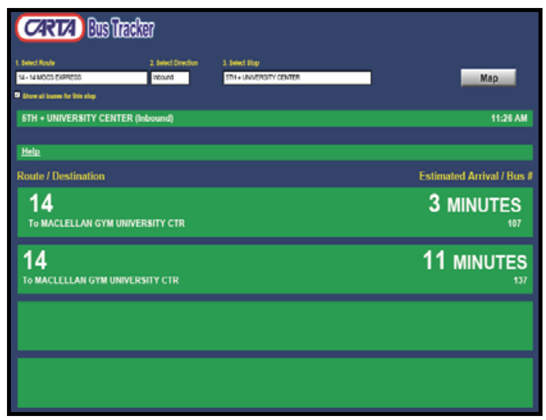
U.S. Department of Transportation

Federal Transit Administration

ADVANCED TECHNOLOGIES FOR TRANSPORTATION RESEARCH PROGRAM

at the University of Tennessee at Chattanooga



January 30, 2009

http://fta.dot.gov/research

Report No. FTA-TN-26-7031-01-2009.1

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (LEAVE BLANK)

2. REPORT DATE
January 30, 2009

3. REPORT TYPE AND DATES COVERED
Final Report
March 15, 2007 – December 31, 2008

4. TITLE AND SUBTITLE
Advanced Technologies for Transportation Research Program at the University of Tennessee at Chattanooga

5. FUNDING NUMBERS
TN-26-7031-01

6. AUTHOR(S)
Mark E. Hairr and J. Ronald Bailey, PhD, P.E.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
ATTRP
University of Tennessee at Chattanooga
615 McCallie Avenue
214 EMCS Bldg., Dept. 2522
Chattanooga, Tennessee 37403-2598

8. PERFORMING ORGANIZATION REPORT NUMBER
R041301017-001-09

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Department of Transportation
Federal Transit Administration
Office of Research, Demonstration and Innovation
1200 New Jersey Avenue, SE
Washington, DC 20590

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
FTA-TN-26-7031-01-2009.1

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
This document is available to the public through the University of Tennessee at Chattanooga, University Relations, 615 McCallie Avenue, 203 Founders Hall, Dept. 5655, Chattanooga, Tennessee 37403, 423-425-4363 (http://www.utc.edu)

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)
This report documents the results of the research program completed by the Advanced Technologies for Transportation Research Program (ATTRP) at the University of Tennessee at Chattanooga (UTC) under Federal Transit Administration Cooperative Agreement TN-26-7031-01. Research activities included providing technical assistance to a wide range of organizations; preparation of technical reports on advanced transit vehicle technologies and energy storage systems for three (3) agencies; participation in leadership roles in the industry through service on the FTA Electric Drive Strategic Plan Steering Committee and acting as Editor-in-Chief for the World Electric Vehicle Journal Volume 2; support of the industry through the dissemination of research results at conferences, seminars and symposia; recommissioning and upgrading a unique and valuable resource in the Advanced Vehicle Test Facility (AVTF) located in Chattanooga, Tennessee; completion of a comprehensive campus transit plan for UTC; deployment of a Dynamic Message Sign (DMS) system in conjunction with CARTA; preparation of a DMS Dual Power Engineering Analysis; and development, testing and demonstration of a Data Acquisition System (DAS) for electric and hybrid-electric buses.

14. SUBJECT TERMS public transportation, advanced vehicle test facility, transit plan, dynamic message signs (DMS), data acquisition system (DAS)

15. NUMBER OF PAGES
106

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
	Unclassified	Unclassified	

NSN 7540-01-280-550 Prescribed by ANSI Std. 239-18298-102 Standard Form 298 (Rev.02-89)

ADVANCED TECHNOLOGIES FOR TRANSPORTATION RESEARCH PROGRAM
at the University of Tennessee at Chattanooga

January 30, 2009

Prepared by
ATTRP
University of Tennessee at Chattanooga
Mark E. Hairr, Research Program Director
J. Ronald Bailey, PhD, P.E., Principal Investigator
615 McCallie Avenue
214 EMCS Bldg., Dept. 2522
Chattanooga, Tennessee 37403-2598
(423) 425-5454

THE UNIVERSITY of TENNESSEE UT CHATTANOOGA
[http://www.utc.edu/cete]

Report No. FTA-TN-26-7031-01-2009.1

Sponsored by
Federal Transit Administration
Office of Research, Demonstration and Innovation
U.S. Department of Transportation
1200 New Jersey Avenue, SE
Washington, DC 20590

Available Online
[http://www.fta.dot.gov/research]

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AC	Alternating Current
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ATTRP	Advanced Technologies for Transportation Research Program
AVERE	European Association for Battery, Hybrid and Fuel Cell Electric Vehicles
AVL	Automatic Vehicle Location
AVTF	Advanced Vehicle Test Facility
CARTA	Chattanooga Area Regional Transportation Association
CMU	Concrete Masonry Units
CNG	Compressed Natural Gas
CPU	Central Processing Unit
CSTCC	Chattanooga State Technical Community College
CTE	Center for Transportation and the Environment
DAS	Data Acquisition System
DC	Direct Current
DMS	Dynamic Message Signs
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EDDS	Electronic Document and Digital Storage
EDGE	Ecological Decisions for a Global Environment
EDSP	Electric Drive Strategic Plan
EDTA	Electric Drive Transportation Association
EIA	Energy Information Administration
EPB	Electric Power Board
ETCFC	East Tennessee Clean Fuels Coalition
EVAPP	Electric Vehicle Association of Asia Pacific
FTA	Federal Transit Administration
GPS	Global Positioning Satellite
GVWR	Gross Vehicle Weight Rating
HVAC	Heating, Ventilation and Air Conditioning
ICE	Internal Combustion Engine
ITS	Intelligent Transportation Systems
KU	University of Kansas

LIST OF ACRONYMS (continued)

M.T.B.F.	Mean Time Between Failures
LED	Light-emitting diode
NATC	Nevada Automotive Test Center
NCAT	National Center for Asphalt Technology
NEMA	National Electrical Manufacturers Association
NTCIP	National Transportation Communications for ITS Protocol
PDA	Personal Digital Assistant
PV	Photovoltaic
SAFETEA LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SBMTD	Santa Barbara Metropolitan Transit District
TDM	Transportation Demand Management
TVA	Tennessee Valley Authority
UL	Underwriter Laboratories
UTC	University of Tennessee at Chattanooga
VAC	Volts of Alternating Current
VCT	Vinyl Composition Tile
WEVA	World Electric Vehicle Association

ACKNOWLEDGEMENTS

This project was conducted under Federal Transit Administration (FTA) Cooperative Agreement TN-26-7031-01. Special recognition and appreciation is extended to the Chattanooga Enterprise Center staff and board, the Chattanooga Area Regional Transportation Authority (CARTA) and the University of Tennessee at Chattanooga (UTC) Campus Transit Plan Advisory Committee all of which contributed greatly in the completion of this research program.

The project team also wishes to thank Mr. Henry Nejako, FTA Program Management Officer, and the countless UTC students, faculty and staff who assisted with many aspects of the projects completed under this work program.

ABSTRACT

This report documents the results of the research program completed by the Advanced Technologies for Transportation Research Program (ATTRP) at the University of Tennessee at Chattanooga (UTC) under Federal Transit Administration Cooperative Agreement TN-26-7031-01. Research activities included providing technical assistance to a wide range of organizations, preparation of technical reports on advanced transit vehicle technologies and energy storage systems for three (3) agencies; participation in leadership roles in the industry through service on the FTA Electric Drive Strategic Plan Steering Committee and acting as Editor-in-Chief for the World Electric Vehicle Journal Volume 2; support of the industry through the dissemination of research results at conferences, seminars and symposia; recommissioning and upgrading a unique and valuable resource in the Advanced Vehicle Test Facility (AVTF) located in Chattanooga, Tennessee; completion of a comprehensive campus transit plan for UTC; deployment of a Dynamic Message Sign (DMS) system in conjunction with CARTA; preparation of a DMS Dual Power Engineering Analysis; and development, testing and demonstration of a Data Acquisition System (DAS) for electric and hybrid-electric buses.

SUMMARY

The research program completed by ATTRP under TN-26-7031-01 has contributed to the knowledge base, research and demonstration of advanced technology and alternative fuel options for public transportation in support of the nation's efforts to reduce dependency on foreign oil and improve air quality. The research program included furthering knowledge and understanding of alternative bus transportation propulsion systems (including hydrogen engines and electric-drive hybrids), intelligent transportation systems, transportation requirements analysis and data acquisition applications to evaluate electric and hybrid propulsion performance.

Specifically, ATTRP provided technical assistance to a wide range of organizations and prepared technical reports on specific topics of need for three (3) agencies; played a leadership role in the industry by serving on the FTA Electric Drive Strategic Plan Steering Committee and serving as Editor-in-Chief for the World Electric Vehicle Journal Volume 2; supported the industry through the dissemination of research results at conferences, seminars and symposia; recommissioned and upgraded a unique and valuable resource in the Advanced Vehicle Test Facility (AVTF); completed a comprehensive campus transit plan for UTC that spawned several specific transit projects; deployed a Dynamic Message Sign (DMS) system in conjunction with CARTA; prepared a DMS Dual Power Engineering Analysis; and developed a Data Acquisition System (DAS) for electric and hybrid-electric buses. These research projects have wide ranging benefits to the industry and have positioned ATTRP to be a national leader in the future in advanced transit vehicle technologies and alternative fuels.

INTRODUCTION

The purpose of the Advanced Technologies for Transportation Research Program (ATTRP) at the University of Tennessee at Chattanooga (UTC) is to assist in the development of advanced technology and alternative fuel options for public transportation in support of the nation's efforts to reduce dependency on foreign oil and improve air quality. The TN-26-7031-01 Federal Transit Administration (FTA) Cooperative Agreement provided funding assistance for a work program that included conducting, documenting and evaluating multiple demonstration projects in advanced technologies ready for real-world, commercial application. These activities encompassed research and educational programs related to the transportation sector and involved faculty, scientists, students and staff at UTC and a number of external partners. The research included furthering knowledge and understanding of alternative bus transportation propulsion systems (including hydrogen engines and electric-drive hybrids), intelligent transportation systems, transportation requirements analysis and data acquisition applications to evaluate electric and hybrid propulsion performance. The dissemination of research results included educating the public and private sectors in the use of electric-drive vehicles, hydrogen fuel and alternative clean fuels in public transportation; offering technical assistance to improve or enhance the performance of bus transportation systems; and recommending the proper deployment of innovative battery charging techniques to support public transportation.

Fortunately, UTC is located in Chattanooga, Tennessee, a city that has earned a reputation as the "Living Laboratory" for clean transportation through operation of a fleet of battery electric buses that carry more than one million passengers each year. This fleet of buses is operated by the Chattanooga Area Regional Transportation Authority (CARTA), which has developed unique expertise in the operation and maintenance of these buses. Chattanooga is also home to the engineering headquarters of the Tennessee Valley Authority (TVA), the nation's largest public electric utility. In addition to production and transmission of electricity, TVA has a long history of participation in clean energy initiatives. This includes the development of the Electric Vehicle Test Track that was built by TVA during the last energy crisis for use in evaluating alternative fuel vehicles. The electric buses used by CARTA were tested at this track, a facility that was made available for this project through a long-term easement agreement. This unique facility includes a paved one-mile banked oval track and a 9,452 square foot building with a high bay maintenance/shop area, offices, and laboratories with adequate utilities to conduct the planned activities of this project.

ATTRP resides in the College of Engineering and Computer Science at UTC. The College strives to serve and support the people, businesses, and industries of the greater Chattanooga metropolitan area and exists as the region's principal resource for engineering education, applied research, and service programs that are grounded in the application of scientific and mathematical principles and based on a commitment to interdisciplinary study. The College recognizes the importance of developing clean, renewable energy systems for transportation as a critical element in national and global efforts to reduce the harmful effects of engine exhaust gases while promoting energy conservation and independence.

The TN-26-7031-01 work program was comprised of six (6) separate tasks including:

- Task 1. Program Management
- Task 2. Technical Assistance and Support of Advanced Transportation Technology Activities
- Task 3. Development of an Improvements Plan and Business Plan for the ATTRP Advanced Vehicle Test Facility (AVTF)
- Task 4. Development of a Comprehensive Campus Transit Plan for UTC
- Task 5. Implementation of a Dynamic Message Sign (DMS) System for the UTC campus transit shuttle and CARTA system
- Task 6. Development of a Vehicle Data Acquisition System (DAS) for Electric and Hybrid Electric Buses

Under Task 1, ATTRP worked in close cooperation with the FTA and maintained frequent contact with the FTA program management officer, conducting project status reviews, preparing milestone/progress, financial, and quarterly reports for FTA review, and notifying FTA promptly of any requested modifications, unexpected problems or changes. Financial management of the project followed the general guidelines outlined in OMB Circular A-21--Principles for Determining Costs Applicable to Grants, Contracts, and Other Agreements With Educational Institutions, and UTC internal policies that govern externally funded research programs. The FTA's Transportation Electronic Award Management (TEAM) system was used for managing, monitoring and documenting the various tasks performed under this grant.

As part of Task 2 under this work program, UTC provided technical assistance to support public transportation agencies, universities, human and social services agencies, national parks, and other entities interested in electric, hybrid-electric, and other advanced transportation technologies applicable to buses and similar vehicles. This task also included monitoring and updating the program's website and providing support to regional, national and international organizations such as the American Public Transportation Association (APTA), the Center for Transportation and the Environment (CTE), the East Tennessee Clean Fuels Coalition (ETCFC), the Electric Drive Transportation Association (EDTA), and the World Electric Vehicle Association (WEVA).

Task 3 of the work program was focused on the Advanced Vehicle Test Facility (AVTF) located near the UTC campus. The AVTF is owned by the Tennessee Valley Authority (TVA) and was built in 1981 through a joint project with TVA and the U. S. Department of Energy (DOE). It includes a one-mile, banked oval asphalt test track and a 9,452 square foot laboratory/office building on 55 acres located near the Chickamauga Dam on the Tennessee River. Until 1997, the facility was used by TVA for testing electric vehicles and batteries. After a number of years of limited use, an agreement was executed for TVA to grant UTC long term access to and use of the test facility through a fifty-year lease.

