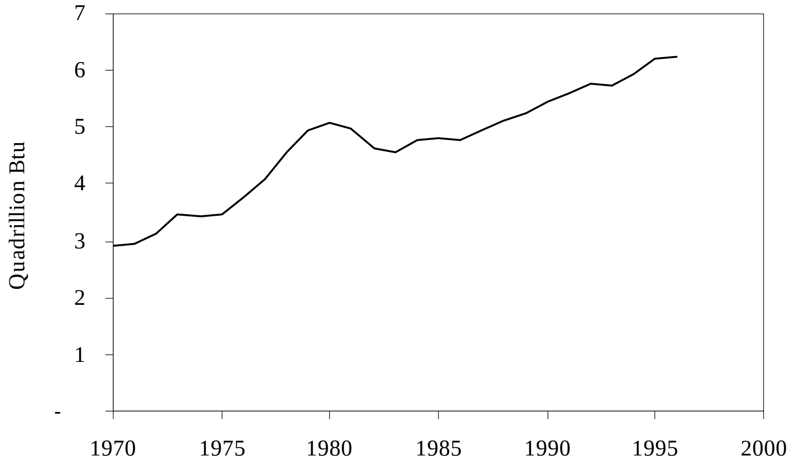


Figure 2. U.S. Energy Consumption by Medium- and Heavy-Duty Vehicles

Although this steady growth in energy consumption can be related to continued growth in travel and shipping, it also results from the fact that efficiency improvements over the last three decades have been modest for medium- and heavy-duty vehicles. As shown in Figure 3, during the same period in which the per-mile energy consumption of the average automobile fell by more than 35 percent, that of the

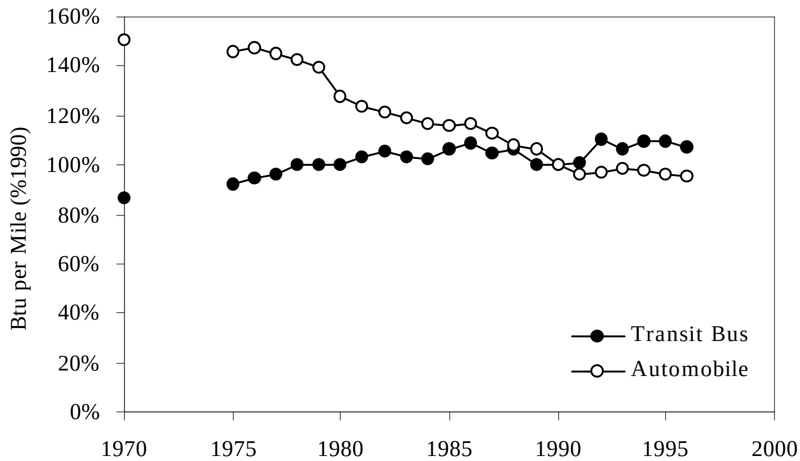


Figure 3. Energy Intensity of Automobiles and Transit Buses

[3] It will, however, eventually become prohibitively expensive to extract remaining oil resources.

[4] Such projections are uncertain. By 2020, it is also possible that petroleum prices will decline slightly to about $15 per barrel (in constant 1997 dollars).

average transit bus actually **rose** by more than 20 percent. As a result, and because of changes in ridership, transit buses in some areas of the country now use more energy per passenger-mile than automobiles. On the other hand, the energy intensity of freight transportation has improved considerably over the same period. Combination trucks now use roughly 20 percent less fuel per mile than in 1970. Accounting for changes in both vehicles and operations, domestic waterborne commerce and Class I freight railroads now consume about 24 percent and 47 percent less energy, respectively, per ton-mile. However, those improvements have been more than offset by continued growth in the freight sector. Absent further improvements in vehicular efficiency, energy consumption by medium- and heavy-duty vehicles should continue to grow steadily with future increases in population and gross domestic product.

Third, in 1992, the U.S. ratified the United Nations Framework Convention on Climate Change (UNFCCC), which called upon developed countries to voluntarily reduce greenhouse gas (GHG) emissions to 1990 levels by the year 2000. The U.S., like virtually every other developed country, will not achieve this goal. Despite significant increases in automobile efficiency between 1970 and 1990, further emission reductions in the transportation sector have been particularly elusive. As shown in Figure 1, GHG emissions from medium- and heavy-duty vehicles have increased by nearly 20 percent since 1990. Without efficiency improvements and/or shifts to less carbon-intensive fuels, these emissions, like energy consumption, should continue to grow steadily.

2.3 Research Needs

Based on past experience, it is reasonable to expect that engine and vehicle manufacturers and fuel producers will respond to increasingly stringent NO_X and PM emission standards and petroleum prices through incremental improvements in engines, vehicles, and fuel quality. Examples could include improved turbochargers, fuel injection systems, and catalytic converters, as well as reformulated fuels with better combustion characteristics. However, as in the past, continued growth in travel and shipping could offset incremental reductions in the emission rates of essentially conventional medium- and heavy-duty technologies and fuels. Further, such incremental improvements are not likely to reduce petroleum consumption or GHG emissions and, because of well-known engineering tradeoffs, could even lead to further increases in some cases.

If real progress is to be made toward simultaneously reducing urban air pollution, petroleum consumption, and greenhouse gas emissions, the development of incremental improvements in conventional technologies and fuels needs to be supplemented with higher-risk research focused on new concepts and technologies. Examples of higher-risk technologies include fuel cells, electric drivetrains, batteries for storing motive power, and hybrid electric drivetrains and associated components.

Although these technologies show tremendous potential to reduce petroleum consumption and GHG emissions, they are generally considered risky because they are currently expensive and a clear transitional pathway forward from today’s market does not yet exist. The use of public resources to promote advancement in these areas is appropriate because, despite the underlying public goals, this perception of risk means that significant industry investment is unlikely, particularly in the medium- and heavy-duty vehicle area, where the industry is made up of many manufacturers, unlike the automobile industry. Because it is impossible to predict which technologies will ultimately succeed, it is also appropriate for the public sector to partner with private industry in developing and demonstrating technologies that—based on prevailing knowledge—appear likely to generate both monetary profit and public benefits.

In addition to R&D aimed directly at reducing the emissions and energy consumption of existing vehicle/fuel systems, R&D is also needed in several related areas. Two prominent examples are information and communications technology and high-speed ground transportation. Also, depending upon local circumstances, new technology high-speed ferry systems may offer attractive service, energy, and environmental benefits for urban areas situated on waterways.

When applied to the transportation sector, information and communications technology can increase capacity and, depending upon where and how they are applied, potentially improve systemwide safety, performance, emissions and efficiency. In the freight sector, for example, these technologies can reduce congestion, idling, and associated fuel consumption and emissions at border crossings. If and when heavy-duty vehicles become equipped with on-board electronic systems capable of diagnosing emissions-related malfunctions, information and communications technologies might enable efficient and reliable remote inspection without actual periodic or roadside testing. Indeed, DOT's ongoing ITS Commercial Vehicle Operations (CVO) program includes the development and use in vehicles of these technologies in order to make safety verification and other administrative processes more efficient. Considerable public resources have already been devoted to developing information and communications technologies for the transportation sector, and it is appropriate that future resources be focused, in part, on potential opportunities to use these technologies to directly improve system efficiency and emissions.

In some U.S. markets, congestion poses a serious constraint to travel by automobile and/or airplane. Depending upon regional conditions, HSGT—a family of technologies ranging from upgraded existing railroads to magnetically levitated vehicles—could offer an important alternative that not only saves time but also reduces emissions and energy consumption relative to other options. Public resources are needed to improve the performance and ensure the safety of HSGT.

2.4 Technical Goals

The general goals of DOT's medium- and heavy-duty vehicle R&D are to improve vehicle fuel efficiency, reduce vehicle emissions, foster economic competitiveness in advanced transportation vehicle technologies, enhance public acceptance of advanced vehicles, fuels, and infrastructure. Such improvements are to be in addition to improvements in safety, which remains the Department's top priority.[5] Based on unique challenges and opportunities specific to several important types of vehicles, DOT has identified "stretch" goals for this program in two focused technical areas:

[5] For example, one of the Department's specific goals for safety is to reduce the rate of transportation-related fatalities per ton-mile of freight shipped.

The first technical goal is to develop production prototype[6] vehicle/fuel systems—including vehicle technology, energy carriers (e.g., gaseous and liquid fuels, electricity), and infrastructure—that increase fuel economy and reduce NO_X, PM, and GHG emissions relative to the base vehicle/fuel system according to the schedule and targets identified in Table 1, and that offer similar utility and performance at similar life-cycle[7] cost and profitability without increasing net emissions of other air pollutants.