As might be expected after several years of inactivity, a number of basic improvements and upgrades to the AVTF were required in order to re-open it for the purpose intended. In order to identify the necessary improvements and associated costs, ATTRP developed a AVTF Improvements Plan. This plan documented the existing condition of the facility, identified equipment needs to support ATTRP research activities, identified initial facility and site improvements required to recommission the facility and also identified additional future improvements needed to ensure the facility would realize its maximum potential in the future. ATTRP worked with the UTC Facilities Department on completing a number of facility improvements such as pavement repair and repaving, painting, building repairs and Americans with Disabilities Act (ADA) upgrades. In addition, ATTRP completed phase one of equipment installation at the facility by installing computer equipment, a power transfer system and relocating energy storage systems to the facility for testing. Following the completion of the improvements and installation of equipment, the facility began being used for a variety of research activities including UTC engineering student projects and demonstrations of various types of electric and hybrid-electric vehicles. In addition to the Improvements Plan, ATTRP also completed a Business Plan for the AVTF which covered a range of market issues related to the facility including identifying target markets and developing an operating/financial plan to ensure the sustainability of the facility in the future.

The purpose of Task 4 under the work program was to develop a comprehensive campus transit plan. Since 2001, CARTA has operated a shuttle in and around the UTC campus. Ridership continues to increase each semester and the transit plan is intended to provide strategies to build upon this success and fully capitalize on the potential of this campus service. The plan focuses on the transit system in the context of overall campus transportation issues and includes recommendations for ensuring that transit and related alternative modes of transportation are viable options in the future. Building on the strengths of the research team, a special focus of the plan was placed on identifying advanced vehicle technologies and Intelligent Transportation Systems (ITS) that support campus sustainability initiatives.

Although Task 5 was initially only a concept in the original TN-26-7031-01 work program, ATTRP and CARTA worked closely together to identify a specific project that would support the other ATTRP research activities and fit within CARTA’s overall ITS program. After careful consideration, ATTRP and CARTA identified a Dynamic Message Sign (DMS) system project that involved the deployment of a real-time electronic passenger information system on campus and at other strategic locations important to university passengers. The project complemented other activities under TN-26-7031-01 in addition to CARTA’s comprehensive ITS system which began in earnest in 2007. Implementation of the DMS system will further support ATTRP’s “Smart and Clean” approach to campus transit by deploying ITS technologies on advanced technology and clean fuel vehicles. The need for improved passenger information at bus stops was identified as a top priority during the development of the UTC Campus Transit Plan completed under Task 4, and this project provided a near-term remedy for addressing this issue.

The real-time passenger information system, or dynamic message sign (DMS) system, is intended to improve customer satisfaction in such a manner as to lead to increased ridership on campus-related transit services. DMS communicates real-time arrival and departure information to passengers via electronic bus stop signs, the internet and wireless hand-held devices such as mobile phones and Personal Digital Assistants (PDAs). The system greatly increases customer access to real-time information by allowing for user-defined views and automated notification of bus arrival times on hand-held devices. This real-time system not only communicates precise arrival and departure times, but also provides passengers with critical information regarding service interruptions, emergencies and other important public service announcements and campus-related event notices. DMS utilizes Global Positioning Satellite (GPS) technology to identify bus locations as well as provides for predictive modeling. The system calculates the arrival time of buses for specific routes and stops and provides definitive information for passengers addressing the uncertainty that often exists at bus stops for passengers.

The final research project under TN-26-7031-01 was identified as Task 6 and included the design, fabrication, testing and demonstration of a new data acquisition system for electric and hybrid-electric vehicles. The system is comprised of a "black-box flight recorder" or small central processing unit (CPU) located "under the hood" that utilizes a handheld computer with a customized data post-processing program to allow for real-time monitoring and stored data downloads. Time and again electric bus deployments have failed because the operating agencies do not have an understanding of how the performance capabilities of any particular electric bus match up with the requirements of the operational duty cycle. Batteries are frequently subjected to over-discharge and over- or under-charge as well as operational conditions that progressively degrade the performance and life expectancy of the battery. The new data acquisition system permits operating agencies to understand, in real time, the impact that an operator or service requirement is having on the entire electric or hybrid-electric propulsion system and, more specifically, the batteries. The DAS units were successfully demonstrated on electric buses at Santa Barbara Metropolitan Transit District (SBMTD) and Emory University in Atlanta and on a hybrid-electric antique-style replica trolley in the City of Sevierville, Tennessee.

The remainder of this report provides full details of the five (5) major research tasks (Task Nos. 2-6) under TN-26-7031-01.

II. TECHNICAL ASSISTANCE AND SUPPORT OF INDUSTRY ACTIVITIES (TASK 2)

As part of Task 2 under TN-26-7031-01, ATTRP participated in several major industry activities, provided technical assistance to a variety of organizations and prepared technical reports in the area of alternative fuels and advanced transit vehicle technologies. For a complete list of Task 2 activities completed during the course of this Cooperative Agreement, please see Appendix I.

The two major industry activities involving ATTRP personnel during the course of this work program included the Federal Transit Administration (FTA) Electric Drive Strategic Plan (EDSP) Steering Committee and the editing and publication of the World Electric Vehicle Journal Volume 2. ATTRP's Research Program Director served on the EDSP Steering Committee as this group provided expert input and feedback to the FTA on a new strategic planning process to guide research activities over the next 20 years. The EDSP defines a 20-year vision for electric drive bus and rail technology and outlines a 5-year schedule of R&D activities that will help industry move toward achieving this vision. The purpose of the plan is to identify and prioritize potential actions that FTA's Research Office could perform to support transit operators in adopting electric drive technology. Typically, FTA research activities fall into three categories:

1) Analysis and Development
2) Demonstrations and Validation
3) Deployment and Implementation

Once completed, the EDSP is intended to summarize the current state of knowledge in electric drive technologies and systems of both bus and rail transit. It will also highlight the historical role of such vehicles in driveline technology innovation, the evolution of electric drive systems, and current innovations. The plan also is intended to present the research activities developed to address the technical gaps and identify the role of FTA research necessary to drive the transit industry toward the 20-year vision. These activities are to be presented in a strategic context, highlighting the tasks that FTA should pursue in the next five years.

Ultimately, the EDSP can guidance to the FTA on a long-range vision for electric drive in transit that results in commercially available technologies and vehicles that enable operations that achieve significantly higher efficiencies and lower emissions and are competitive on a life-cycle cost basis with technologies and vehicles available today. This vision has two major implementation components: to improve the overall performance of the national transit fleet; and to develop and deploy innovative advanced transit vehicles including propulsion systems, components, accessories and infrastructure. Typically, FTA programs are technology and fuel neutral, and this vision assumes that there are limits to what can be achieved in the development of any one propulsion system and related vehicle technology. Several different, and possibly simultaneous, technological pathways to widespread deployment may be necessary and advantageous. The EDSP vision is intended to help drive the transit industry forward in achieving commercial success with necessary technologies.

ATTRP also served in the lead role as Editor-In-Chief for the WEV Journal Volume 2, a Journal which serves as the primary scholarly publication for electric vehicle technology in the international arena. The Journal is unique in that it is the primary scientific publication that covers all studies related to battery, hybrid and fuel cell electric vehicles comprehensively. The Journal is intended to complement the Electric Vehicle Symposium (EVS), an international event organized under the umbrella of the World Electric Vehicle Association (WEVA) and rotated

Figure 1. **World Electric Vehicle Journal Volume 2 Cover**

between the three regions of Europe, the Americas, and Asia-Pacific. WEVA was launched in 1990 for the purpose of promoting research, development and dissemination of electric vehicles. WEVA consists of three regional organizations, the European Association for Battery, Hybrid and Fuel Cell Electric Vehicles (AVERE), the Electric Drive Transportation Association (EDTA), and the Electric Vehicle Association of Asia Pacific (EVAPP). AVERE, EDTA and EVAAP are international associations designed to popularize electric vehicles in their respective regions of Europe, the Americas, and Asia-Pacific.

Volume 2 of the Journal is based on papers that were presented at EVS-23 held in Anaheim, California, December 2-5, 2007. The papers have been organized into four issues. Issue 1 begins with a historical perspective of the industry and includes articles on subjects ranging from small commercial to full electric hybrid vehicles. Issue 2 focuses on energy demand, consumption and storage from a global perspective with articles on advanced batteries and electric propulsion systems. Fuel cells and use of wind energy to produce hydrogen are included in Issue 3. Issue 4 covers propulsion systems, control technologies and sustainability. The task of editing the Journal was completed prior to December 31, 2008 in order to assist the EVS-24 International Program Committee in preparation for the upcoming symposium scheduled for May 13-16, 2008 in Stavanger, Norway. Final publication of the Journal is expected to be completed in the first quarter of 2009.

Other activities under the task of technical assistance ranged from informal assistance through telephone and email communications to full scale technical assessment reports throughout the term of the cooperative agreement. In order to gauge the effectiveness of ATTRP's performance in providing technical assistance under this work program item, a survey was conducted of three (3) entities that received technical assistance through ATTRP. This assistance consisted of the completion of a technical assessment report for each of the respective organizations, namely the

Chattanooga Area Regional Transportation Authority (CARTA), the National Parks Conservation Association (NPCA) and ValleyRide, the public transportation provider located in Boise, Idaho. Specifically, ATTRP completed the following technical reports:

a. CARTA Electric Bus Battery Analysis (March 26, 2008)
b. Alternative Fuel Options for ValleyRide (October 4, 2007)
c. Alternative Fuel Vehicle Options for Cades Cove Shuttle (November 28, 2007)

The evaluation survey was developed and administered to the three organizations in November of 2008 for the purpose of measuring the effectiveness of ATTRP in addressing the organization's objectives through technical assistance and the level of satisfaction with expertise provided by ATTRP. The survey included six (6) questions with a rating system of 1 through 5 with 5 being very satisfied and 1 being very dissatisfied (see Appendix II for survey instrument). Additionally, the survey included a question as to whether the organizations would recommend ATTRP to other organizations with a need for similar technical assistance. Finally, the survey also allowed respondents an opportunity to provide other general comments they deemed important to mention that may not be covered in the other survey questions.

The survey results included in Appendix III of this report indicate the highest level of satisfaction by the three organizations with all responses being a "5" or very satisfied. Additionally, all of the organizations indicated they would recommend ATTRP to other organizations with a similar need for technical assistance and the "other comments" section also included a number of positive comments reflecting a high level of satisfaction with the performance of ATTRP. The survey results were forwarded to the UT Chattanooga Director of Research Integrity for review and it was determined and confirmed on December 1, 2008 that ATTRP's performance under Task 2 of TN-26-7031-01 was acceptable.

III. ADVANCED VEHICLE TEST FACILITY (AVTF) (TASK 3)

The primary purpose of Task 3 under TN-26-7031-01 was to recommission the Advanced Vehicle Test Facility (AVTF) following its transfer to ATTRP through an easement agreement with the Tennessee Valley Authority (TVA). This facility was developed and opened in 1981 by TVA for the purpose of conducting electric vehicle research. After several years of operation, the test track became dormant and was used most recently by a hydro-electric contractor for storing heavy equipment. UT Chattanooga began efforts to secure use of the test track facility in 2006 as a critical asset to be used in support of a newly formed advanced vehicle technology research program (i.e., ATTRP) housed in the College of Engineering and Computer Science. Once ATTRP secured use of the AVTF, additional work was completed on improvements and business plans and initial facility upgrades.

The AVTF is located at 4605 Amnicola Highway approximately 7.5 miles from the UTC campus on the southwestern side of the Chickamauga Dam adjacent to a Southern Railroad right-of-way. Chattanooga State Technical Community College (CSTCC), a two-year academic institution, is located immediately to the west of the railroad right-of-way. As shown in Figures 2 and 3, the AVTF site consists of approximately 55 acres of property, a one-mile asphalt oval track, a 9,452 square foot pre-engineered frame building and a wetlands ecosystem covering the area inside the track. The design of the building incorporates a clerestory that allows for light to be reflected into the office spaces and high-bay maintenance work areas. On the southern elevation, the windows in the office area are recessed approximately four feet from the exterior wall of the building which allows the winter sunlight to enter the offices while shading the interior of the building from the southern summertime sun. The design and orientation of the building on the site were optimized for future installation of solar arrays on the roof of the structure.

Figure 2. One-Mile Oval Track at AVTF

Figure 3. 9,452 Sq. Ft. AVTF Building

Once the test track facility transitioned to ATTRP, its initial use was focused on a UTC engineering student project involving the conversion and testing of a Saturn Vue to operate on ethanol; storage and charging of an electric vehicle; demonstration of a hybrid cutaway transit vehicle from Azure Dynamics; and the demonstration of a hybrid Class 6 truck from Kenworth. Additionally, an ABC-150 Power Processing System was relocated to the AVTF and computer equipment was installed in several offices to support future staff work.

Figure 4. New Hybrid Electric Cutaway Transit Vehicle Demonstration at AVTF

a. AVTF Improvements Plan

In order to address improvements and upgrades to the AVTF in an orderly and comprehensive manner, ATTRP completed an Improvements Plan for the facility. This plan documented the condition of the facility at the time ATTRP secured use of it, identified initial improvements and equipment needs required to return the facility to an operable status and identified additional improvements and equipment needs to ensure the facility reaches its maximum potential in the field of clean vehicle and renewable energy research. The condition of the facility at the time ATTRP secured its use can be summarized as follows (based primarily on the Site and Facilities Evaluation completed by Franklin Associates on May 1, 2006): [1]

1) The building exterior is a pre-engineered frame with a combination of corrugated metal siding over concrete masonry units (CMU) and corrugated metal siding over metal studs and gypsum wallboard. There are portions of the metal siding at the bottom where it meets the ground that are rusted and in need of repair.
2) The roof is in satisfactory condition and there is no evidence from the building interior of roof leaks.
3) The building interior is either painted CMU, painted gypsum wallboard or prefinished metal panels. Several interior ceiling tiles need to be replaced.
4) The office areas have carpet and rubber base while the entrance lobby and kitchen have vinyl composition tile (VCT) and rubber base.
5) The restrooms have ceramic tile floors with a ceramic tile base and wainscot. The two toilets are outdated and not in compliance with Americans with Disabilities (ADA) requirements.
6) The high-bay maintenance area has sealed concrete floors and painted walls and/or prefinished metal panels. Some of the clerestory windows appear to be inoperable. This area is in need of a thorough cleaning especially along the sides and around the clerestory windows and ceiling interior.
7) Safety features include fire extinguishers, a wet sprinkler system, a fire alarm system and emergency eyewash stations in the high-bay maintenance area.
8) The entrance driveway has a number of areas of pavement damage and potholes in need of repair and/or repaving.
9) The track itself is in generally good condition with a few potholes in need of repair. A modest amount of pavement damage exists on the back side of the track.
10) Chain link fencing on the western side of the building has separated from the building and is in need of repair. Fencing along the western portion of the track is damaged and in need of repair.

Based on the Site and Facilities Evaluation Report performed by Franklin Associates and a comprehensive review and evaluation by the UTC Facilities and Planning Director, a number of specific improvements were identified for the AVTF.

[1]Franklin & Associates, May 1, 2006, *Test Track Site and Facilities Evaluation, SBC Project No. 540/05-01-06*.

These improvements are listed below in order of priority:

1) Inspect and recharge all fire extinguishers
2) Review the present grounds maintenance, landscaping and mowing arrangements with the two private contractors in order to determine whether one organization (i.e., either UTC Facilities or one private contractor) would be more cost-effective for these services
3) Repair and/or repave the entrance road
4) Repair the exterior of the building where the siding close to the ground is rusted and deteriorated in order to prevent water filtration into the building at the floor line
5) Paint all interior walls including the high-bay maintenance area with a high quality, eggshell, latex product
6) Replace toilets and ensure bathrooms meet ADA requirements
7) Replace all door handles and hardware to meet ADA requirements
8) Repaint all exterior doors and install proper weatherstripping and thresholds
9) Repair gutters
10) Inspect and repair HVAC and other climate control systems
11) Clean interior VCTs

Once the facility improvements were identified and prioritized, an implementation schedule and cost estimates were developed. Table 1 below shows the list of improvements, costs, completion dates and responsible party for completing the work. The total cost of the initial repairs, upgrades and improvements was $32,824.

Table 1. Implementation Schedule for AVTF Site and Facilities Improvements

Improvement	Cost	Completion Date	Responsible Party
1) Recharge fire extinguishers	$50	Nov 15, 2008	UTC Facilities
2) Rearrange grounds maintenance arrangement	$350/month*	Dec 1, 2008	ATTRP
3) Repair entrance road	$16,800	Sep 19, 2008	UTC Facilities
4) Repair bottom of building exterior	$1,000	Sep 15, 2008	UTC Facilities
5) Paint and repair building interior	$1,240	Sep 15, 2008	UTC Facilities
6) Upgrade restrooms	$881	Sep 24, 2008	UTC Facilities
7) Replace door handles	$125	Aug 22, 2008	UTC Facilities
8) Repaint exterior and weatherstrip doors	$7,329	Aug 29, 2008	UTC Facilities
9) Repair gutters	$3,518	Aug 29, 2008	UTC Facilities
10) Complete HVAC and electrical repairs	$1,431	Sep 30, 2008	UTC Facilities
11) Clean VCTs	$450	Oct 31, 2008	UTC Facilities
Total Estimated Costs	**$32,824**		

Monthly operating cost—not included in total improvements costs

As noted above, all of these facility improvements were completed prior to December 31, 2008 resulting in significant upgrades to the AVTF. Documentation of the improvements are shown in the before and after photographs Appendix IV of this report.

b. AVTF Business Plan

Following completion of the AVTF Improvements Plan, ATTRP developed a Business Plan to address a wide range of market issues related to the test facility including identifying target markets and developing an operating/financial plan to ensure this valuable resource is used to its maximum potential in the future.

i. AVTF Asset Value

As a beginning point in evaluating the value of the AVTF asset, ATTRP analyzed a real estate broker opinion of value that was completed in late 2006 as the facility was being considered for transition from TVA to the university. The real estate broker's analysis resulted in an estimate of the value of the land, property and building. The real estate report indicated that the land and building have a defined value resulting from an analysis of industrial real estate activity; however, the test track is unique and the value indicated is based solely on its replacement cost less the deferred maintenance.[2] As shown in Table 2, the real estate analysis revealed that the total value of the facility was $1,745,000 with the land accounting for $1,195,000 in value, the building $300,000 in value and the one-mile test track accounting for $250,000. These values assist in developing pricing arrangements and provide a documented asset value that can be used as an important advantage to ATTRP when competing for research funding.

Table 2. Estimate of Value for AVTF

Element	Estimated Value
Land	$1,195,000
Building	$300,000
Track	$250,000
Total Facility Value	**$1,745,000**

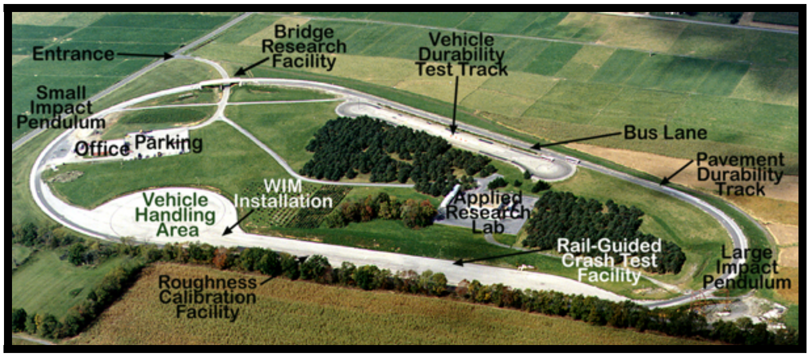
ii. Review of Vehicle Test Track Market

During the course of the market research element of the Business Plan, analyses showed that there are a number of vehicle test tracks operating in the United States but the ATTRP facility is fairly unique. The major test tracks identified and reviewed included the Altoona Bus Research and Testing Center which is the site where all new model public transportation buses are tested under Federal Transit Administration (FTA) regulations; the Nevada Automotive Test Center (NATC) which is dedicated to ground vehicle, component and weapons systems testing; automotive proving ground sites where private auto manufacturers conduct vehicle systems and safety tests; automotive test tracks located in conjunction with manufacturing plants (e.g., Nissan Facility in Smyrna, Tennessee); and the National Center for Asphalt Technology (NCAT) which conducts pavement testing and is moving into serving as a vehicle test site. Although there are a number of test tracks in the United States, the AVTF has a unique combination of elements that provide opportunities for clean energy research activities.

---

[2] DeVaney, David, November 13, 2006, *Broker Opinion of Value*, NAI Charter Commercial Real Estate Services.

Figure 5. Altoona Bus Research and Testing Center



Source: Altoona Bus Research and Testing Center Website (http://www.vss.psu.edu/btrc.htm)

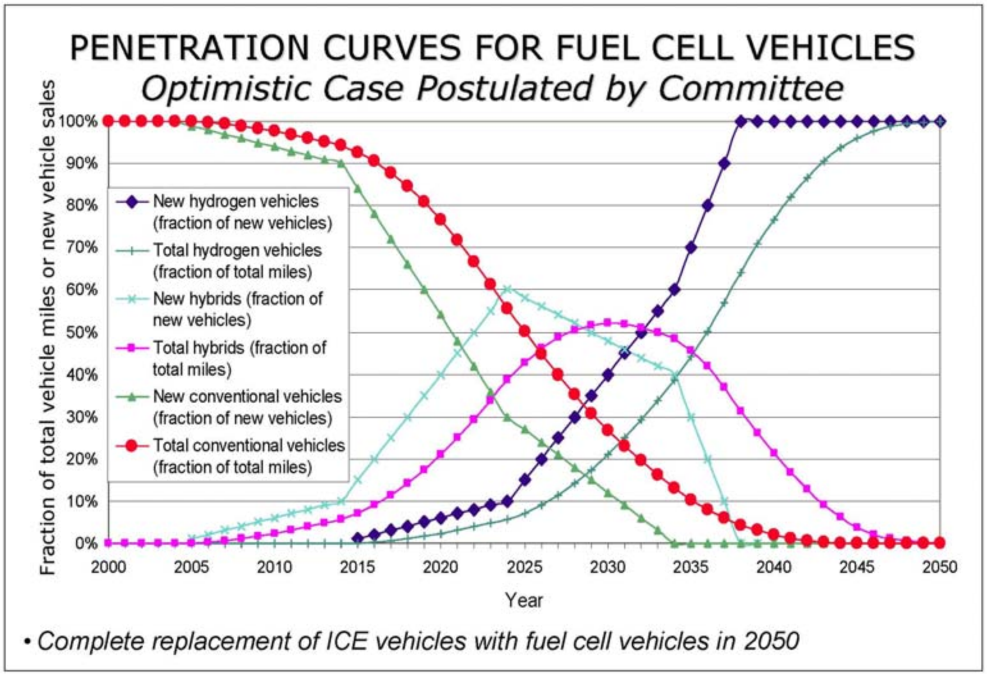
iii. Industry Trends and Barriers

Among the major market conditions that affect the vehicle testing industry include fuel costs and the penetration rates of alternative fuel vehicles. Gasoline and diesel prices rose to unprecedented levels in the summer of 2008 with regular gasoline averaging more than $4.00/gallon and diesel fuel averaging slightly less than $5.00/gallon in the eastern part of the U.S.[3] The substantial fluctuations in fuel costs recently is reflected in the fact that gasoline has ranged from $2.30/gallon to more than $4.00/gallon and diesel fuel has ranged from $2.60/gallon to approximately $5.00/gallon in the eastern U.S. between November 2007 and October 2008.[4] The historic high fuel prices and continued fluctuations in fuel prices have driven increased interest by the general public, government organizations and private businesses in high fuel economy vehicles and alternative fuel vehicles. This situation and a strong desire for more stable fuel costs are expected to continue to drive demand for vehicles fueled by other alternatives rather than just the gasoline internal combustion engine (ICE).

In addition to fuel price issues, another important factor affecting potential utilization of the AVTF is the penetration rates of alternative fuel vehicles. As shown in Figure 6, research from the National Academies of Science indicates that ICE vehicles will begin being replaced in significant numbers after 2015 with hybrid vehicles. Their projections also show that fuel cell vehicles will begin to be deployed in increasing numbers after 2025 with the ICE and hybrids being completely replaced by 2050. As a result, there is a critical need for testing, evaluation and demonstration of the new vehicle technologies projected to replace the ICE by 2050. With the increased emphasis on a more sustainable transportation system in the U.S., opportunities for research and testing of alternative fuel and advanced technology vehicles are expected to expand in the near term.

[3] Energy Information Administration (EIA), November 7, 2008, "Weekly Retail Gasoline and Diesel Prices," http://www.eia.doe.gov/.
[4] Ibid

Figure 6. Penetration Curves for Fuel Cell Vehicles



Source: The National Academies of Science

As the alternative vehicle market is examined in more detail, current figures show that there are 155,000 public transportation vehicles in service with 83,080, or 53.5% of these vehicles classified as buses.[5] In addition, there are another 43,509, or 28% of transit vehicles classified as paratransit vehicles (typically <30 feet cutaway vehicles).[6] Although 80% of all public transit vehicles use diesel fuel, almost 25% of all transit vehicles use some type of alternative power. The most prevalent alternative source of power for transit vehicles is Compressed Natural Gas (CNG) at 13.7% and electric or hybrid vehicles represent 2.3% of alternative fuel transit vehicles.[7] It should be noted that the hybrid transit bus market is expanding rapidly with more than 2,000 hybrids in service and more than 27% of all new transit bus sales being hybrids.[8] With ATTRP's strong foundation in the Federal Transit Administration (FTA) research program, there will be a number of new research opportunities in the future related to alternative fuel and advanced technology public transportation vehicles.

In terms of the growth in the hybrid automobile market, the number of hybrids have increased each year since 2000. The most significant increase in the sale of hybrids occurred between 2004 and 2005 when sales increased more than 150% in just one year.[9]

---

[5] American Public Transportation Association (APTA), June 2008, 2008 Public Transportation Factbook, 59th Edition.
[6] Ibid
[7] Ibid
[8] American Public Transportation Association (APTA), December 15, 2008. Volume 66, No. 41, page 19, *Major Trends for Buses: Hybrids, Eye Appeal, BRT*, Passenger Transport.
[9] Electric Drive Transportation Association (EDTA), *2008 Hybrid Electric Passenger Vehicle Sales By Model (October 2008)*, http://www.electricdrive.org, November 10, 2008.

Sales of hybrids exceeded 330,000 in 2007 representing an increase of more than 30% compared to 2006.[10] However, sales of hybrid automobiles have slowed in 2008 and it is likely total figures for 2008 will show a decline. The use of flex fuel vehicles which can operate on either gas or E-85 ethanol is now prevalent in the U.S. with nearly all major manufacturers offering flex fuel vehicles. Although not commercially available at this time, hydrogen powered light duty vehicles are being deployed in demonstration sites and it is expected that publicly available hydrogen powered cars may be on the market in 10 years.

The last major category of vehicles examined as potential markets for the AVTF were medium duty trucks classified as trucks with a Gross Vehicle Weight Rating (GVWR) of 10,001 to 26,000 lbs. U.S. DOT figures indicated that there were 2,824,400 medium duty trucks operating in 2002 compared to 2,164,900 trucks in 1997, an increase of 30%.[11] If the growth rate of 30% is applied to the five-year period covering 2002-2007, the total number of medium duty trucks in the market would exceed 3,600,000. This amount does not include a total of 1,615,000 vehicles owned by federal, state and local governments.[12] When combined, these two sectors of the medium duty truck market exceed 5,500,000 million trucks. Although the development of the electric and hybrid truck industry lags behind the automotive industry by at least 10 years, recent progress shows this as an important and emerging market with growing vehicle testing needs. The major hybrid truck manufacturers are based in the U.S. and more than six (6) truck manufacturers and ten (10) hybrid system manufacturers are actively developing prototypes and pre-production models.[13] The major focus in this market is on refuse, delivery and utility trucks. Work in the commercial truck market is also expected to pay dividends in the military vehicle market by reducing its costs for hybrid vehicles.

As part of the development of the Business Plan, there were a number of potential barriers identified that could inhibit the successful utilization of the AVTF. These factors are categorized as follows: (a) market entry issues, (b) the potential for an environment that results in low demand for the AVTF facility and associated ATTRP research services, and (c) high capital and equipment costs. Among the market entry issues identified is the ability to effectively gauge demand for vehicle testing services and facilities, developing effective niche marketing and promotions materials, and competition from other facilities (particularly large-scale, well-funded long-standing facilities), or institutions and organizations staffed with individuals with specialized expertise in advanced vehicle technology. Regarding the barrier of potential low demand for the AVTF, there could be changing conditions such as significant decreases in fuel costs that would have a detrimental impact and lessen the emphasis on alternative fuel vehicles. This situation has been repeated several times since the oil embargo of the

[10] Ibid

[11] U.S. Department of Transportation, Research and Innovative Technology Administration (RITA), Bureau of Transportation Statistics, April 2007, *U.S. Automobile and Truck Fleets By Use (1997).*

[12] 2002: U.S. Census Bureau, *2002 Economic Census: Vehicle Inventory and Use Survey, United States*, ECO2TV-US (Washington, DC: 2004).

[13] CALSTART, June 10, 2008, Testimony for the U.S. House Committee on Science and Technology, Energy and Environment Subcommittee.