Table 1. Goals for Medium-and Heavy-Duty Vehicle R&D

Vehicle Type	Year		Fuel Economy[8]	Emission Reduction Targets[9]		
	Base	Goal	Target	NOx	PM	GHG
Transit Bus	2000	2010	+200%	-98%	-85%	-67%
Freight Truck	2000	2010	+100%	-98%	-90%	-50%
Freight Locomotive[10]	2000	2020	+67%	-90%	-90%	-40%
Marine Vessel	2000	2020	+67%	-90%	-90%	-40%

The second technical goal is to develop a production prototype system by 2005 in which emission-related malfunctions in medium- and heavy-duty vehicles—as well as other information useful to, for example, fleet managers and vehicle manufacturers–are reported to remote locations capable of tracking this and related vehicle-specific information, and which is projected to be cost-effective relative to other pollution control strategies.

Goals for DOT's HSGT activities are identified in other DOT budget and planning documents.

2.5 Recent R&D Activities

DOT's medium- and heavy-duty vehicle research complements DOE's heavy vehicle research focus primarily on diesel engine powertrains and fuel systems for these vehicles. Key DOE research areas include diesel engine materials, new diesel engines for light trucks and sport-utility vehicles, efficient and flexibly fueled engines for heavy trucks, combustion and exhaust aftertreatment, and storage tanks for compressed gases such as natural gas and hydrogen.

This plan builds upon recent DOT R&D activities supporting goals identified above. Key current and planned activities include the AVP, FTA's Equipment and Infrastructure R&D, and

[6] This goal does not extend to commercialization, which is an industry role and must be preceded by an assessment of compliance with existing and future safety regulations.

[7] Under identical tax revenue assumptions.

[8] For highway vehicles, miles per gallon (or per volume of fuel that contains the same energy as a gallon of conventional highway diesel fuel). For locomotives and marine vessels, ton-miles per Btu. It should be noted that quantification methods appropriate for transit buses are assumed to contain more braking events—and therefore more recoverable braking energy—than those appropriate for freight trucks.

[9] Full life-cycle and fuel-cycle basis under identical operating conditions, using prevailing global warming potential (GWP) factors for different greenhouse gases.

[10] These departmental energy and environmental goals for freight locomotives are in addition to goals—railroad safety and HSGT advancement—that are the focus of current R&D managed by the Federal Rail Administration.

FRA’s HSGT program. Related activities include a Marine Fuel Cell Initiative and the Intelligent Transportation Systems/Intelligent Vehicle Initiative.

Advanced Vehicle Technologies Program (AVP)

The AVP, which is managed by RSPA for all DOT modes, combines the best in transportation technologies and innovative program elements to produce new vehicles, components, and infrastructure for medium- and heavy-duty transportation needs. The program draws upon roughly five hundred companies in order to achieve significant breadth in expertise and capability. The goal is to improve energy efficiency and U.S. competitiveness while reducing emissions and transportation dependence on petroleum. Authorized in 1998 under the Transportation Equity Act for the 21st century, this program is managed by DOT in partnership with other federal agencies (e.g., DoD, DOE), private companies, research institutions, and state and local governments.

The AVP is a bottom-up, public-private partnership program that has demonstrated proven success in the deployment of new and innovative electric- and hybrid-electric technologies, and their entry into the commercial transportation industry. It seeks an annually balanced portfolio of projects across various technologies and degrees of risk and potential benefit. This approach provides significant opportunity to capitalize on emerging developments that may not lend themselves to a “top-down” planning approach with narrow objectives and schedules. This is particularly important given the nature of the medium- and heavy-duty vehicle industry. The AVP is designed to complement the activities of the Partnership for a New Generation of Vehicles (PNGV) and other vehicle-related programs by addressing needs not currently met in these federal initiatives.

DOT also manages two major activities that focus on two specific subcategories of medium-and heavy-duty vehicles—transit buses and passenger trains, and is involved in R&D activities related to marine vessel emissions and energy consumption.

FTA’s Equipment and Infrastructure R&D

Through this R&D managed by FTA, transit has an opportunity to lead the nation in the research, development, and deployment of advanced, efficient and environmentally friendly technologies for all vehicles. In partnership with transit operators, the bus and rail equipment industries and other Federal agencies with similar outcome goals, FTA is pursuing advancements in bus propulsion systems, enhancements in bus testing, adaptation of radio-based communication and control systems, and other innovative technologies through research, tests, deployment, standards development, technical assistance and training. Specific research areas include bus technology, advanced technology buses, fuel cell transit buses, alternative fuels, hybrid-electric and electric vehicles, and rail equipment and systems.

High-Speed Ground Transportation (HSGT)

FRA manages HSGT research, which is focused on a family of technologies ranging from upgraded existing railroads to magnetically levitated vehicles. HSGT is a passenger transportation option that can best link cities lying about 100-500 miles apart. Common in Europe and Japan, HSGT in the United States already exists in the Northeast Corridor between New York and Washington, D.C. and will soon serve travelers between New York and Boston. DOT's HSGT program is intended to directly support the goals of passenger service and HSGT safety—not emissions and energy consumption. HSGT is mentioned in this plan because it could have important emissions and energy benefits, depending upon how highway, rail, and air traffic respond to HSGT's market performance, and because some of the technologies under development for HSGT (e.g., turbine propulsion, flywheels) may have the potential to improve performance in more than one type of vehicle.

Marine Fuel Cell Initiative

MARAD and CG have been concentrating on R&D that affects the maritime industry. MARAD is leading a partnership with CG and DOE to develop and demonstrate the application of natural gas aboard ships. MARAD is also investigating the potential installation of a marine fuel cell laboratory at the United States Merchant Marine Academy. CG has partnered with the Office of Navy Research in the development of large-scale marine fuel cells for heavy duty vessels. In addition, the Research and Special Programs Administration (RSPA) has sponsored a Small Business Innovation Research (SBIR) Program project for an infrared marine engine emission analyzer and another on the reformation of marine fuels for fuel cell utilization.

Intelligent Transportation Systems/Intelligent Vehicle Initiative

The national ITS Program managed by the FHWA JPO aims to use advanced technology—including the latest in computers, electronics, communications and safety systems—to improve the efficiency and safety of our Nation's surface transportation system. The Commercial Vehicle Operations (CVO) portion of the ITS program aims to streamline the commercial vehicle safety regulatory system and enhance its effectiveness in the trucking industry. They apply both to truck fleet operators and state regulators. Among the elements of the current ITS program for commercial vehicles are electronic clearance, onboard safety monitoring systems, automated administrative processes, and hazardous materials incident response. The *Intelligent Vehicle Initiative* (IVI) portion of the ITS program aims to accelerate the development and commercialization of in-vehicle safety systems such as collision avoidance and driver condition monitoring. Although the IVI addresses all vehicle types, it is specifically addressing the unique safety needs of medium- and heavy-duty vehicles, which are commonly used in commercial, transit, and highway maintenance operations.

3. R&D SUPPORTING PROGRESS TOWARD TECHNICAL GOALS

Several general areas of research offer important opportunities to make progress toward the technical goals identified in Section 2.4. Because these are interrelated, a systems approach toward innovation could make success more likely.

3.1 Fuels

Alternative fuels such as electricity, hydrogen, natural gas, and alcohols (e.g., ethanol, methanol) may offer opportunities to reduce petroleum consumption and emissions, although results could vary significantly by fuel, vehicle technology, and local conditions. Continued research is needed to reduce the capital investment required for a widespread and time-efficient electric vehicle recharging infrastructure, and to develop efficient, safe, and affordable ways to produce, distribute, and deliver hydrogen.

Changes in the characteristics (e.g., aromatic content, cetane number, density, oxygen content, sulfur content) of diesel fuel could also yield and/or facilitate important improvements in vehicular and full-fuel cycle emissions. Changes in corresponding feedstocks and processing technology could provide a means to reduce petroleum consumption and emissions. Potential research areas include: relationships between fuel characteristics and emissions formation, fuel/aftertreatment compatibility, durability and performance effects of reformulated fuels, and lower-cost processes for producing diesel fuel and blending agents from alternative feedstocks such as biomass and natural gas.

3.2 Energy Storage

Bulk energy storage remains an important issue for some potential fuels (e.g., hydrogen), and research is needed to reduce costs, improve performance, and ensure safety. Specific research needs include chemical battery technology (e.g., lithium ion, lithium polymer), absorptive and/or high-pressure gaseous fuel storage, and low-temperature liquid fuel storage.