1970s and may occur again in the future. A sustained decrease in fuel prices is an external factor that ATTRP could not control and would negatively impact demand for AVTF services. As pointed out during the review of the Business Plan by the Enterprise Center, it is advisable for CETE to develop a contingency plan to address ongoing operations in the event that energy prices remain low for a prolonged period of time. Lastly, as CETE continues to upgrade the AVTF to a world-class research facility status, there are additional capital and equipment costs to be addressed to ensure sustainability. These necessary capital, equipment and facilities costs must be managed in a strategic manner to ensure ATTRP's research program responds to current and emerging market conditions.

iv. Future AVTF Equipment Needs

ATTRP has identified additional capital funds for improvements that would further enhance the facility and open up new research project opportunities. As shown in Table 3, the additional short-term capital and equipment costs to the test track facility are estimated to cost $584,025 and include signage, fiber optic installation, purchase and installation of chassis and engine dynamometers, installation of emissions analysis equipment, acquisition of a hydrogen gas generator (electrolyzer), installation of photovoltaic solar arrays for the AVTF building, installation of a power processing system (ABC-150) and equipping the facility with the latest audio-visual equipment and technology.

Table 3. Cost & Implementation Schedule for AVTF Equipment

Improvement	Estimated Cost	Timeframe for Completion	Responsible Party
a) Install facility signage	$2,975	Jan. 31 2009	UTC Facilities
b) Install fiber optic connection	$20,000	Dec 31, 2009	EPB
c) Purchase & install chassis dynamometer	$60,000	Jun 30, 2009	ATTRP
d) Purchase & install engine dynamometer	$30,000	Mar 31, 2009	ATTRP
e) Purchase & install emissions analysis equipment	$25,000	Sep 30 2009	ATTRP
f) Purchase & install hydrogen gas generator (electrolyzer)	$125,000	Dec 31 2009	ATTRP
g) Purchase & install photovoltaic solar array	$300,000	Dec 31 2010	ATTRP
f) Complete installation of ABC-150	$16,350	Jan 2009	ATTRP
g) Install audio-visual equipment	$4,700	Feb 2009	ATTRP
Total	**$584,025**		

v. Potential AVTF Customers

Based on the market research conducted during the course of developing the Business Plan, ATTRP identified potential AVTF users including Chattanooga's local utility provider, the Electric Power Board (EPB), transit vehicle manufacturers, CARTA, Chattanooga State, and automotive manufacturers with an initial focus on Volkswagen and medium duty truck manufacturers and suppliers. Since there are a number of test facilities focused on safety, durability, etc., ATTRP efforts will be focused on alternative fuels and advanced vehicle technologies and associated components. ATTRP will use its modeling capabilities in conjunction with vehicle tests on the one-mile test track to ensure the highest level of comprehensive testing possible.

vi. Marketing Strategies and Forecasts for the AVTF

A number of specific marketing strategies were identified in the Business Plan that will focus on maximizing the utilization of the AVTF. Among the strategies to be employed by ATTRP are promotion, pricing and forecasts of potential use of the facility. The Business Plan includes a number of specific promotional activities that will ensure information is disseminated on a wide scale basis in a cost-effective manner to potential users. When establishing pricing for use of the facility and associated services, ATTRP will consider the value of the facility, current office and research facility rental costs, operating costs, overall revenue generators and other relevant factors. With the test track facility being a secured facility "behind the fence," there are certainly opportunities for private companies to conduct proprietary research. Several separate office spaces exist at the AVTF and a portion or all of the high bay area could be made available. Pricing for this type of arrangement depends upon the testing/project requirements, project duration and desired outcomes. Exclusive use of the test track facility would require a "premium cost" due to the fact that this type of use can severely limit the availability of space to other entities.

As ATTRP developed the Business Plan, an analysis of the rental cost of comparative office and research/development space in the Chattanooga market was conducted. The real estate market data shows the following:[14]

Office Space:

- Rental cost is $12.00 per sq. ft. for typical Class B secondary suburban office space in the Chattanooga market
- Office space square footage = 3,375 square feet
- Cost for all office space = $40,500 per year or $3,375/month

Research & Development (R & D) Space:

- Rental cost is $8.00 per sq. ft R & D space in Chattanooga market
- R & D space square footage = 5,918 square feet
- Cost for all R & D space = $47,344 per year or $3,945/month

[14] NAI Charter Real Estate, December 2008, *2008 Global Market Report, Chattanooga, Tennessee.*

**If two sections of R & D area split 1/3 & 2/3 for leasing purposes, yearly cost = $15,781 & $31,563 respectively

Total Cost of Office and R & D space at AVTF

- **$87,840/year or $7,320/month**

The Business Plan included a use of facility forecast that anticipates that funding will be secured for additional capital facility and equipment improvements no later than the end of 2008 with improvements scheduled for completion by the end of the first quarter of 2009. As a result of the improvements, the AVTF will be upgraded to a level that will expand business opportunities not available in its current status. There are testing projects that can proceed at the AVTF in its current condition including the Georgetown Fuel Cell Bus Testing Project. Based on the project schedule, it is anticipated that this project will begin by the second quarter of calendar year 2009. It is possible that other testing projects such as one involving work by Chattanooga State and EPB on the two electric vehicles presently at the AVTF could also proceed at this time. Once the additional facility and equipment improvements have been made, it is expected that private companies such as vehicle and component manufacturers would have a greater interest in the facility. Based on the needs of the automotive industry, it is likely that an additional $500,000 to $1,000,000 million may be required to upgrade to facility to garner the attention of companies such as Volkswagen.

vii. Operations and Financial Plans

The operations and financial plan developed for the facility includes provisions for staffing and management, estimated operating expenses and revenue projections. ATTRP benefits from its organizational arrangement as it relates to the AVTF. First, the sporadic activity at the AVTF does not require full-time on-site management and staffing. The oversight and management of the AVTF can be handled by the Research Program Director as part of his overall responsibilities. Staffing the AVTF is dependent upon the workload and the particular expertise required for projects on a case-by-case basis. Again as with management and oversight, the nature of some projects may not require regular on-site staffing. In cases where on-site staffing is required, it is likely this research would have finite time periods associated with the project work program and schedule and staffing would be managed closely by the ATTRP management team to ensure cost-effective and efficient operations.

During the development of the Business Plan, operating costs and projected revenues were identified. Estimated operating costs total $38,300 annually and include insurance, easement license fees, utilities, grounds maintenance, facility maintenance, supplies and other expenses. Revenue projections are based on dedicated revenue from grants, overhead generated from grants, and contracts and contract revenue from research projects.

Table 4. Advanced Vehicle Test Track Estimated Operating Expenses

Operating Expense Item	Annual Cost
Insurance Coverage	$8,500
Easement License Fee	$5,000
Utilities:	
Electricity	$13,200
Water	$600
Grounds Maintenance	$9,000
Building Maintenance & Upkeep	$2,500
Supplies	$3,000
Other Expenses	$10,000
Total	**$38,300**

It is anticipated that $58,300 will be generated in year one. If new research contracts are not included, it is anticipated that ATTRP will have dedicated test track revenue from grants and overhead/indirect funds to cover the estimated $38,300 annual expenses in the near term (i.e., 2009). Prospects are favorable for dedicated test track revenue to become available through 2011 in conjunction with testing activities associated with the reprogramming of funds to CETE under the TN-26-7034 FTA Cooperative Agreement. Also, revenue from contracts and/or federal funding for Phase II and Phase III AVTF build-out would cover additional capital and operating expenses in 2012 and beyond.

Table 5. Advanced Vehicle Test Track Estimated Revenue

Revenue Item	Annual Revenue
Dedicated Test Track Revenue from Grants	$27,500
Contract Revenue	$20,000
Overhead/Indirect Revenue Generated from Grants & Contracts	$10,800
Total	**$58,300**

In summary, market conditions are favorable for increased use of the AVTF as ATTRP continues to expand its research program and enlist additional project partners. The current emphasis in the U.S. on clean energy technologies, alternative fuels and energy independence, particularly in the transportation sector, provides a climate in which ATTRP can flourish and contribute greatly to meeting national goals in clean energy research.

As ATTRP developed the AVTF Improvements Plan and Business Plan, guidance and input was sought from the Chattanooga Enterprise Center. The business expertise and experience of the Enterprise Center staff and board members was invaluable in drafting the plans. Once the plans were completed, ATTRP submitted both plans to the Enterprise Center in December of 2008 for review. Subsequently, the Enterprise Center endorsed both plans on January 26, 2009 and a copy of the endorsement letter signed by Wayne Cropp, Enterprise Center Executive Director, is included in Appendix V.

IV. UTC CAMPUS TRANSIT PLAN (TASK 4)

The University of Tennessee at Chattanooga (UTC) Campus Transit Plan provides an assessment of existing campus public transportation services, programs and technologies and recommends enhancements to this system in order to create a shuttle system that supports the university's strategic initiatives. UTC is experiencing significant growth as reflected by the fact that the student population increased more than 7% to 9,558 students in the fall of 2007. After more than ten years of stable enrollment figures, this recent growth is expected to continue over the next several years creating a number of challenges for a campus that lies within an environment constrained by physical geography, adjacent land uses and the existing transportation network.

Figure 7. UTC MOCS Express Shuttle

The campus transit plan focuses on the university transit service in the context of overall campus transportation issues and recommends a number of strategies for ensuring that transit and related alternative modes of transportation are viable options in the future. A special focus of the plan is on advanced vehicle technologies and Intelligent Transportation Systems (ITS) applications that can break the mold of traditional transit service and create a truly "Smart and Clean" transit system that contributes to campus sustainability initiatives.

a. Existing Conditions Related to UTC Campus Transit Plan

An assessment of existing conditions, projected growth in student enrollment and planned campus facilities reveals that increased pressure will continue on the campus transportation system. Based on these conditions and the fact that campus shuttle ridership has risen significantly since its inception in 2001 (see Table 6), there are great opportunities to increase the use of campus transit. Projections indicate that student enrollment will continue to increase over the next several years and that more than 1,000 parking spaces in the core of campus will be lost with the construction of new buildings and facilities. This situation requires that public transportation become an even more important element of the overall campus transportation system and that an integrated multi-modal approach be taken to ensure transportation challenges do no create an overly negative impact on the quality of life on campus. A key element in increasing public transportation's role in campus life is on cleaner advanced vehicles and technologies that address customer service needs and system efficiencies.

Table 6. Route 14 MOCS Express Ridership 2001-2008

Month	2001-02	2002-03	2003-04	2004-05	2005-06*	2006-07	2007-08
August	2,900	3,731	3,941	1,786	2,477	4,900	6,323
September	5,574	6,111	7,073	6,488	10,242	11,570	13,828
October	6,315	5,945	6,623	4,710	9,832	11,887	14,425
November	5,929	4,985	6,711	7,007	9,988	11,571	11,720
December	908	1,599	1,591	2,543	3,873	3,384	3,148
January	3,949	6,293	6,237	4,414	9,525	13,277	11,703
February	4,434	5,961	6,680	4,745	12,519	11,540	12,565
March	2,739	4,472	5,661	4,222	10,555	11,638	7,985
April	3,336	5,483	4,432	4,566	9,120	9,744	10,743
May	0	0	0	0	424	34	0
Total	**36,084**	**44,580**	**44,949**	**40,481**	**78,555**	**89,545**	**92,440**
% Change		**23.6%**	**9.8%**	**-9.9%**	**94.1%**	**14.0%**	**3.2%**

***MOCS Express Route Restructured to Serve UTC Place Student Housing**

In the fall of 2008, UTC completed its Strategic Plan which has a strong focus on technology and research initiatives that build upon the strengths of the university and the city of Chattanooga. The Strategic Plan calls for a connection between the university and the "environmental city" of Chattanooga and includes a goal of becoming the most environmentally sustainable campus in the state of Tennessee. Momentum in supporting this goal has already begun as reflected by the fact that a UTC Green Fee was implemented in the fall of 2007 to generate funds for recycling, renewable energy initiatives and other activities that promote and support sustainability. The Strategic Plan initiatives and programs supported by the Green Fee show the commitment of the campus community to the types of improvements and enhancements outlined in the transit plan.

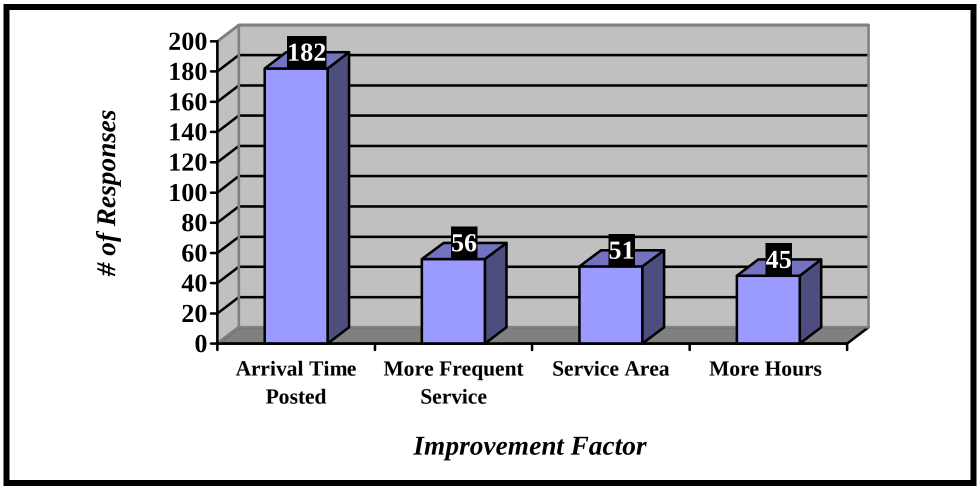
Figure 8. UTC Green Initiative Logo

b. Public Input and Market Research

A critical element in the formulation of recommendations in the UTC Transit Plan was public input and market research conducted by ATTRP. A variety of methods were used to collect input during the development of this transit plan including surveys, focus groups, stakeholder interviews and a public outreach meeting. This input complemented other analyses and provided a mechanism for a wide variety of stakeholders to convey their attitudes, needs and future vision for the campus transit system. The major highlights of the market research included results from a student survey conducted in the spring of 2007 which revealed the following:

- 93.4% of students drive or walk to get around campus rather than use the existing shuttle bus
- 46.5% do no use the shuttle because they have their own car and prefer to drive
- 88.3% of respondents indicate that they are willing to wait no more than 5 minutes for a shuttle
- 46.9% indicated that having the shuttle's arrival time displayed at the bus would encourage use of the shuttle

Figure 9. Factors Encouraging UTC Student Ridership



Another mechanism used to collect input included the use of focus groups centered on public transportation issues. The major issues identified during this process included the following:

- Students expressed a strong desire to arrive to class on time and for there to be short wait times for the shuttle
- There is a perceived lack of information about the existing MOCS Express Service
- Students identified the main benefits of the existing bus service as providing comfort and protection from inclement weather

- There was a perception that the existing one-way route is limiting and that the ride-time can be too long, especially from the University Center back to UTC Place and the campus housing centered around Vine and Houston Streets
- Students expressed a desire to have more advertising for the existing bus service
- There was a strong feeling among students that alternative fuels and advanced technologies are an important element of the shuttle system

There are a number of important stakeholders with an interest in campus transit issues and interviews were conducted with several of these individuals. The results of the stakeholder interviews can be summarized as follows:

- There was an overall positive impression of the existing shuttle system
- The major positive aspects of the existing shuttle system were identified as helping overcome steep topography, high level of frequency of service and effective integration with overall CARTA service
- The major negative aspects of the existing shuttle system were identified as long travel times from the University Center to UTC, bus service on campus which ends too early, a need for increased marketing and a desire to have smaller vehicles serving campus and its surrounding communities
- Several priorities for improving the system were identified by stakeholders including:
  - A desire to have shorter ride times on the existing route
  - A need for more information at bus stops
  - The creation of a shuttle to connect downtown and campus
  - A desire for CARTA and UTC to serve as leaders in clean transportation on campus and downtown

Finally, the input provided during a public outreach meeting in the fall of 2007 provided "top-of-the-mind" impressions from students and faculty who participated. The results of the outreach event can be summarized as follows:

- The overall impression of the UTC campus transit system was positive
- A number of respondents indicated that downtown was a highly desired new location for expanded transit service
- Respondents indicated a desire for real-time bus stop information
- There was strong interest in alternative fuel/clean vehicles serving the campus
- Respondents indicated a need for increased transit marketing

c. UTC Transit Plan Recommendations

As part of the development of the transit plan, a review of alternative fuels and advanced vehicle technologies was conducted in order to determine appropriate applications for the UTC campus transit system. Additionally, ATTRP hosted two major advanced vehicle demonstrations involving a 22-foot hydrogen hybrid bus and a 25-foot hybrid electric minibus or cutaway. Additionally, ATTRP stands in a unique position in the area of inductive charging for electric buses by having access to a complete inductive charging system at the Advanced Vehicle Test Facility (AVTF) in Chattanooga. Capitalizing on this, ATTRP has developed a project plan for a deployment of this system at the University of Kansas (KU) in collaboration with the KU Transportation Research Institute. During the development of the transit plan as part of the evaluation of various vehicle technologies, ATTRP began developing an energy model that allows for an evaluation of various advanced clean vehicle technologies in relation to specific routes to determine the appropriateness and feasibility of the technologies. This model will be used as individual technologies are considered for specific applications on the UTC campus transit system. Based on ATTRP's initial evaluations, there are several advanced vehicle technologies appropriate for campus-related services including:

- A hybrid electric minibus or cutaway type vehicle
- A hydrogen hybrid ICE shuttle (<30-foot)
- A battery-centric small hydrogen fuel cell bus (<30-foot)
- An electric bus with inductive charging

Another major focus of the campus transit plan is on Intelligent Transportation System (ITS) applications. ATTRP coordinated closely with CARTA and identified a core set of ITS applications to pursue in the near term. These include the following:

- Implementation of an Automatic Vehicle Location (AVL) System
- Installation of a Dynamic Message Sign (DMS) system on campus and at other strategic locations for students, faculty and staff
- Activation of a wireless internet service throughout the CARTA bus system
- Implementation of an advanced fare collection system including deployment of a smart card fare payment system

These ITS applications add the "smart" element to the "clean" transit system and position CARTA and UTC as leaders in clean advanced transit applications.

Complementing the vehicle and ITS applications, there were a number of other transit services and programs identified that can improve and enhance the overall shuttle system. These recommendations are as follows:

- Future modification and improvement of existing Route 14 MOCS Express
- Implementation of a "Smart and Clean" on-demand shuttle
- Implementation of a UTC-Downtown Connector using clean fuel vehicles
- Implementation of a new Off-Campus Apartment Shuttle
- Construction of an Intermodal Parking Facility that incorporates transit passenger facilities, charging/fueling infrastructure, bicycling facilities, car sharing and other Transportation Demand Management (TDM) initiatives;
- Development of enhanced bus stops that create a high quality visible passenger area with locations strategically placed to support commercial activity
- Increased transit marketing and advertising

An implementation schedule and cost estimates have been provided for the recommendations for planning purposes. As individual projects are pursued, additional detailed cost figures should be calculated. It is recommended that ATTRP and CARTA work together with UTC administration and the student body to move forward the recommendations in the transit plan to ensure future growth pressures do not negatively impact the campus and that the pursuit of sustainability is successfully achieved in the future.

Table 7. Implementation Schedule and Cost Estimates for UTC Transit Plan Recommendations

RECOMMENDATION	YEAR	COST	FUNDING SOURCES		
			Federal	State	Local
8.1 – Alternative Fuel & Advanced Vehicle Technologies					
8.1.1 Biodiesel	*	$12,500(a)	$0	$0	$12,500
8.1.2 Hybrid Minibus (Cutaway)	2009	$195,000(b)	$156,000	$19,500	$19,500
8.1.3 Hydrogen Hybrid ICE Shuttle	2009	$200,000(c)	$160,000	$20,000	$20,000
8.1.4 Hydrogen Fuel Cell Bus	2012	$625,000(d)	$500,000	$62,500	$62,500
8.1.5 Electric Bus w/Inductive Charging	2010	$450,000(e)	$360,000	$45,000	$45,000
8.2 – ITS					
8.2.1 AVL System	2008-09	$3,600,000(f)	$2,880,000	$360,000	$360,000
8.2.2 Dynamic Message Signs	2008-09	$245,000(g)	$196,000	$24,500	$24,500
8.2.3 Wireless Internet Service	2008	$340,240(h)	$272,192	$34,024	$34,024
8.2.3 Smart Cards	2008	$1,000,000(i)	$900,000	$100,000	$100,000
9.1 - Transit Services					
9.1.1 Modify MOCS Express Route	2009	(j)	NA	NA	NA
9.1.2 Clean Smart Shuttle	2010	$120,000(k)	$0	$0	$120,000
9.1.3 UTC-Downtown Connector	2009	$256,000(l)	$0	$0	$256,000
9.1.4 Off Campus Housing Shuttle	2010	$128,000(m)	$0	$0	$128,000
9.2 - Intermodal Facility	2009	$9,000,000(n)	$7,200,000	$900,000	$900,000
9.3 - Enhanced Bus Stops	2009	$30,000(o)	$24,000	$3,000	$3,000
9.5 – Marketing	2009	$10,000(p)	$0	$0	$0
9.6 - Transportation Demand Management	2010	$50,000(q)	$40,000	$5,000	$5,000

Notes: Recommendation numbers (i.e., 8.1 through 9.6) refer to designation in UTC Campus Transit Plan. *ATTRP recommends additional analysis of the major issues involved with CARTA's pilot biodiesel program conducted 2005-2008. See Appendix VI for additional notes related to Table 7.

d. Endorsement of the UTC Campus Transit Plan

At the start of the campus transit plan development process, an advisory committee was formed to provide input and guidance to ensure the plan responded to pressing transit needs on campus and beyond. The Advisory Committee was composed of a wide range of stakeholders representing the UT Chattanooga faculty, staff and students; the regional public transportation organization (CARTA); downtown interests (RiverCity Company), and the regional transportation planning agency. The Advisory Committee met regularly during the development of the Transit Plan and provided important feedback and input along the way. This input from the Advisory Committee was combined with an extensive public input and market research efforts to ensure the plan was truly reflective of the needs and desires of the campus community. The UTC Transit Plan Advisory Committee endorsed the plan on July 25, 2008 and a copy of the endorsement letter is included in Appendix VII of this report.

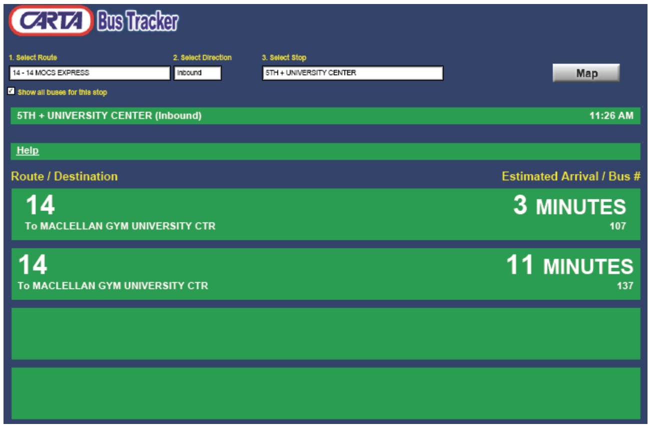
V. DYNAMIC MESSAGE SIGN (DMS) SYSTEM (TASK 5)

Although Task 5 was initially only a concept in the original TN-26-7031-01 work program, ATTRP and CARTA worked closely together to identify a specific project that would support the other ATTRP research activities and fit within CARTA's overall ITS program. After careful consideration, ATTRP and CARTA identified a Dynamic Message Sign (DMS) system project that involved the deployment of a real-time electronic passenger information system on campus and at other strategic locations important to university passengers. The project complemented other activities under TN-26-7031-01 in addition to CARTA's comprehensive ITS system which began in earnest in 2007. Implementation of the DMS system will further support ATTRP's "Smart and Clean" approach to campus transit by deploying ITS technologies on advanced technology and clean fuel vehicles. The need for improved passenger information at bus stops was identified as a priority by both transit users and non-users during the market research portion of the UTC Campus Transit Plan completed under Task 4, and this project provided a near-term remedy for addressing this issue.

a. DMS Implementation

The real-time passenger information system, or dynamic message sign (DMS) system, improves customer satisfaction in such a manner as to lead to increased ridership on campus-related transit services. DMS communicates real-time arrival and departure information to passengers via electronic bus stop signs, the internet and wireless hand-held devices such as mobile phones and Personal Digital Assistants (PDAs). The system greatly increases customer access to real-time information by allowing for user-defined views and automated notification of bus arrival times on hand-held devices. This real-time system not only communicates precise arrival and departure times, but also provides passengers with critical information regarding service interruptions, emergencies and other important public service announcements and campus-related event notices. DMS utilizes Global Positioning Satellite (GPS) technology to identify bus locations as well as provides for predictive modeling. The system calculates the arrival time of buses for specific routes and stops and provides definitive information for passengers addressing the uncertainty that often exists at bus stops for passengers. The DMS system deployed on campus and at other strategic locations is part of an overall passenger information system that allows passengers to track bus movements via the internet (see "Bus Route Tracker" section of CARTA website at www.gocarta.org).

Figure 10. Website Screenshot of CARTA Bus Tracker Display



The implementation of the DMS system was completed in December 2008. Installation of DMS units were completed at the following locations in and around campus and other strategic locations in the city:

- E 5th Street at the UTC University Center
- UTC Place on 8th Street at University Street
- McCallie Avenue at Douglas Street adjacent to UTC Fletcher Hall
- Eastgate Shopping Center
- Brainerd Road at Germantown Road
- Downtown Chattanooga at Market Street and E. 6th Street (2 signs)
- Hamilton Place Shopping Mall
- CARTA Park-and-Ride (2 signs)

All sign units located at bus stops were tested for operability, accuracy and reliability during the test period. Additionally, the DMS system was evaluated by the CARTA Technology Director to ensure proper integration with CARTA's overall ITS system. As noted in the CARTA endorsement letter dated January 26, 2009 included in Appendix VIII, the DMS project was implemented successfully and meets the goals and objectives identified by ATTRP and CARTA.

Figure 11. DMS at Market St.@ E. 6th St.

Figure 12. DMS at UTC University Center

b. DMS Dual Power Engineering Analysis

The DMS project also involved the design of a dual power supply system for the operation of the DMS system that utilizes solar power and grid power. Overall, a DMS requires computer hardware and software; sign hardware and associated equipment, site preparation and installation; and electrical connections. The design calls for a system that will be powered primarily using solar power under normal operating conditions with a utility grid-supplied power as a back-up. The solar power is supplied through an array of solar panels mounted on the roof of the bus stop shelter with enough capacity to meet the power demands of the various equipments. However, during periods of low sun light intensity such as at night or during overcast weather, the system can automatically switch to power grid when the voltage supply from the solar panel falls below a pre-set threshold value.

The DMS system requires computer hardware and software, as well as the ability to communicate with other electronic devices. In order to ensure a seamless operation, the deployment of the system is being done according to the National Transportation Communications for ITS Protocol **(**NTCIP) standards, which allows interoperability among various manufacturers of ITS products such as DMS, cameras, signals, and communication methods such as fiber, radio, Ethernet, etc. The implementation of this ITS project conformed with all applicable FTA procurement regulations and the National Intelligent Transportation Systems (ITS) Architecture and Standards as required by SAFETEA LU paragraph 5307, 23 U.S. C. paragraph 512 note, and FTA Notice, "FTA National ITS Architecture Policy on Transit Projects", 66 Fed. Reg. 1455 et seq., January 8, 2001, and any subsequent directives, except to the extent that FTA determines otherwise in writing.

i. DMS Specifications

DMS commonly use NTCIP as their method of communicating with the software and communication devices that run them because the protocol sets the ITS industry standard. NTCIP stands for National Transportation Communications for ITS Protocol. It allows interoperability among various manufacturers of ITS products such as DMS, cameras, signals, and communication methods such as fiber, radio, Ethernet, etc. Most of the vendors evaluated for participation in this project use equipment that conforms exclusively to NTCIP and do not require any proprietary communications protocols. The system that was selected by CARTA for the DMS project was provided by the company Clear Devices and the system conforms to NTCIP. In addition, the signs are NEMA-4X, IP66 rated. NEMA is the National Electrical Manufacturers Association. IPxx is known as the International Protection Rating which is used for electronics enclosures. The first digit indicates protection against solid objects (dust), the second indicates protection against liquid objects. NEMA 4 enclosures are constructed to protect personnel from enclosed equipment, to provide a degree of protection against falling dirt, rain, sleet, snow, windblown dust, splashing water, and hose-directed water and will be undamaged by external frost during winter. NEMA 4X adds protection against corrosion. Basically, IP66 can be pressure washed, which ensures easy maintenance and preservation of external aesthetics.

The Clever Devices Passenger Information Display Sign System is an All LED and automatic electronic sign system with 5-line display and clock. The intent of this sign system is to utilize as many common components that reside within current transit vehicles with Electronic Document and Digital Storage (EDDS) Systems in order to provide commonality for aftermarket parts support and repair.

- Variable Display: 5 lines, 160 x 7 pixels
- Height minimum: 2 inch characters,
- Display width: 48”
- Clock: 40 x 7 pixels
- Overall Size of DMS panel: Length – 1400 mm (55.118 in.); Height – 900 mm (35.433 in.); Depth – 185 mm (7.283in.)