3.3 Powertrain

Changes in drivetrains offer the potential for significant efficiency and emissions improvements. Hybrid electric drivetrains are particularly promising, especially for vehicles (e.g., urban buses) where stop-and-go operation provides an opportunity for significant energy recapture. Research is needed to improve the cost and performance of these systems and ensure safety. Specific research areas include peak energy storage devices such as chemical batteries and flywheels, electrical motors and controllers, electrical power management systems, and hybrid powertrain systems analysis.

Advances in diesel engine technology and exhaust aftertreatment systems also promise considerable potential gains in efficiency and reductions in emissions. Research needs include low heat rejection engines (LHRE) and aftertreatment devices to reduce NO_X and fine PM.

Research may also be needed to improve compatibility with reformulated and/or alternative fuels. Finally, research is needed to develop and characterize innovative combustion engine technologies and other energy conversion devices—in particular fuel cells and fuel processors—that could significantly improve efficiency and/or emissions.

3.4 Materials

Changes in materials offer the potential to significantly reduce the weight of some vehicles—thereby reducing energy consumption—without compromising safety. However, cost remains a significant barrier for some materials. Further, while recycling of some materials (e.g., aluminum) is well established, considerable uncertainty remains regarding the potential to recycle other materials, in particular advanced carbon-fiber-reinforced composites. Research is needed to reduce the cost of these materials, develop improved technologies for manufacturing and joining vehicle components using these materials, develop tools for simulating crashes involving vehicles that use such materials, and improve recycling techniques applicable to some of these materials.

3.5 Vehicle Design

Changes in vehicle design that go beyond powertrain and materials could offer important opportunities to reduce energy consumption. Examples where research is needed include aerodynamic design and efficient tires. In addition, new materials, construction techniques, and powertrains offer the potential for considerable changes in the way vehicles are designed.

3.6 Accessories

Some vehicle accessories, such as air conditioners, can have a significant influence on vehicular energy consumption and/or emissions. Research is needed to develop lighter and more efficient accessories that are competitive in terms of cost and performance, and to develop and/or improve accessories, such as auxiliary heaters, that may be important as enablers of vehicles with highly efficient powertrains.

3.7 Information and Communications Systems

Advances in information and communications technology are already changing the nature of some activities in ways that has an influence on transportation demand. For example, internet-based shopping can influence both shopping trips and package deliveries, and telecommuting can influence both commuting travel and locational choice. Some of these technologies may also have a more direct impact on vehicular emissions and/or energy consumption. For example, using these technologies to improve traffic flow could reduce emissions under some conditions. Even more directly, these technologies could improve the diagnosis of vehicle deterioration and malfunctions that influence emissions and/or efficiency, and could lead to better maintenance through reporting to stationary locations.

Research is needed to better understand opportunities to use information and communications technology to achieve reductions in emissions and energy consumption, and where appropriate—including systems that link vehicle diagnosis to entities responsible for managing emissions and/or maintenance—to develop and demonstrate new systems. Such research would build upon ongoing research under the *Intelligent Vehicle Initiative* related to the use of such technologies as to make similar administrative processes more efficient, and could also help increase the availability of similar data to, for example, fleet managers and vehicle manufacturers.

3.8 Vehicle/Fuel Systems and Infrastructure Analysis

Vehicles and fuels operate together as an integrated system supported by very significant accumulated infrastructure that encompasses elements such as materials supply and processing; component manufacturing and vehicle assembly; fuel production, distribution, and delivery; vehicle maintenance, repair, and recycling; and supporting activities such as highway design, intermodal connections, and emergency response. Some of these areas represent accumulated investments in the hundreds of billions of dollars. This infrastructure can likely accommodate some new types of vehicles and fuels without significant change. However, others could require dramatic changes in infrastructure components. In order to anticipate such changes before making major long-term investments, research is needed to better understand what changes might be required by or result from shifts to different vehicle/fuel systems. Modeling and simulation of vehicles and fuels together as systems can help to identify and characterize potential barriers. This will enable a strategic approach toward making major transitions between established and emerging systems.

4. MILESTONES AND PRIORITIZATION OF TASKS

Consistent with its dynamic, flexible, bottom-up approach to annual project portfolio development, the AVP defines research priorities on an annual basis, prioritizes project proposals based on case-by-case peer review, and develops detailed milestones specific to each project selected for funding. FY 2001 research priorities are documented in the *FY 2001 Program Announcement* shown in Appendix A. Milestones for projects selected in FY 1999 are documented in the project summaries shown in Appendix B.

More specific milestones and priorities are appropriate for FTA's transit bus research, which projects the following accomplishments in FY 2001:

- Develop a full-sized, domestically produced, advanced (200 kW) PEM fuel cell transit bus.
- Provide technical assistance for the investigation and completion of design of the urban maglev system with potential for infrastructure cost savings in less dense area applications.

FRA's HSGT research also has specific milestones and priorities that are presented in other DOT budget and planning documents, and address issues such as safety, reliability, cost, noise, and migration paths for new train control systems.

This R&D plan includes one new task, the development of systems in which vehicle performance and emission-related malfunctions in medium- and heavy-duty vehicles are reported to remote locations that track this data and link it to other vehicle-specific data (e.g., registration status), and which are projected to be cost-effective relative to other pollution control strategies; in particular, periodic and/or roadside emissions inspection for these vehicles. The priority for FY 2001 will be to bring together potential partners (FTA, ITS JPO, EPA, and manufacturers) to develop target technical characteristics for such systems, identify leading technological and administrative approaches, and agree to a plan for research that will lead to a production prototype by 2005 to be demonstrated the following year in one or more locations. The ITS JPO will initiate this coordination and identify funding requirements for FY 2002 and beyond.

5. MANAGEMENT PLAN

DOT's medium- and heavy-duty vehicle R&D is organized into three main programs: the AVP, FTA's transit bus research, and FRA's HSGT program. MARAD and CG also participate in R&D related to marine applications of fuel such as natural gas and technologies such as fuel cells. In addition, the ITS program has many elements relevant to medium- and heavy-duty vehicles—this R&D plan identifies a basis for developing systems that directly address the above-mentioned technical goals. All of these research activities are coordinated within DOT through the Department's Research and Technology Coordinating Council (RTCC), and with other federal agencies through the National Science and Technology Council (NSTC).

The AVP will continue to be managed by DOT's Research and Special Program's Administration (RSPA). The AVP represents a transition and shift in emphasis of the Electric and Hybrid Vehicle (EHV) program established by congressional direction in FY 1993. The EHV program was managed by the Defense Advanced Research Projects Agency (DARPA) using seven geographically dispersed regional consortia representing private industry and other non-Federal organizations. The consortia were competitively selected to organize industry teams to develop technology solutions, provide a decentralized management structure, share in the administrative burden, and provide a minimum 50 percent cost share. The AVP continues to rely on this management approach and structure. In response to an annual program announcement, projects are selected through a process of proposal, submission, review, and acceptance. Each proposal is reviewed jointly by DOT and, as appropriate, other agencies. This ensures that projects selected for AVP funding do not duplicate other Federal activities, and that any opportunities for financial participation of other federal departments are identified and pursued.

FTA will continue to be responsible for management of DOT's transit bus technology research. When feasible, FTA will work with industry and other Government and private research entities under the Joint Partnership Program (JPP) to achieve program objectives. Likewise, FRA will continue to manage the HSGT program, coordinating as appropriate with the industry as well as FTA, DOE, EPA, and other federal, state, and local agencies. Finally, MARAD and CG will continue to lead DOT participation in R&D related to technologies (e.g., fuel cells), that may affect the maritime industry, partnering as appropriate with other agencies and entities such as DoD and the U.S. Merchant Marine Academy.

6. RESOURCES AND FUNDING

DOT expects that the resources identified in Table 2 will be required through fiscal year 2001 in order to maintain progress toward the goals identified above. Resources planned for the AVP between fiscal years 2000 and 2001 are within amounts authorized for that period under TEA-21.

Table 2. Funding Plan for DOT Medium- and Heavy-Duty Vehicle R&D

Fiscal Year	AVP				Transit Bus/Rail[11]	HSGT	Marine Fuel Cells[12]
	Federal[13]	Matching	Total				
1999	$7m	≥$7m	≥$14m		$9.8m	$9.8m	$0.4m
2000	$5m	≥$5m	≥$10m		$13.7m	$7.0m	$1.1m
2001	$20m	≥$20m	≥$40m		$8.3m	$6.8m	$1.1m

[11] Transit Bus R&D accounts for a portion of the total *New Bus and Rail Vehicles and Infrastructure* funding reported here.

[12] Combined USCG and MARAD appropriations and estimates.

[13] From DoD budget in FY 1999, and DOT budget in later fiscal years.