The entire display area of all signs is readable in direct sunlight, at night, and in all lighting conditions between those two lighting extremes, with evenly distributed illumination appearance to the un-aided eye.

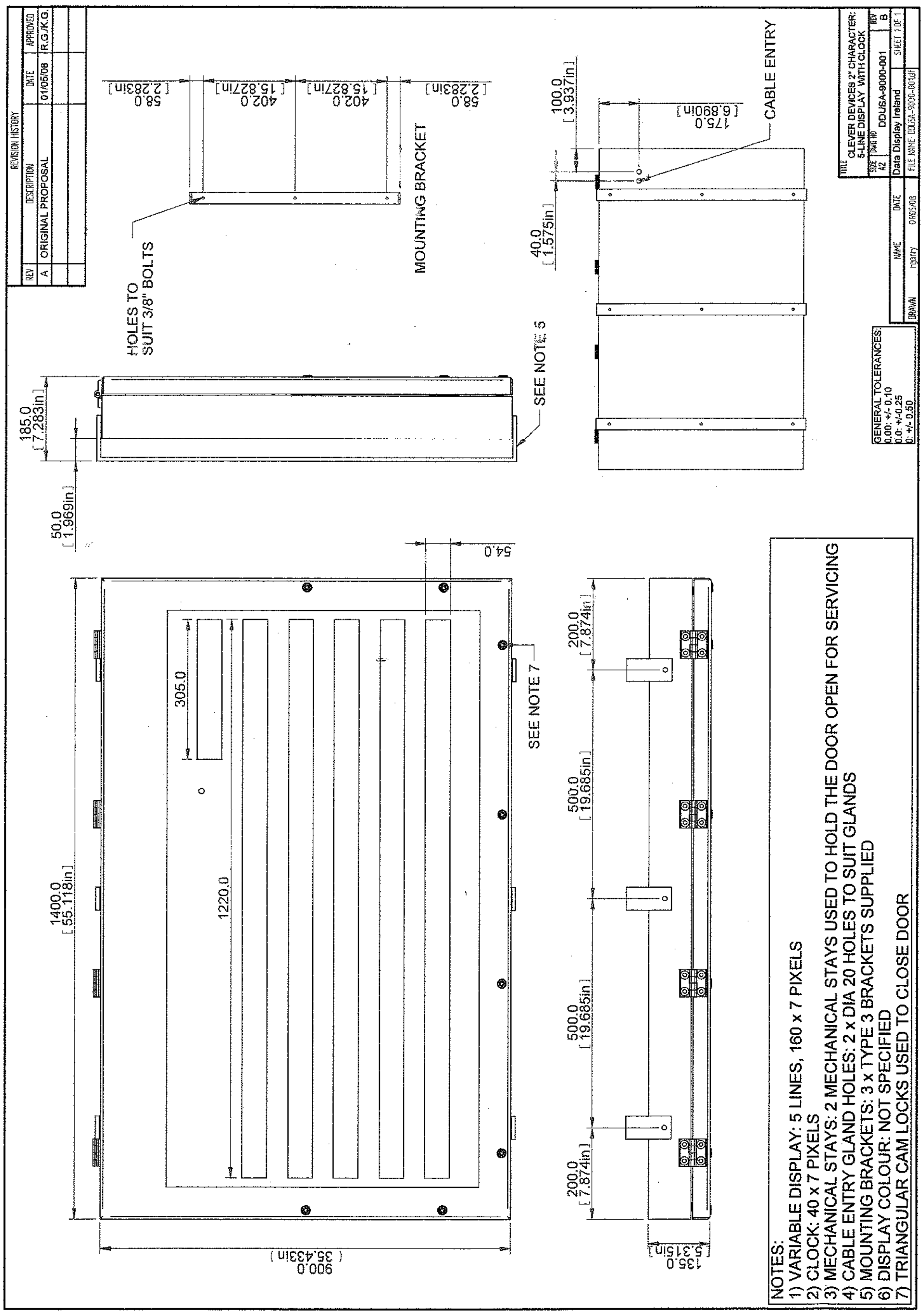
Figure 13 shows a diagrammatic representation of the specifications of the DMS unit. The figure also shows some relevant cross -sectional views as well as dimensions for mounting and installation.

ii. DMS Display and Display Illumination

All sign displays consist of pixels utilizing High Intensity Light Emitting Diode’s (“LED”), for superior outdoor environmental performance, (of Amber illumination appearance of light wavelength of 590 NM). LED is made of AllnGaP II, superior UV resistant Epoxy lens and superior resistance to the effects of moisture. Each pixel has a dedicated LED for illumination of that pixel in all lighting conditions. The sign system has multi-level intensity changes, which adjust automatically as a function of ambient lighting conditions. There is no requirement for any fan or any specialized cooling or air circulation.

This LED can be mounted such as to be visible directly to the observer positioned in the viewing cone, allowing for full readability 65 degrees either side of the destination sign centerline. The LEDs is the only means of illumination of the sign system. The LED illumination source has an operating life M.T.B.F. (Mean Time Before Failures) of not less than 100,000 hours. Each LED does not consume more than 0.045Watts. The characters formed by the System meets the requirements of the Americans with Disabilities Act (ADA) of 1990 Reference 49 CFR Section 38.39.

Figure 13. DMS Specifications: 2" Character; 5-Line Display with Clock



iii. Sign Enclosures

All signs are NEMA-4x, IP66 rated, which means they are enclosed in a manner such as to inhibit entry of dirt, dust, water and other contaminants during normal operation or cleaning. Access panels and display boards are mounted for ease of maintenance/replacement.

iv. Electronic System Requirements

All electronic circuit boards used in the DMS system are conformal coated to meet the requirements of military specification MIL-I-46058C. All sign system components are certified to have been subjected to a "burn-in" test of a minimum of twelve (12) hours operation in a temperature of 150 degrees F, prior to final inspection.

Figure 14. DMS Sign Circuitry

v. Readability

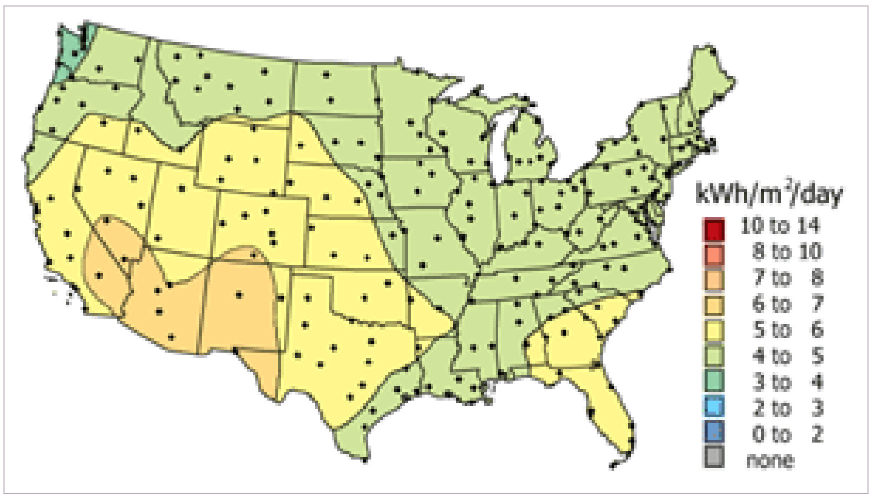
The sign message is readable by a person with 20/20 vision, from a distance of not less than 110 feet. The Side Sign has a viewing cone of equal readability at 65 degrees on either side of a line perpendicular to the center of the mean plane of the display. The intensity of the illumination of the display pixels appear, to the naked eye, to be approximately uniform throughout the full viewing cone.

vi. Power Supply

Power supply to the DMS can be accomplished in three ways: it can be supplied exclusively from the power utility grid; exclusively from solar power, or as a hybrid of both sources - solar and grid power supplies. Each method has its advantages and disadvantages. Power that is supplied from the utility grid can maintain a constant and stable supply, installation costs are inexpensive when easily accessible, and the system is reliable. On the other hand, solar power has the advantage that it can be used to supply power to isolated bus stops which may be far from the nearest grid infrastructure. It is also useful at sites with built up private and/or public property where installation may be costly due to the need for trenching and consequent disruptions to normal daily activities at these locations. However, solar power involves a higher upfront costs such as required to mount panels on the roof of bus shelter and maintenance costs related to the batteries or capacitors that are required to serve as storage devices and voltage regulators. Furthermore, the capacity of the solar power supply maybe limited by several factors such as:

- Roof surface area and angle – the available roof surface area of the bus stop shelter may not be adequate to accommodate enough solar panels to meet specified capacity
- Shadow of nearby buildings or trees – may interfere with sunlight and hinder direct sunlight incidence on to the solar panels
- Cost of panels, and
- Local solar activity – variation in sunlight intensity. Figure 3 shows that the re is only moderate solar activity in the Tennessee Valley compared to Florida for example

Figure 15. **Map of Annual Average Daily Solar Radiation per Month, Using a Flat Plate Collector Facing South at a Fixed Tilt Equal to the Latitude of the Site**



Source: Renewable Energy Sources in the US;
http://www.natinalatlas.gov/articles/people/a-energy.html

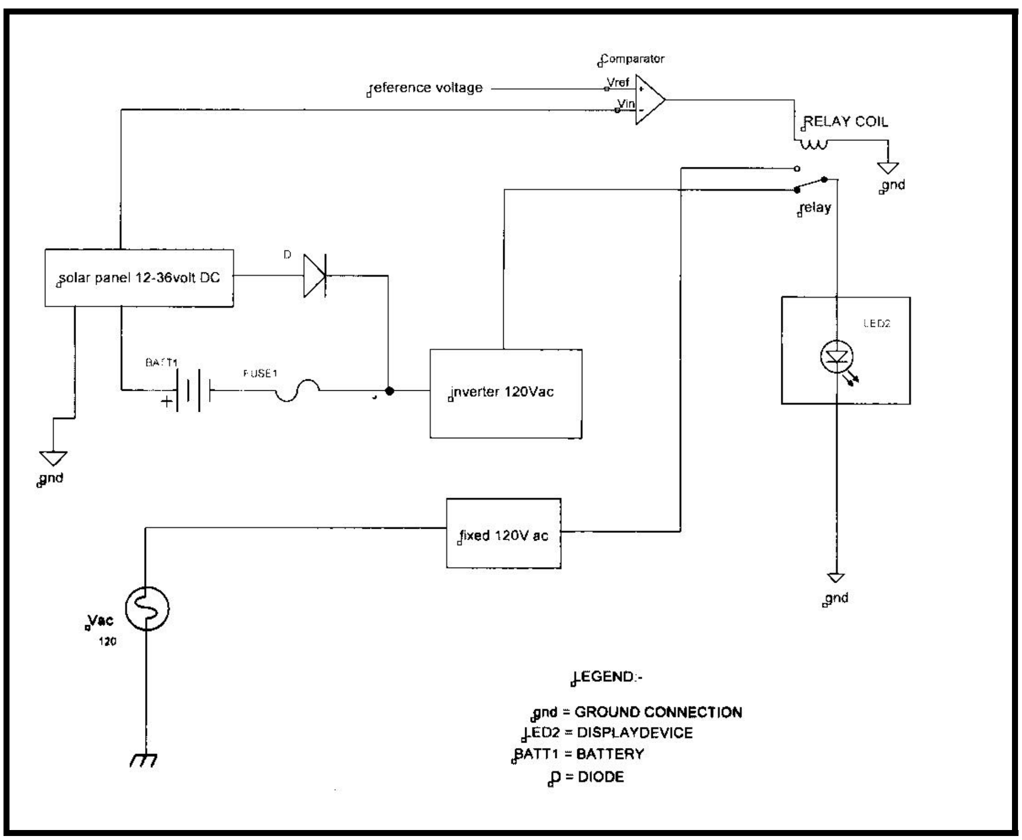
vii. Design of DMS Dual Power System

In order to promote the use of alternative energy and minimize the carbon foot print of the university's activities, the preferred power supply for the next phase of DMS units to be installed is the hybrid version of a dual power supply system. The design calls for a system that will be powered primarily using solar power under normal operating conditions with a grid-supplied power as a back-up. The solar power is supplied through an array of solar panels mounted on the roof of the bus stop shelter with enough capacity to meet the power demands of the various equipments. The solar panels have a variable supply voltage of 12V - 36V, thereby requiring voltage regulator. The panels are also equipped with an internal diode, which is a requirement for any UL listed panel. Shelter roof geometry allows for 4x 175W panels or 7x 85W panels to be mounted. The respective weights are 38lbf and 17lbf each. On average, each LED consumes 45mW of power and a voltage drop of 1.8V.

The design allows for the system to be powered either from solar energy or power grid depending on local solar activity. During periods of low sun light intensity such as at night or during overcast weather, the system can automatically switch to utility power grid when the voltage supply from the solar panel falls below a pre-set threshold value.

Figure 16 shows the schematic drawing of the circuit design to support the use of dual power sources, with solar power as the primary source. As designed, the solar panel will convert solar energy into electricity (DC supply), which charges the battery using a charge controller. The main function of a charge controller or regulator is to fully charge a battery without permitting overcharge while preventing reverse current flow at night. If a non-self-regulating solar array is connected to lead acid batteries with no overcharge protection, battery life will be compromised. A simple charge controller contains a transistor that shunt the PV charging circuit, terminating the charge at a pre-set high voltage and, once a pre-set reconnect is reached, opens the shunt, allowing charging to resume. A charge controller limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may prevent against overvoltage, which can reduce battery performance or lifespan, and may pose a safety risk. It may also prevent completely draining ("deep discharging") a battery, or perform controlled discharges, depending on the battery technology, to protect battery life.

Figure 16. Circuit Design for Dual Power Supply to DMS

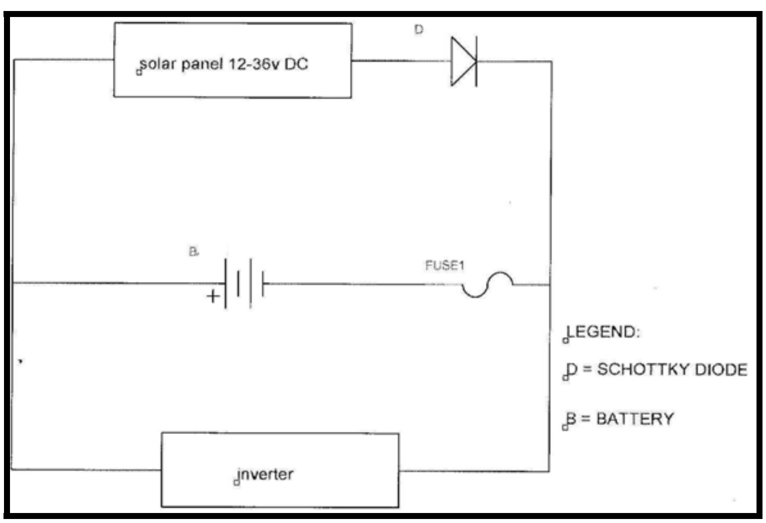


The circuit is designed to work in a step-by-step process. First, the solar panels supply a DC voltage which is a variable source of supply (12 V-36V), depending upon the amount of sunlight falling on the panel, (2) this DC supply is then routed to an inverter which coverts it to an AC voltage and steps it up to a higher voltage as well. For this to work, the DC supply has to be provided at a constant voltage to the inverter. For this reason, the DC supply generated by the solar panels is first stored in the battery which is contained within a sub-circuitry along with a Schottky diode and a fuse. In this sub circuit the battery serves the purpose of storing energy from solar panel and supplying a constant voltage to the inverter, the Schottky diode does not allow the battery to discharge through the solar panel during the night time periods by ensuring that current flows in one direction only, the Fuse is serves a safety purpose.

The DC output of solar panel is compared with a reference DC voltage, labeled V_{ref} in the circuit diagram, using a comparator. A comparator is a device which compares two voltages or currents and switches its output to indicate which is larger. If there is any fluctuation in the input voltage, labeled V_{in} in Figure 4, of the comparator and V_{in} drops below a pre-set value, the comparator will sense the difference and produce an output, which will energize the relay coil and switch the connections of the relay from a normally closed (NC) position to the normally opened (NO) position. The normally closed (NC) point of relay is connected to the inverter which will keep on supplying current to the display device unless there is voltage drop from the solar panel. The NO of relay is connected to the 120 volt AC from the utility grid. By resting on NC position, the design ensures that solar power supply is the primary source of power, with power from the utility grid (relay at NO position) as a back-up. Thus, the display device is assured of getting an adequate and continuous power supply either from the solar panel or utility grid depending upon the amount of sunlight.

Figure 17 shows a more detailed view of the circuitry for the battery voltage regulator, which is part of Figure 16.

Figure 17. Circuit Design for the Battery Regulator



Even though the dual power supply system makes more sense from an environmental perspective, it can be very costly and complex to install due in large part to the limitations cited above for solar power supply system, but also due to the time it will require to adequately design and test such a system. Because of time constraints and limited budget under the current contract, the current deployment of the DMS is being done with power supplied from the electric utility grid only.

viii. Power Draw

The display device draws power from the solar array, batteries, or the electric utility grid. On initial power up, the display is rated at 400 watts at 110 VAC. During normal operation, the power consumption varies around 200 watts. Normal operation includes lighting all five lines with text. If no LED message is being displayed, the power consumption is reduced to approximately 50 watts. This idle consumption is used to power the internal clock, communications, and conversion losses related to the internal power supplies.

ix. DMS Dual Power System Lab Test

In order to test the feasibility of the DMS dual power design concept, a prototype was built in the UTC Engineering Lab using the following scaled down components and values:

- Relay: 5V DC, rated 1A at 120V AC or 24V DC
- LM-339 Quad OP Comparator with a supply voltage of 36V DC or 18V DC; input current: 50 mA
- Bread board
- LED: voltage: 1.8V DC; current: 20mA; power: 40 mW

These components compare to the actual dual power design which require a voltage supply of 110 volts, power consumption of up to 400 watts, a solar panel array of at least 100 square feet, or at least 3 175-watt panels or 6 85-watt panels. The lab test is ongoing and will be completed prior to additional work on the dual power concept.

x. Next Steps on DMS Dual Power

As noted earlier, the current deployment of the DMS system employs grid-connected power only and does not incorporate the dual power supply system that has been designed as part of this project. Nevertheless, if funding become available it will be a simple matter to go in and retrofit all the bus stops that have been installed with DMS to function in the dual power design mode with solar power as the primary power source. In the interim, plans are underway to request funding to install a stand alone non-grid connected solar powered bus stop system for at least one campus bus stop location for a demonstration project. Because solar technologies produce few negative environmental impacts, a potential source of funding is through the UTC Environmental Task Force Green Fee, which is dedicated to promoting an environmentally friendly campus. A potential draw back is cost. Although sunlight is free, solar cells and the accessories needed to convert their DC output to AC for use in this and other projects is expensive.

The cost estimates associated with a typical non-grid connected solar bus system under consideration is as follows:

Table 8. DMS Solar System Cost Summary

Item	Cost
Solar Panel System & Associated Equipment*	$16,000
DMS Sign Unit	$14,739
Bus Shelter	$9,100
Installation Labor Cost	$4,000
Total Cost for all Elements	**$43,839**

* Includes 3-175W or 6-85W solar panels, 6-12V 108Ah batteries, charge controller, inverter, digital timer, disconnect switch, cabling, etc.

Clearly, the initial capital outlay for a stand alone solar powered bus stop system could be prohibitive. According to the EIA, electricity generated by solar cells is still more than twice as expensive as electricity from fossil fuels.[15] It also requires a long payback period to break even point on the initial investment making it potentially unattractive as a viable option. However, apart from its environmental benefits, another valuable benefit of solar power generating systems is their long equipment lifetimes and easy maintenance. A solar system can last up to 25 years or longer with no substantial replacement necessary.[16] For these reasons, and cost notwithstanding, there may be an opportunity for the UTC environmental task force to fund the construction installation of a stand alone non-grid connected solar powered bus stop DMS system on campus. It is recommended that a demonstration of proof of concept be presented to the student group EDGE (Ecological Decisions for a Global Environment), a campus environmental advocacy group that could play an important role in supporting the funding request.

[15] Energy Information Administration (EIS), http://www.eia.doe.gov/oiaf/aeo.
[16] BP Solar, 2009, http://www.bp.com/faq.do?categoryId=90195808.

VI. VEHICLE DATA ACQUISITION SYSTEM (DAS) (TASK 6)

Electric and hybrid-electric bus deployments have sometimes failed because the transit system did not have a clear understanding of how the performance capabilities of any particular bus match up with the requirements of the operational duty cycle. Batteries are frequently subjected to over-discharge and over- or under-charge and other operational conditions that progressively degrade the performance and durability of the battery.

ATTRP in conjunction with its independent contractor, Paul Griffith, conducted a review and evaluation of vehicle data systems appropriate for addressing these issues under Task 6. Following a thorough review, a Data Acquisition System (DAS) system was identified that will permit transit agencies to understand, in real time, the impact that an operator and/or service requirement is having on the entire electric or hybrid-electric propulsion system and batteries. DAS can be used to increase the utility and successful implementation of the electric or hybrid-electric bus fleet. Driving techniques can be monitored and studied; energy consumption versus road/load conditions can be scrutinized; the energy requirements of existing and potential routes can be analyzed; battery recharge profiles can be monitored and submitted to the appropriate battery manufacturer to ensure compliance with recommended practices (this may strengthen the transit system's position in the event of battery warranty claims). In essence, this operational mode of the DAS system performs the functions of a digital storage oscilloscope, thereby enabling sophisticated evaluation and diagnosis.

The DAS system is comprised of a "black-box flight recorder" designed for installation in an area of the bus inaccessible to passengers and drivers, and an input/output module located in the interior of the bus to allow for real-time monitoring and stored data downloads. Data files recorded and stored by the input/output module are easily downloadable using the provided storage media for transfer to a customer-provided PC for subsequent post-processing using DAS software.

a. DAS Features

The following general features are incorporated into the DAS:

- Simple hardware installation;
- Easy set-up and calibration;
- Use of laptop not required for data downloads;
- Download charge profiles of interest "after-the-fact" (no need to connect extraneous equipment prior to collecting real-time data);
- Ability to download data records for all buses in a fleet in a single morning;
- Evaluate energy-flow events leading up to low-power events "after-the-fact"; and
- Sufficient memory capacity for storing approximately two (2) weeks of data between downloads.
- Low incidence of system crashes; and
- No high-voltage signals to areas accessible to passengers and drivers

The DAS has been designed to automate and maximize the yield of information of interest to the transit operator, while simultaneously minimizing intrusion upon the bus system (for example, a relatively simple wiring arrangement is employed).

The Central Processing Unit (CPU) samples and stores the following vehicle data at a rate of 2.0 samples/sec:

- 2 Separate channels of Battery Current
  - Range: -400 to +400 Amps
  - Resolution: 0.2 Amps
  - Typical maximum Error: 1%

- 2 Separate channels of Traction Battery Potential
  - Range: 30 to 475 Volts
  - Resolution: 0.2 Volt
  - Typical maximum Error: 1%

- 2 Separate channels of Ambient Temperature
  - Range: +5 to +255 deg. Fahrenheit
  - Resolution: 1.0 deg. Fahrenheit
  - Typical maximum Error: +/- 5 deg. Fahrenheit

- Vehicle Axle Pulse Counts – from existing or new sensor
  - Allows precise velocity and distance calculations
  - Easy calibration using provided Pocket PC Auto-Calibration Function by driving vehicle a known distance (i.e. 100 ft)

- Genset Current (Uses 500Amp/50mV Current Shunt in negative line)
  - Range: -400 to +400 Amps
  - Resolution: 0.2 Amps
  - Typical maximum Error: 1%

- Genset Voltage
  - Range: 30 to 475 Volts
  - Resolution: 0.2 Volt
  - Typical maximum Error: 1%

b. DAS Development Process

Following identification of the specific type of vehicle data system required to accomplish the objectives of Task 6 under TN-26-7031, work began in June 2007 on technical specifications and supporting documentation required for the procurement process to solicit bids on the vehicle data acquisition system equipment. A Request for Proposals (RFP) was released publicly through the UTC Purchasing Department on August 20, 2007. One proposal from Stone Electronics was submitted by the September 19, 2007 deadline, and after a review by an ATTRP evaluation committee and cost analysis by ATTRP staff, it was determined that the proposal from Stone Electronics met the evaluation criteria and procurement requirements. Subsequently, a UTC purchase order was issued on October 24, 2007 to Stone Electronics, based in Gig Harbor, Washington, for the design, development and installation of a vehicle data acquisition system specified in the RFP. Once the procurement process was completed, work began on the DAS conceptual design, a preliminary firmware logic flow diagram, an interconnection drawing, the hardware design and other associated tasks required at the initial stage of the project. During this stage of the project, Jeff Stonestreet of Stone Electronics met on-site at UT Chattanooga on December 14, 2007 with Dr. Ron Bailey, Mark Hairr, Dan Simpson and Paul Griffith (by telephone) to complete the design review process.

Following the design review process meeting, work began on developing the DAS prototype unit (S/N 1001) for installation at Santa Barbara MTD. Project work included completion of the circuit board design, fabrication of boards, and procurement of parts. Additionally, the core firmware was developed along with code entry (over 1800 lines of code) and design was completed on a surge suppressor for high voltage input lines intended to protect inputs from brief surges up to 1000V. Next, work was completed on the assembly and testing of prototype S/N 1001 (except for real-time firmware) and the acquisition of IPAQ HX 2495 Pocket PCs and parts for assembly of S/N 1002-1004 (the S/N 1004 unit was retained by Stone Electronics for product support). Following this work, development and installation of Visual Studio 2008 for IPAQ real-time code was completed along with the real-time firmware code for the CPU microcontroller (with approximately 2,000 total CPU lines of code). Work was also performed on an end-to-end communication test between the CPU and the IPAQ Pocket PC (RS-232) and the development of IPAQ real-time software and the desktop post processing code. Lastly, the DAS Installation Guide was completed.

Next, a number of activities were completed in preparation for the installation of prototype S/N 1001 at Santa Barbara including:

- Completion of the real-time and post-processing software packages
- Completion assembly of prototype S/N 1001 custom wiring harness assembly (per Santa Barbara MTD requirements)
- Completion of integrated bench testing of all DAS System Elements (hardware, firmware, and software)
- Installation of S/N 1001 in a 1999 model Ebus electric bus (EV#19) at SBMTD on April 16-18, 2008. Mark Hairr, Paul Griffith and Jeff Stonestreet of Stone Electronics were on-site for the DAS installation. The UTC DAS system performed satisfactorily during initial test
- Completion of assembly of UTC DAS CPU Module circuit boards for prototype units 2 and 3
- Continuing refinement and upgrades to post-processing software
- Fabrication of DAS unit #2 and custom harness for the Emory installation
- Ongoing coordination with the Sevierville maintenance staff and Ebus technicians

Following the successful DAS installation at Santa Barbara MTD, DAS unit #2 was installed on battery electric Bus #802 at Emory University on July 10, 2008 and DAS unit #3 was installed on hybrid electric antique replica trolley #954 in Sevierville, Tennessee on August 19, 2008.

c. DAS Data Analysis from Santa Barbara and Emory University

Following the installation of the DAS units, a comparative analysis was completed for the battery strings on the Santa Barbara MTD and Emory University buses. The DAS system allows for the monitoring a number of parameters such as voltage, current, distance traveled, and battery temperature (and derivative parameters such as power, energy, and vehicle speed) during motoring and recharge. This assessment compares and contrasts data collected on these two buses.

i. Battery String Balance

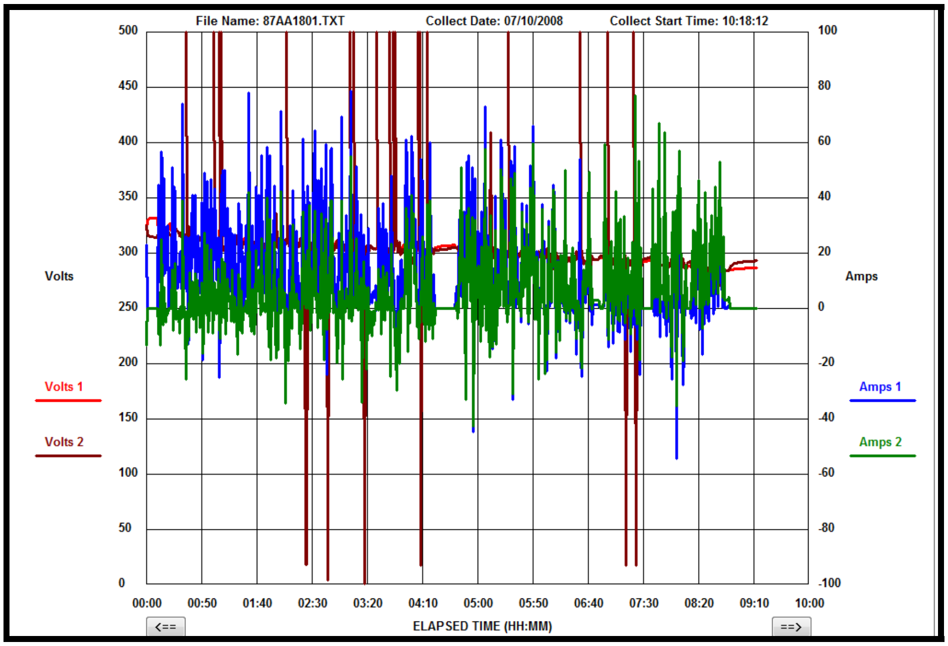
An analysis of data for SBMTD bus EV19 shows that the batteries appear to be out of balance. On average, String 1 (packs A, B, C) provides 65% of the energy used during the overall driving cycle. This ratio is even higher during the first six hours of driving before String 1 runs very low on energy, at which time String 2 becomes dominant. This phenomenon is illustrated in Table 9.