REFERENCES

Davis, Stacy, *Transportation Energy Data Book: Edition 18*, ORNL-6941, Oak Ridge National Laboratory, Oak Ridge, Tennessee, September 1998.

U.S. Department of Energy, *Annual Energy Outlook 1999*, DOE/EIA-0383(99), Washington, D.C., December 1998.

U.S. Environmental Protection Agency, *National Air Pollutant Emission Trends Update: 1970-1997*, EPA 454/E-98-007, Washington, D.C., December 1998.

U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–1997*, EPA 236-R-99-003, Washington, D.C., April 1999.

U.S. Department of Transportation, *National Transportation Statistics 1997*, Washington, D.C., December 1996.

U.S. Department of Transportation, Federal Railroad Administration, *Improving Railroad Safety and Rail Passenger Technology through Targeted Research and Demonstrations, 1992-1997,* DOT/FRA/ORD-98/DOT-VNTSC-FRA-98-9, Washington, D.C., Draft, December 1998.

Appendix A.

Advanced Vehicle Technologies Program
FY 2001 Program Announcement

FY 2001 ADVANCED VEHICLE PROGRAM

BACKGROUND

The basis for the Advanced Vehicle Program (AVP) can be found in the FY 1999 Program Announcement, also known as The Red Book, issued November 3, 1998. The Red Book provides information concerning the background of the program transition from the Defense Advanced Research Project Agency's (DARPA) Electric and Hybrid Vehicle (EHV) Program to the Department of Transportation (DOT). It identifies the key issues of concern relative to energy security, air quality, and transportation industry development that will be addressed by the AVP.

Program goals and objectives for the AVP were established as part of the Red Book. These have not changed. **The Advanced Vehicle Program will develop, demonstrate, and deploy in the United States advanced transportation vehicle technologies. The primary vehicle focus of the program is on medium and heavy-duty vehicles planned for realization by 2004. The technology focus of the program is on electric and hybrid electric vehicles and their technologies and infrastructure.** The goals of the program are:

- Reduced vehicle emissions.
- Significantly improved fuel efficiency.
- Establishment of a globally competitive U.S. industry for advanced vehicles and their components.
- Increased public acceptance of the advanced vehicles.

Program and performance objectives as part of the AVP goals and objectives also were established with the Red Book.

FY 2001 PROGRAM DIRECTIONS

The AVP will be funded in FY 2001 by funds from DOT. FY 2001 DOT funds may be supplemented by FY 2001 funds from DOE and DOD.

The FY 2001 AVP will maintain a balanced approach for the Program by selecting projects of differing modes, periods of performance, risk levels, technical approaches, applications, and project sizes. A balanced portfolio of selected projects of small, medium and large projects with a variety of technical risks and applications will achieve the most significant benefits. The guidance set forth is to help the Proposer address the issues rather than to indicate a DOT preference or focus.

For FY 2001, the AVP intends to work towards its objectives with the following additional considerations:

- ❖ All projects must support the Program goals and objectives, but projects within the focus areas identified below are preferred.
- ❖ Efforts that duplicate the approach and objectives of other U.S. efforts are of lower priority to the Program.
- ❖ The Program seeks to have some of the funds directed toward radical, innovative technologies that could provide significant payoff.
- ❖ Indication of the ability and a sincere intent to commercialize the results of the project is very important. High quality cost share is a strong indicator of both the ability and the intent to commercialize. Clear demonstration of a technical advantage coupled with a sound commercialization plan reinforces this indication.
- ❖ DOT is interested in efforts that will lead to the commercial deployment of vehicles. Deployment project efforts should involve specific users of the vehicles with interest in the advantages offered by electric and hybrid electric vehicles. Preference is for projects with users who have resources available for large-scale purchases of additional vehicles. Some potential user partners include: transit agencies (Federal Transit Administration's bus capital program including the Clean Fuels Formula Grant Program), national parks (Federal Highway Administration's Federal Lands Highway Program), airports (Federal Aviation Administration's Airport Improvement Program), military bases (DOD Alternative Vehicle System Program), and local municipalities (DOE Clean Cities Program, DOT's Congestion Mitigation and Air Quality Program).
- ❖ DOT is interested in deployment efforts that establish or reinforce sustainable transportation solutions for communities with widespread applicability to other geographical areas.
- ❖ Projects should be performed over a period of three years (36 months) or less.
- ❖ In general, no single project should require more than approximately $1,000,000 in FY 2001. Dependent on the level of funding, DOT may be receptive to larger scale projects.

FY 2000 FOCUS AREAS

The following are DOT's greatest interest:

- ♦ Technologies that have multi-modal applications.
- ♦ Demonstrations and deployment projects that lead to sustained large-scale adoption of electric and hybrid-electric vehicles.
- ♦ Micro-electro-mechanical systems (MEMS) that have significant payoff in advancing electric and hybrid-electric vehicles.
- ♦ Nano-technology for advanced materials that significantly enhance electric and hybrid-electric vehicles.
- ♦ Demonstrations and deployment projects that support sustainable transportation solutions for communities.

Focus areas are outlined below. These are the areas believed to be most important to the Program.

Enabling technologies:

- Charging infrastructure
- Light-weight materials
- Micro-electro-mechanical systems
- Nano-technology

Electric and hybrid-electric drive systems:

- Energy storage – ultracapacitors, batteries, flywheels
- Energy and battery management
- Power electronics
- Auxiliary sub-systems
- Fuel cells and reformers

Vehicles:

- Trucks
- Buses
- Marine vessels
- Rail

PROPOSAL SUBMISSION

The consortia and DOT will select AVP projects by a process of proposal submission, review, and acceptance. The consortia will prepare proposals and submit them to the DOT. DOT will select the best proposals for funding and fund them through agreements between DOT and the consortia.

In order to minimize the effort required for proposal preparation and review, the selection will take place in two phases. First, the consortia will prepare white papers for DOT to review and comment on. The consortia will then prepare proposals on the best topics.

Prospective project performers should submit white papers to their consortia. The consortia will select and edit the white papers for submittal of five copies of each to DOT by February 4, 2000. White papers should be two pages or more, but less detailed and less complete than full proposals while addressing all of the important topics. Important topics include a description of what will be done and why, the commercialization plan, the qualifications of the performers, the technical innovations, the expected cost, the source of cost share.

DOT expects to complete its review of the white papers and provide feedback to the consortia by February 29, 2000.

The consortia should submit five copies of each completed proposal to DOT on or before March 15, 2000. DOT anticipates making awards by April 14, 2000.

Both white papers and proposals should be submitted to:

Mr. Shang Hsiung

AVP Program Manager
DOT/TRI-20
400 Seventh Street SW
Washington, DC 20590

Questions may be addressed to Shang Hsiung (202-366-0241, shang.hsiung@fta.dot.gov)

COST SHARE

The performer pays for all of the cost of each project. The performer is reimbursed in part by the government. The portion not reimbursed by the Government is referred to as cost share. The Government expects to share in the costs of all tasks of a project. The Government evaluates the quality of cost share in the following terms:

High Quality Cost Share - These are financial resources that will be expended by the award recipients on the proposed project's statement-of-work (SOW) and will be subject to the direction of the project management team. This basically means the funds the non-federal participants will spend for man-hours, materials, new equipment (prorated if appropriate), subcontractor efforts expended on the project's SOW, and restocking the parts and material consumed. High quality cost share can include new IR&D effort, but only if those funds are offered by the proposers to be spent on the SOW and subject to the direction of the project management team.

Low Quality Cost Share - These are non-financial resources that will be expended on the proposed project's SOW and will be subject to the direction of the project management team. This is typically wear-and-tear on in-place capital assets like machinery or the prorated value of space used for the project.

Unacceptable Cost Share - This is a resource that either (1) will not be expended on the proposed project's SOW or (2) will not be subject to the direction of the management team as discussed above. Unacceptable cost share will be subtracted from the proposer's claimed total cost for the project, and the required industry cost share recalculated. Unacceptable cost share examples include:

- Sunk costs, i.e., costs incurred before the start of the proposed project;
- Foregone fees or profits;
- Foregone G&A or cost of money applied to a base of IR&D;
- Bid and proposal costs;
- Value claimed for intellectual property or prior research;
- Parallel research or investment, i.e., research or other investments that might be related to the proposed project but which will not be part of the SOW or subject to the direction of the project management team. Typically these activities will be undertaken regardless of whether the proposed project proceeds;
- Off-Budget Resources, i.e., resources that will not be risked by the proposer on the SOW, and should not be considered when evaluating cost share.

PROPOSED GUIDELINES

Each consortium may propose more than one project. The consortium proposal should have a main section and a section for each project. One project may be for consortium program management.

Project or milestone costs are referred to below. Where referred to, they always include, in order: cost to the Government, cost to the project team, and total cost. The total cost should be the cost to the Government plus the cost to the project team.

The main section and each project proposal should be separately page numbered and dated on all pages. If a project proposal is revised, reissue and re-date the entire project proposal. (If attachments do not have the same date, make a specific reference to each attachment and its date in the project proposal.)

<u>Main Section</u>

This section of the consortium proposal should include the following:

- Body. This should include any preliminary information and a statement submitting the proposal. Also, the body should include a brief statement for each of the projects stating:
    - Why each project is believed to be for additional work within the scope of the original agreement.
- Projects list with one line for each project and a line for the total costs. For each project give the project name, the date of the most recent proposal for the project, and project costs as explained above.

<u>Project Proposals</u>

Proposals should be complete in all respects, even where the Government has asked no questions about a white paper on the project. Where the Government has asked questions about the white paper, cover the answers in the body of the proposal, not as a separate section of the proposal. Each project proposal should contain the following:

- Objective of the proposed work and a summary of the work to be done. These should be brief and fully supported by the detailed proposal.
- List of participant organizations with the name, telephone, and e-mail for the point of contact at each organization. Identify the lead organization.
- Other detailed information on the proposed project such as:
    - Background. This may include information on the state of the technology and the longer term goals of the performing organization.
    - Importance of the work.
    - Explanation of the principle of operation of the product to be developed.

  - Quantitative specifications for the expected performance of product to be developed or produced. Specifications of major subcomponents should also be stated. The Government frequently compares specific power and energy and power and energy density.
  - Test or performance data that give credibility to the proposed innovation.
  - Plans for commercialization and/or military application.
  - Qualifications and experience of the performing organization.
- Statement of Work consisting of a list of numbered tasks with descriptions. Milestones, including the milestone number, short description, expected date, and milestone payments should be part of the SOW and associated with the completion of key events. (Milestones, even if listed separately from the SOW, must reflect the work being done.)
- Schedule chart showing the timing of all tasks listed in the Statement of Work and their major precedence relationships.
- Costs.

Prepare a matrix showing the uses of funds (costs) by milestone and by category. The suggested form is one row of the matrix for each category and the total, and one column of the matrix for each milestone and for the total. The major categories are labor, materials, subcontracts, travel, overhead, and total. The costs for a milestone are the costs of the underlying tasks.

Also show, in similar matrix form, the sources of funds for each milestone. These include the costs to the Government, other federal funds (if any), cash costs to the project team, in-kind costs to the project team, and total costs. Show the contribution from each team member separately for each milestone. Costs of labor and materials purchased for the project are considered cash costs. Explain any of the in-kind costs to the project team, such as value claimed for use of buildings, previously purchased materials, or capital equipment that could and would be used for other purposes. The explanation should indicate who is making the in-kind contribution.

The two cost matrices may be combined into one with a single column for each milestone. In a combined matrix include rows for the uses of funds and rows for the sources of funds.

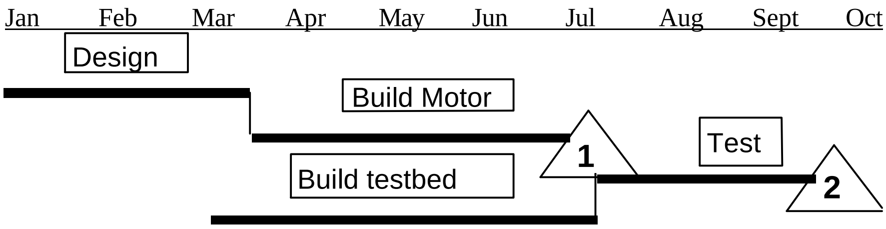
Costs not acceptable as cost share may be claimed and discussed, but not included in the matrices.

EXAMPLES OF PROJECT SCHEDULE & COSTS

Consortium Project List

No.	Name	Proposal Date	Cost to Gov.	Matching Funds	Total Cost
1	Motor	3/1/97	100,000	100,000	200,000
2	Battery	2/14/97	50,000	75,000	125,000
	TOTAL		150,000	175,000	325,000

Motor Project Schedule



Motor Project Costs

(Additional details and explanations of labor, materials, and subcontracts may be appropriate.)

Milestone	1 (Build)	2 (Test)	TOTAL
Labor	45,000	30,000	75,000
Materials	25,000	0	25,000
Subcontracts	0	5,000	5,000
Travel	2,000	1,000	3,000
Facilities	0	14,000	14,000
Overhead	53,000	25,000	78,000
TOTAL	125,000	75,000	200,000

Motor Project Sources of Funds

Milestone	Cost to Gov.	Project Team Cash Cost	Project Team In-Kind Cost	TOTAL
1 (Build)	60,000	65,000		125,000
2 (Test)	40,000	21,000	14,000*	75,000
TOTAL	100,000	86,000	14,000	200,000

*Rental value of 2500 sq. ft. test facility @ $2,000 per month.
In addition, Ajax Corp. is supplying patents and prior research worth $200,000.

Appendix B.

Advanced Vehicle Technologies Program
FY 1999 Project Summaries

FY 1999 PROJECTS

WestStart – CALSTART

- **Fuel Cell Auxiliary Power Unit for Over-the-Road Trucks**
- **Electric Propulsion System for Medium- and Heavy-Duty Vehicles**
- **Hybrid Electric Transit Bus with Flywheel Power Management**
- **All-Purpose Electric Airport Tow Tractor**
- **Electrochemical Capacitors Using Carbon Lead-Oxide Electrodes**

ELECTRICORE

- **The AV-900 Cycler: A 600-900 Volt Test System for Heavy Duty Hybrid Electric Vehicles**
- **Installation of Capstone Microturbines into Cape Cod Passenger Trams**
- **Advanced Silicon Carbide Power Electronics**

Hawaii Electric Vehicle Demonstration Project

- **Electric Vehicle Ready State**
- **Zero-Emission 100 Passenger Electric Tram for Airports**
- **Battery Cycle Life Prediction**

Mid-Atlantic Regional Consortium for Advanced Vehicles

- **Unmanned Hybrid Electric High Mobility Multi-Purpose Wheeled Vehicle**
- **20kWh Nickel Hydrogen Segmented Battery for Hybrid Electric Military Vehicles, Commercial Trucks, and Buses**
- **Optimization of a Compression Ignition Engine Generator System for Heavy-Duty Hybrid Electric Vehicles**
- **Integrated Simulation and Testing System for Electric Vehicle Batteries**
- **Smaller, Better Inverters with Polymer Multi-Layer Capacitors**
- **Hybrid Electric Bradley Fighting Vehicle Demonstrator Testing and Model Refinement**

FY 1999 PROJECTS (cont'd)

Northeast Advanced Vehicle Consortium

- Model Park for the 21st Century
- Heavy-Duty Hybrid Electric Vehicle Emission Test Certification Protocol
- Battery Electric Dominant Heavy-Duty Hybrid Electric School Bus
- Jet Vapor Deposition for Catalyzing Fuel Cell Membranes

Southern Coalition for Advanced Transportation

- Utility Industry Trouble Truck and Mobile Power Source
- Hybrid Electric High Mobility Multi-Purpose Wheeled Vehicle Improvements
- Demonstration of Advanced Components on the Advanced Technology Transit Bus

Sacramento Electric Transportation Consortium

- Nickel Metal Hydride Battery System for an Electric Bus
- Plastic Lithium Ion Hybrid Electric Vehicle Battery

Project Title: ***Fuel Cell Auxiliary Power Unit For Over-the-Road Trucks***

Funding Year: **1999**

Consortium: **WestStart - CALSTART**

Participants: **Freightliner (Portland, OR), dbb Fuel Cell Engines (San Diego, CA), DaimlerChrysler (Detroit, MI)**

Project Objective:

A fuel cell auxiliary power unit for over-the-road trucks will be developed and demonstrated to replace the current practice of idling the trucks' diesel engines to generate electricity for various accessories and truck cabin/sleeper compartments' climate control during non-driving operations. This replacement will result in significant reductions in emissions, fuel consumption, and noise. The fuel cell system will provide a better quality rest period for long-haul truck drivers resulting in health and safety benefits. A requirements analysis will be performed; a fuel cell auxiliary power unit will be integrated into a class 8 truck and tested; and a brassboard methanol-based fuel cell system will be fabricated.

Project Cost:

Federal Funding	**$ 500,000**
Matching Funding	**$1,055,000**
Total Cost	**$1,555,000**

Schedule: **24 months**

Project Status: **No progress to report as project has not yet begun.**

Project Title: ***Electric Propulsion System for Medium- and Heavy-Duty Vehicles***

Funding Year: **1999**

Consortium: **WestStart - CALSTART**

Participants: **Santa Barbara Electric Bus Works, Santa Barbara Electric Transportation Institute (Santa Barbara, CA), Carpenter Industries Richmond, IN), Durham Transportation (Austin, TX)**

Project Objective:

Development of a reliable electric propulsion system for medium- and heavy-duty vehicles by integrating the best available sub-systems, performing modifications where needed, and testing on a school bus. Components from existing manufacturers will be carefully evaluated for specific applicability for this system and their compatibility with other components. The focus here will be on the long-term reliability of the drive system. Santa Barbara Electric Bus Works will utilize their vast experience with electric propulsion to perform the component selection and system integration.

Project Cost:

Federal Funding	**$200,000**
Matching Funding	**$200,000**
Total Cost	**$400,000**

Schedule: **24 Months**

Project Status: **No progress to report as project has just been initiated.**

Project Title: ***Hybrid Electric Transit Bus with Flywheel Power Management***

Funding Year: **1999**
Consortium: **WestStart - CALSTART**
Participants: **Trinity Flywheel (Livermore, CA), Nova Bus (Roswell, NM), ISE Research (San Diego, CA), AC Transit (Oakland, CA)**

Project Objective:

Demonstrate a hybrid-electric transit bus using an integrated flywheel power management system. The vehicle platform will be a 40-foot NovaBus RTS model, and will incorporate the ISE hybrid power train and the Trinity flywheel (previously developed in the DARPA Program.) AC Transit will then operate the bus in revenue service for a test period of two months.

Project Cost:

Federal Funding	$459,725
Matching Funding	$629,975
Total Cost	$1,089,700

Schedule: **14 Months**

Project Status: **No progress to report as project has just been initiated.**

Project Title: ***All-Purpose Electric Airport Tow Tractor***

Funding Year: **1999**

Consortium: **WestStart - CALSTART**

Participants: **ISE Research (San Diego, CA), United Airlines (Los Angeles, CA), Coherent Power (Santa Rosa, CA)**

Project Objective:

Develop an all electric AC powered 35,000 pound airport tow tractor, which will function as a test bed for several new key technologies. The All-Purpose Electric Tractor (APET) addresses a promising off-road vehicle market segment and will focus on achieving advances in three new technology areas:

1) **Development of an improved accuracy State-of-Charge/Voltage meter;**
2) **Improved control algorithms for maximizing the recapture of regenerative breaking energy, and;**
3) **Development of a high voltage DC-DC converter (500-800 VDC to 13.8 VDC)**

This airport tow tractor will also demonstrate the use of AC motors in a direct drive configuration for this extremely high torque application.

A tow tractor that incorporates these new technologies will have superior performance in terms of efficiency, power, and smoothness than diesel and competing DC-based electric technologies, at a cheaper cost than non-direct AC drive systems.

Project Cost:

Federal Funding	**$169,000**
Matching Funding	**$217,596**
Total Cost	**$386,596**

Schedule: **18 Months**

Project Status: **No progress to report as project has just been initiated.**

Project Title: ***Electrochemical Capacitors Using Carbon and Lead-Oxide Electrodes***

Funding Year: **1999**

Consortium: **WestStart - CALSTART**

Participants: **UC Davis (Davis, CA), Bolder (Golden, CO), Johnson Controls (Milwaukee, WI)**

Project Objective:

To demonstrate that combining a high surface area carbon (double layer) electrode with a battery-like, lead-oxide cathode, an electrochemical capacitor having an energy density of 15-20 Wh/kg and 30-35 Wh/liter can be developed. This would meet or execeed requirements for the PNGV Program. This ultracapacitor would utilize an aqueous electrolyte (sulfuric acid) and thus have a very high power capability (>2 kW/kg) and relatively low cost.

Project Cost:

Federal Funding	$ 68,000
Matching Funding	$ 87,000
Total Cost	$155,000

Schedule: **12 Months**

Project Status: **No progress to report as project has just been initiated.**

Project Title: ***The AV-900 Cycler: A 600-900 Volt Test System for Heavy-Duty Hybrid Electric Vehicles***

Funding Year: **1999**
Consortium: **ELECTRICORE**
Participants: **Allison Transmission Division of GMC (Indianapolis, IN)**

Project Objective:

Design, build, and prototype the key infrastructure items for Heavy Duty Hybrid Electric Vehicles: battery cyclers and chargers, which will enable Allison to meet near-term commercial requirements for their Electric Variable Transmission Project (being developed partially through the DARPA Program). The cycler will also be designed for long-term compatibility for all battery technologies, as well as fuel cell and reformer systems. It will facilitate a common test system for industry testing and demonstration efforts. The market trend is a movement toward higher voltage drivetrains for increased performance and packaging options while reducing the size and weight of components and reducing the cooling requirements. The cycler will provide a test system capable of handling the higher voltages.

Project Cost:

Federal Funding	$ 900,000
Matching Funding	$2,032,000
Total Cost	$2,932,000

Schedule: **15 Months**

Project Status: **No progress to report as project has just been initiated.**

Project Title: ***Installation of Capstone Microturbines into Cape Cod Passenger Trams***

Funding Year: **1999**

Consortium: **ELECTRICORE**

Participants: **Advanced Vehicle Systems (AVS) (Chattanooga, TN), Capstone Turbine (Woodland Hills, CA)**

Project Objective:

This project will retrofit two previously delivered electric trams with Capstone Microturbines, test, and deliver them back to Cape Cod National Seashore for use in transporting park visitors. These new hybrid trams will provide the park with the desired 60 mile range and will still allow for rapid recharge.

Project Cost:

Federal Funding	$37,500
Matching Funding	$37,500
Total Cost	$75,000

Schedule: **9 Months**

Project Status: **No progress to report as project has just been initiated.**

Project Title: ***Advanced Silicon Carbide Power Electronics***

Funding Year: **1999**
Consortium: **ELECTRICORE**
Participants: **Rutgers University (Piscataway, NJ), Silicon Power Corp. (Malvern, PA)**

Project Objective:

The goal of this project is to:

1) Design, model, and experimentally demonstrate a novel power switch (JFET-Gated Thyristor, or JFGT) based on SiC capable of 75% improvement in energy efficiency, weight, and size of EV powertrain in close collaboration with Silicon Power Corp;
2) Fabricate and deliver 5 JFGTs capable of 1,200 V and 10 A total current and 5 JFGTs capable of 800 V and 20 A of total current for operation temperatures over 300 degrees Celsius; and
3) Demonstrate the applications of JFGTs in inverter circuits for motor control.

This project has the potential to reduce thyristor gate turn-off current by at least a factor of 100 while eliminating the reliability issues associated with metal-oxide semiconductor-based gate switching technology. Powertrains based on this technology can reduce power consumption up to 75% while increasing the power handling capacity by a factor of 10. The cooling requirements are also significantly reduced. A 75% reduction in the overall weight and size of the powertrain is expected.

Project Cost:

Federal Funding	$ 613,726
Matching Funding	$ 675,104
Total Cost	$1,288,830

Schedule: **24 Months)**

Project Status: **No progress to report as project has just been initiated.**

Project Title: ***Electric Vehicle Ready State***

Funding Year: 1999

Consortium: Hawaii Electric Vehicle Demonstration Project

Participants: Hawaii Electric Vehicle Demonstration Project (Honolulu, HI), AeroVironment (Monrovia, CA), ELECTRICORE (Indianapolis, IN), Hawaii Electric Vehicles (Honolulu, HI), Hawaiian Electric Co. (Honolulu, HI)

Project Objective:

This project completes the first phase of making Hawaii the first "EV Ready State" by implementing a 24-hour accessible, high power recharging infrastructure on the island of Oahu (previously funded by DARPA.) Chargers will be located to provide full coverage for the island of Oahu. This is a large demonstration designed to meet the needs of EV operators, and thereby remove the negative perception that range is an issue. Also, as part of this program, electric vehicles from various manufacturers will be supplied to fleet operators on Oahu and operational data will be kept and analyzed.

Project Cost:

Federal Funding	$ 792,400
Matching Funding	$ 817,395
Total Cost	$1,609,795

Schedule: 18 Months

Project Status: No progress to report as project has just been initiated.

Project Title: ***Zero-Emission 100 Passenger Electric Tram for Airports***

Funding Year: **1999**

Consortium: **Hawaii Electric Vehicle Demonstration Project**

Participants: **U.S. Electricar, Inc. (Torrance, CA), EPRI (Palo Alto, CA), Hawaii Electric Co. (Honolulu, HI), Honolulu International Airport (Honolulu, HI)**

Project Objective:

Design, engineer, and construct a battery powered, 3-module electric tram for use at airports, parks, and malls as local people movers where short distances need to be covered at low speeds. This specific vehicle is being built for in-service use and acceptance testing at Honolulu International Airport. If successful, 7 additional vehicles will be purchased by the airport. The 120 volt AC drive system previously developed under the DARPA program will be used as the drive train for this in-vehicle test.

Project Cost:

Federal Funding	$ 500,000
Matching Funding	$1,938,000
Total Cost	$2,438,000

Schedule: **22 Months**

Project Status: **No progress to report as project has just been initiated.**

Project Title: ***Battery Cycle Life Prediction***

Funding Year: **1999**
Consortium: **Hawaii Electric Vehicle Demonstration Project**
Participants: **Hawaii Natural Energy Institute (Honolulu, HI), Pennsylvania State University (University Park, PA)**

Project Objective:
Develop a reliable and fast prediction tool for battery cycle life through a full understanding and characterization of the nature of the primary deterioration and failure processes in valve-regulated lead acid batteries and nickel metal hydride batteries used for electric and hybrid vehicle applications. The battery behavior will be be investigated and modeled in a laboratory, and a non-destructive prediction tool for cycle life will be developed. The tool will then be validated against further battery tests, and the process of artificial aging based on elevated temperatures will be employed to accelerate the life-cycle studies and a correlation made to standard driving cycles at ambient temperature. Accurate, reliable, and fast prediction of battery cylce life for electric vehicles is critical to both vehicle/fleet operators and battery manufacturers.

Project Cost:

Federal Funding	$225,263
Matching Funding	$225,263
Total Cost	$450,526

Schedule: **12 Months**

Project Status: **No progress to report as project has just been initiated.**

Project Title: ***Unmanned Hybrid Electric High Mobility Multi-Purpose Wheeled Vehicle***

Funding Year: **1999**

Consortium: **Mid Atlantic Regional Consortium for Advanced Vehicles**

Participants: **CTC (Johnstown, PA)**

Project Objective:

Support the conversion of the Hybrid-Electric High Mobility Multi-Purpose Wheeled Vehicle (HE-HMMWV) into an unmanned vehicle by adding a robotics kit provided by the U.S.'s Unmanned Ground Vehicle/Systems Joint Project Office. Preliminary testing of the HE HMMWV has shown performance advantages over conventional HMMWVs in areas such as acceleration, fuel efficiency, and silent mobility. The tactical unmanned vehicle already provides benefits as a force multiplier, increasing the force commander's area of influence, and removing soldiers from potentially hazardous areas of the battlefield. The silent mobility and increased range of an HEV further enhances these benefits.

Project Cost:

Federal Funding	**$125,205**	
Matching Funding	**$ 0**	**(Matching funds not required as vehicle is being delivered to the Federal Government – US Army)**
Total Cost	**$125,205**	

Schedule: **12 Months**

Project Status: **No progress to report as project will not be started until previous project to test HMMWV at Aberdeen Proving Ground is complete.**

Project Title: ***20kWh Nickel Hydrogen Segmented Battery for Hybrid Electric Military Vehicles, Commercial Trucks, and Buses***

Funding Year: **1999**
Consortium: **Mid Atlantic Regional Consortium for Advanced Vehicles**
Participants: **Ergenics (Ringwood, NJ)**

Project Objective:

This project will complete the construction and testing of a 20 kWh Nickel Hydrogen Segmented Battery previously funded in the DARPA program. The novel approach is to keep the energy storage separate from the power production side of the battery. This enables the optimization of each function, and results in longer cycle life, improved deep discharge tolerance, safety, and much greater shelf life since there is no potential for self-discharge. This design has great potential as a hybrid vehicle battery, particulary for vehicles requiring high power, fast acceleration, and the ability to recapture high power generated through regenerative braking.

Project Cost:

Federal Funding	$135,800
Matching Funding	$165,778
Total Cost	$301,578

Schedule: **9 Months**

Project Status: **This project was started under DARPA's EHV Program and the battery is currently being fabricated.**

Project Title: ***Optimization of a Compression Ignition Engine Generator System for Heavy-Duty Hybrid Electric Vehicles***

Funding Year: **1999**

Consortium: **Mid Atlantic Regional Consortium for Advanced Vehicles**

Participants: **Navistar International Transportation Corp (Fort Wayne, IN), Lockheed Martin (Johnson City, NY)**

Project Objective:

Optimize a compression ignition engine generator system for hybrid electric vehicle applications, and develop and validate an engine test procedure that models the vehicle system-level performance. The testing will be done first on a conventional truck, repeated as a hybrid electric truck, optimized and tested again. These tests will be used to establish the correlation between engine transient cycle emissions (g/bhp-hr) and vehicle chassis emissions (g/mile) on several recognized driving cycles. This project will lead to the emission certification testing of heavy duty hybrid electric vehicles on an engine basis as opposed to the costlier and more complex vehicle chassis approach.

Project Cost:

Federal Funding	**$252,000**
Matching Funding	**$308,000**
Total Cost	**$560,000**

Schedule: **16 Months**

Project Status: **No progress to report as project has just been initiated.**

Project Title: ***Integrated Simulation and Testing System for Electric Vehicle Batteries***

Funding Year: **1999**

Consortium: **Mid Atlantic Regional Consortium for Advanced Vehicles**

Participants: **Pennsylvania State University (University Park, PA), Arbin Instruments (College Station, TX)**

Project Objective:

Design and build a battery testing and analysis system with both simulation and testing capabilities integrated seamlessly into a single product. By integrating the battery test data and the battery design calculations into a single system, the user will be able to improve battery designs as cells are being tested, and the parameters affecting battery performance can be isolated and understood more easily.

Project Cost:

Federal Funding	$435,050
Matching Funding	$532,224
Total Cost	$967,274

Schedule: **24 Months**

Project Status: **No progress to report as project has just been initiated.**

Project Title: ***Smaller, Better Inverters with Polymer Multi-Layer Capacitors***

Funding Year: **1999**

Consortium: **Mid Atlantic Regional Consortium for Advanced Vehicles**

Participants: **Sigma Technologies (Tucson, AZ), United Defense LP (Santa Clara, CA), Solectria (Wilmington, MA)**

Project Objective:

Produce new inverter designs for a variety of applications that exploit the properties of the polymer multi-layer (PML) capacitors being developed by Sigma. This technology combination (inverter and capacitor) allows for smaller, lighter, and more efficient power electronics with reduced cooling requirements than other more conventional designs. The new inverter designs will be tested by commercial and military inverter companies.

Project Cost:

Federal Funding	$186,000
Matching Funding	$227,536
Total Cost	$413,536

Schedule: **18 Months**

Project Status: **No progress to report as project has just been initiated.**

Project Title: ***Hybrid Electric Bradley Fighting Vehicle Demonstrator Testing and Model Refinement***

Funding Year: **1999**
Consortium: **Mid Atlantic Regional Consortium for Advanced Vehicles**
Participants: **United Defense LP (Santa Clara, CA)**

Project Objective:

This project will complete the Hybrid Electric Bradley Fighting Vehicle's (BFV) check-out testing and hardening prior to its delivery for initial military testing at Aberdeen Proving Ground. Simulation modeling support will also be provided to DARPA. Fuel economy and other performance improvements over a conventional BFV will be demonstrated. This is a continuation of a project previously started in the DARPA program.

Project Cost:

Federal Funding	$808,377	
Matching Funding	$ 0	(Matching funds not required as vehicle is being delivered to the Federal Government – US Army)
Total Cost	$808,377	

Schedule: **10 Months**

Project Status: **The HE BFV was rolled out 9/99 and is now operational. After additional modifications, control integration, and shake-down of the systems, testing at Camp Roberts, CA will commence.**

Project Title: ***Model Park System for the 21st Century***

Funding Year: **1999**

Consortium: **Northeast Advanced Vehicle Consortium**

Participants: **Boston Edison (Boston, MA), New England Aquarium (Boston, MA), MA Dept. of Environmental Management (Boston, MA), U.S. National Park Service (Boston, MA), Boston Parks & Recreation Dept. (Boston, MA), Modern Continental Companies (Cambridge, MA), University of Massachusetts - Urban Harbor Inst. (Boston, MA)**

Project Objective:

Design, develop specifications, procure and install a sustainable energy system at the Boston Harbor Island National Recreation Area on Spectacle Island. This system will emulate a "sustainable community living" approach to national park design by minimizing environmental impact while maximizing energy efficiency. This project will help establish a new model of what a natural park area should be in the 21st Century. A photovoltaic energy capture and management system and infrastructure will be installed, and electric vehicles and maintenance equipment will be procurred and deployed, including mini electric pick-up trucks, electric bicycles, and an electric powered boat.

Project Cost:

Federal Funding	$ 495,000
Matching Funding	$ 570,000
Total Cost	$1,065,000

Schedule: **20 Months**

Project Status: **No progress to report as project has just been initiated.**

Project Title: ***Heavy Duty Hybrid Electric Vehicle Emission Test Certification Protocol***

Funding Year: **1999**

Consortium: **Northeast Advanced Vehicle Consortium**

Participants: **NAVC (Boston, MA), MJBradley (Concord, MA), West Virginia University (Morgantown, WV), and working group members from various organizations such as DOT, EPA, and CARB**

Project Objective:

The objective of this project is to develop a comprehensive test protocol for the emission certification of heavy-duty hybrid electric vehicles that is consistent and comparable to current protocols used for certifying conventional heavy-duty engines and vehicles. This project will leverage the test plans developed, experience gained, and lessons learned from the previous DARPA project testing heavy-duty transit buses.

Project Cost:

Federal Funding	$300,000
Matching Funding	$300,000
Total Cost	$600,000

Schedule: **18 Months**

Project Status: **No progress to report as project has just been initiated.**

Project Title: ***Battery Electric Dominant Heavy-Duty Hybrid Electric School Bus***

Funding Year: **1999**

Consortium: **Northeast Advanced Vehicle Consortium**

Participants: **Solectria (Wilmington, MA), Blue Bird Bus (Fort Valley, GA), EVermont (Waterbury, VT)**

Project Objective:

Develop a fully integrated, battery electric dominant, hybrid pre-production Blue Bird Model 3209, 33,000lb (Gross Vehicle Weight Rated) school bus. The focus will be on integration and engineering solutions that are cost effective for manufacturing and production. The bus shell and the hybrid electric drive system will be designed and built, integrated, and road tested for 6 months.

Project Cost:

Federal Funding	**$312,000**
Matching Funding	**$312,000**
Total Cost	**$624,000**

Schedule: **21 Months**

Project Status: **No progress to report as project has just been initiated.**

Project Title: *Jet Vapor Deposition for Catalyzing Fuel Cell Membranes*

Funding Year: 1999
Consortium: Northeast Advanced Vehicle Consortium
Participants: Jet Process Corporation (New Haven, CT), Analytic Power (Boston, MA), E-TEK (Natick, MA), W.L. Gore (Elkton, MD), IFC (South Windsor, CT), Plug Power (Latham, NY), Ballard Power Systems (Vancouver, BC), Dupont (Wilmington, DE), Lydal Technical Papers (Rochester, NH)

Project Objective:
To optimize a jet vapor deposition (JVD) process for adding catalyst to fuel cell membranes. This process offers more control over coating properties than conventional vacuum technologies. Test membranes will be coated and a test fuel cell stack demonstrated. These membranes should offer a 5-10 fold increase in the specific activity of platinum based catalysts. This will result in more efficient fuel cells at lower costs.

Project Cost:

Federal Funding	$350,000
Matching Funding	$350,000
Total Cost	$700,000

Schedule: 24 Months

Project Status: No progress to report as project has just been initiated.

Project Title: ***Utility Industry Trouble Truck and Mobile Power System***

Funding Year: **1999**

Consortium: **Southern Coalition for Advanced Transportation**

Participants: **PEI Electronics (Huntsville, AL), NEETRAC (Atlanta, GA), Southern Co. (Atlanta, GA), McKee Engineering (Lake Zurich, IL), Unique Mobility (Golden, CO), Electrosource (San Marcos, TX)**

Project Objective:

This project will develop a high performance, hybrid electric utility trouble truck for general service operations by the Southern Company and its family of electric utilities. A pre-production prototype will be designed, fabricated, and tested to determine the performance and functionality of the vehicle and its suitability for this application. If successful, this truck should reduce or eliminate idling time, reduce airborne emissions by 75%, improve fuel economy (by as much as a factor of 2), extend service range and operating time, and will provide auxiliary power to the truck's and personnel's support equipment where grid power may not be available.

Project Cost:

Federal Funding	**$ 547,112**
Matching Funding	**$ 545,029**
Total Cost	**$1,094,224**

Schedule: **18 Months**

Project Status: **No progress to report as project has just been initiated.**

Project Title: ***Hybrid Electric High Mobility Multi-Purpose Wheeled Vehicle Improvements***

Funding Year: **1999**

Consortium: **Southern Coalition for Advanced Transportation**

Participants: **PEI Electronics (Huntsville, AL), McKee Engineering (Lake Zurich, IL), Unique Mobility (Golden, CO), Electrosource (San Marcos, TX), Ovonic Battery (Troy, MI), NEETRAC (Atlanta, GA), Altec Industries (Birmingham, AL), Southern Co. (Atlanta, GA)**

Project Objective:

This project will replace the current HMMWV's right angle drive motors with in-line drive and will replace the current lead acid batteries with nickel metal hydride (or lithium ion). Both of these modifications will result in a lower vehicle weight while improving the performance of the vehicle. The current Hybrid Electric HMMWV is heavier than the stock vehicle of the same type, and reducing weight is critical for both fuel economy and for increasing the payload capacity.

Project Cost:

Federal Funding	**$700,000**	
Matching Funding	**$ 0**	**(Matching funds not required as vehicle is being delivered to the Federal Government – US Army)**
Total Cost	**$700,000**	

Schedule: **15 Months**

Project Status: **No progress to report as this project will not be initiated until the HE HMMWV completes testing at Aberdeen Proving Ground.**

Project Title: ***Demonstration of Advanced Components on the Advanced Technology Transit Bus***

Funding Year: **1999**
Consortium: **Southern Coalition for Advanced Transportation**
Participants: **UT-CEM (Austin, TX), PEI Electronics (Huntsville, AL)**

Project Objective:

This project will complete the demonstration of the components previously developed in the DARPA program on the Advanced Technology Transit Bus (ATTB) previously funded by the DOT's Federal Transit Administration. A flywheel energy storage system, an electro-mechanical suspension system, and advanced wheel motors will be integrated onto one of the ATTB prototypes. An advanced controller will be built and installed on the bus, and the bus will undergo testing.

Project Cost:

Federal Funding	**$498,707**	
Matching Funding	**$ 0**	**(Matching funds have already been applied exceeding 50% as this is a continuation of a previous DARPA project)**
Total Cost	**$498,707**	

Schedule: **12 Months**

Project Status: **The components have been developed and individually tested. The system integration and control software development is now being performed.**

Project Title: ***Nickel Metal Hydride Battery System for an Electric Bus***

Funding Year: **1999**

Consortium: **Sacramento Electric Transportation Consortium**

Participants: **SMUD/Davis EVs (Sacramento, CA), Ovonic Battery (Troy, MI), Blue Bird Bus(Fort Valley, GA), CA Energy**

Project Objective:

Develop and test a complete high-capacity (270 Ahr) Nickel Metal Hydride battery system and demonstrate its use in school district service on two pure electric Blue Bird Buses. A battery management system will also be designed and built as part of the battery system and carefully integrated within the bus. These batteries should extend the range of the pure electric buses to 80 miles (almost doubling the range achieved with lead acid batteries.)

Project Cost:

Federal Funding	$ 650,000
Matching Funding	$ 650,000
Total Cost	$1,300,000

Schedule: **36 Months**

Project Status: **No progress to report as project has just been initiated.**

Project Title: ***Plastic Lithium Ion Hybrid Electric Vehicle Battery***

Funding Year: **1999**
Consortium: **Sacramento Electric Transportation Consortium**
Participants: **SMUD (Sacramento, CA), Compact Power (Monument, CO), High Energy Technologies (Downer's Grove, IL), UC Davis (Davis, CA), HEVDP (Honolulu, HI), Davis EVs (Davis, CA), Battery M.D. (Sacramento, CA)**

Project Objective:
This project will develop a plastic lithium ion battery for hybrid electric vehicle applications. Specifically, a higher power battery (> 300 W/kg continuous power, 500-600 W/kg for 10-30 second bursts) will be built for a battery dominant hybrid electric vehicle design. This battery type has the potential to meet all of the requirements set forth in USABC's mid-term and long-term goals for hybrid vehicles - goals which are not currently being met by any battery manufacturer.

Project Cost:

Federal Funding	**$ 716,000**
Matching Funding	**$ 821,000**
Total Cost	**$1,537,000**

Schedule: **36 Months**

Project Status: **No progress to report as project has just been initiated.**