Table 9. Bus EV19, 7/10/08, Carpinteria

Interval	Ah – String 1	Ah – String 2
0-2 hrs	33.78	2.67
2-4 hrs	35.35	8.77
4-6 hrs	23.79	12.30
6-8 hrs	14.59	21.54
8-10 hrs	5.05	10.75
	112.56	***56.03***

Plots of voltage and current for this driving cycle are depicted in Figure 18. It may be noted that because the battery strings are bussed together during driving the string voltages are essentially equal (the voltage spikes on String 2 will be addressed later in this report). However, these plots corroborate the finding that String 1 provides more current during the initial portion of the driving cycle before fading, at which point String 2 becomes the dominant string.

Figure 18. EV19, 7/10/08, Carpinteria



In contrast, Emory Bus #802 exhibits better load sharing and balance, as illustrated in Table 10. (Note: the Emory buses typically receive a midday recharge after the first 90 minutes of driving, as is reflected by the 1.5-hour gap in the interval column)

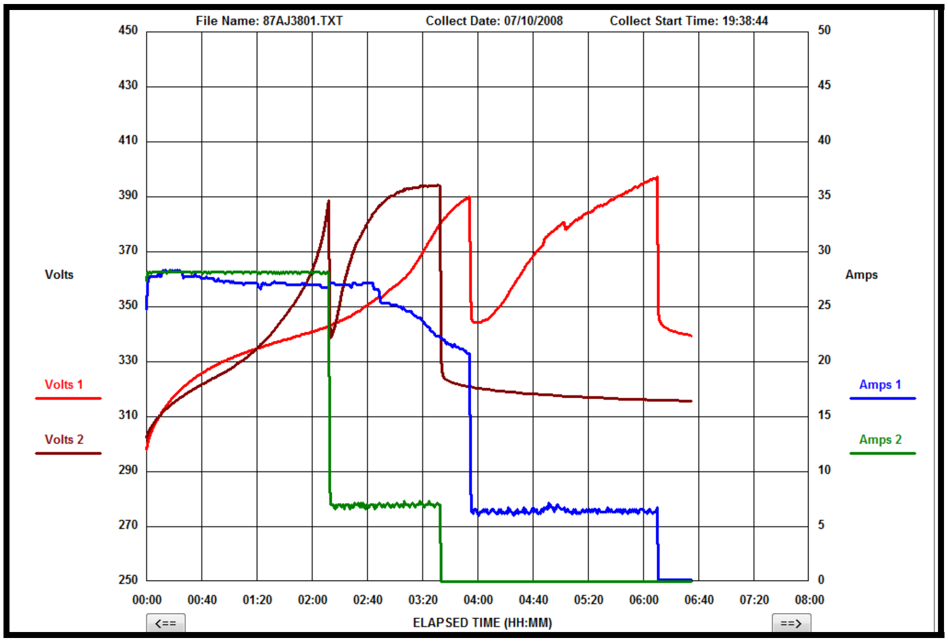
Table 10. Emory Bus #802, 7/11/08

Interval	Ah – String 1	Ah – String 2
0-1 hrs	16.07	13.59
1-1.4 hrs	7.31	6.42
1.4-1.5 hrs	0.87	0.77
3-5 hrs	35.28	27.18
5-5.6 hrs	9.30	10.30
5.6-5.7 hrs	0.20	0.19
	69.03	***58.45***

ii. Charge Profiles and Charge Coefficients

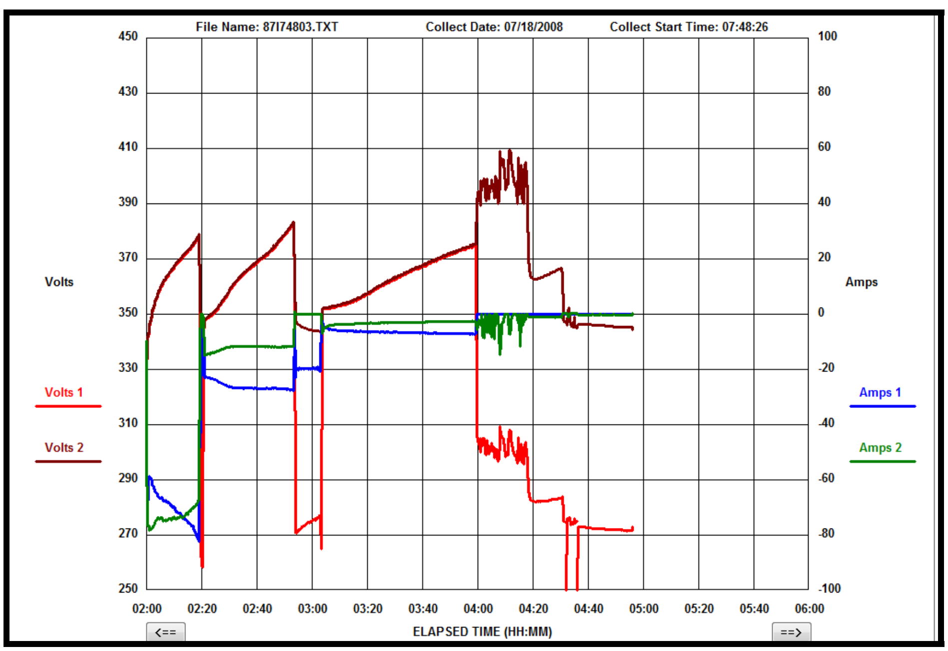
The charge profile for the recharge event after EV19's 7/20/08 Carpinteria deployment is shown in Figure 19. As would be expected, the charge of String 2 is of shorter duration than that of String 1.

Figure 19. EV19 Recharge Profile



In comparison, a typical charge profile for the Emory buses is depicted in Figure 20. (Because the Emory buses are recharged immediately after they are returned from service, the charge profiles are included in the same file as the drive cycles and current is therefore plotted as negative values.)

Figure 20. Emory #802 Charge Profile



Review of the above charge profiles indicates that SBMTD's EV19 charger delivers a recharge profile that more closely reproduces that specified by Saft.

(This is indicative of the many hours of effort that the MTD maintenance department has devoted to this task.) The profile delivered by the charger that recharges Emory's #802 bus, however, does not approximate that specified by Saft, the battery manufacturer, and is worthy of further attention.

Average charge coefficients for the two buses are shown in Table 11. Saft recommends a charge coefficient of 1.15 for these batteries. Therefore, the only battery string that is significantly out of bounds with respect to this parameter is String 2 on SBMTD's EV19.

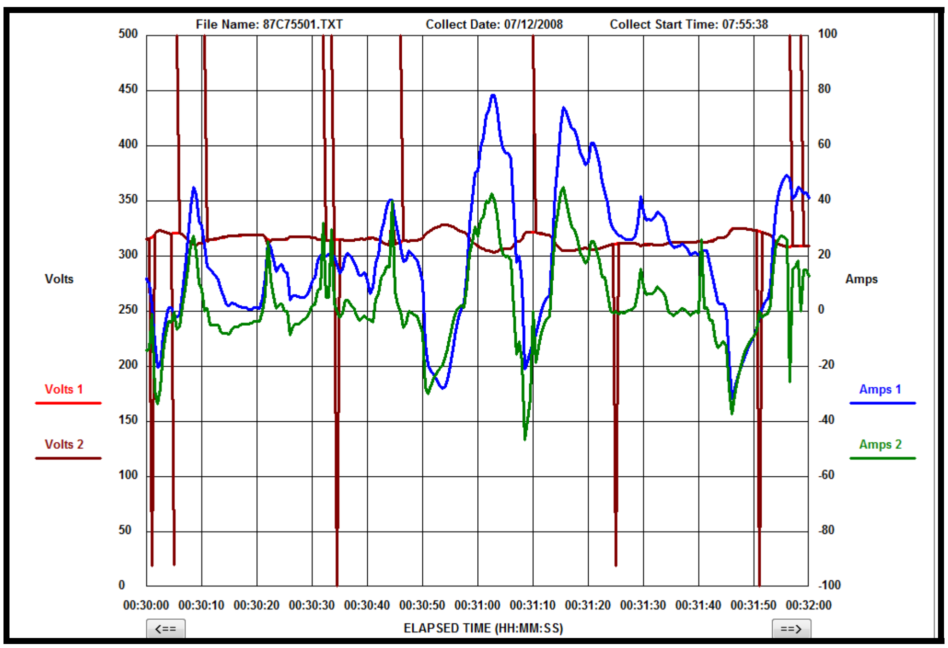
Table 11. Charge Coefficients

Bus	String 1	String 2
SBMTD EV19	1.07	1.32
Emory #802	1.10	1.09

iii. Voltage Spikes

SBMTD's EV19 has shown evidence of voltage spikes on String 2 during driving mode but not during charge mode. A representative depiction of this phenomenon over a relatively short time span is shown in Figure 4.

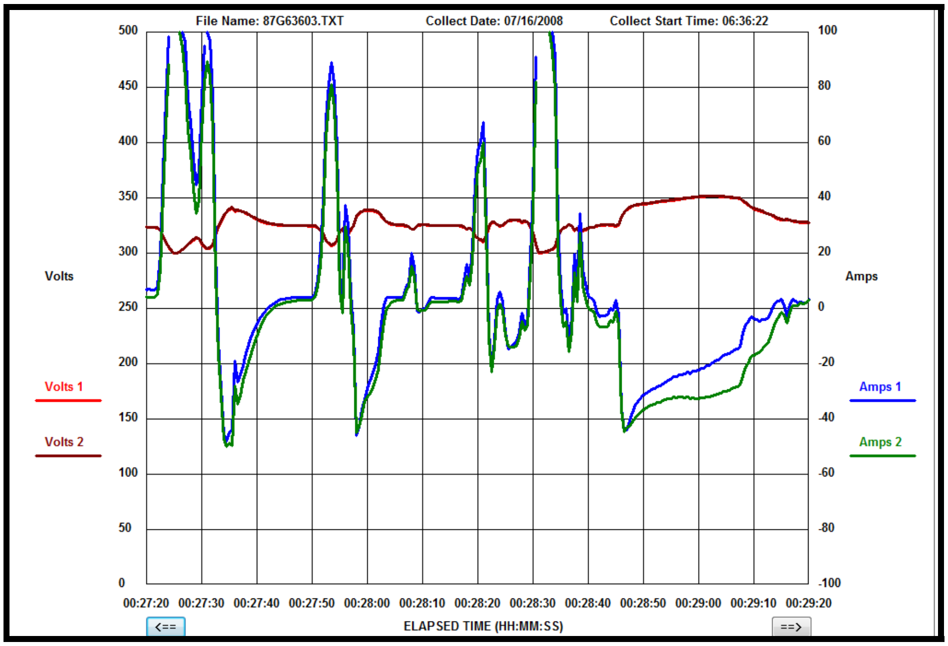
Figure 21. Voltage Spikes on String 2, EV19; 2-min Window



A brief assessment of a random sampling of EV19 driving cycles suggests that these spikes may occur more frequently when the amperage of String 2 drops to zero or goes negative (i.e., drawing a charge from String 1 or regen) while String 1 is still in a discharge state.

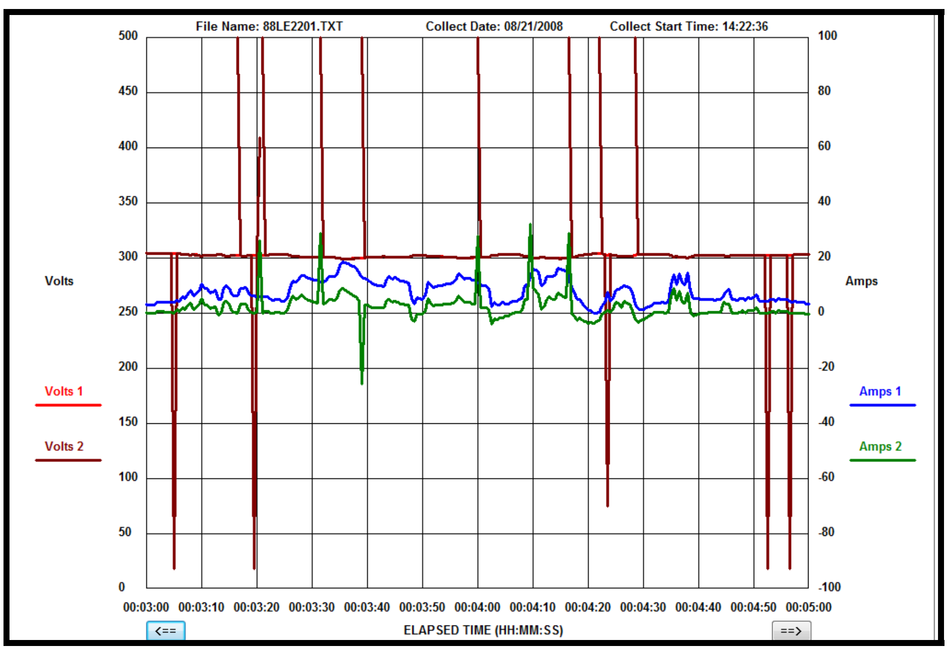
For comparison, a driving cycle from Emory #802 is presented in Figure 22.

Figure 22. Driving Profile, Emory Bus #802; 2-min Window



SBMTD EV19 recently had its battery system swapped out. A non-service driving profile (i.e., across the depot) collected with the replacement battery set is depicted in Figure 23.

Figure 23. Voltage Spikes on String 2, EV19; Replacement Battery Set



Although the magnitude of the current draw was not as great during this cycle as compared with an operational cycle, the voltage spikes on String 2 persist with the replacement battery set.

It is suggested that these findings be shared with Ebus and Saft for review and comment.

d. DAS Conclusion

The DAS project has been a success based on the development, installation and operation of the three (3) DAS prototypes units at Santa Barbara MTD, Emory University and the City of Sevierville. Data analysis of all three systems show the DAS is operating as intended, and as can be seen from the comparative analysis report in Section (c) of this chapter, the DAS unit provides specific data that can isolate problems such as the out-of-balance battery strings on the Santa Barbara bus. This type of report is representative of the useful data that can be used to diagnose problems and allow for well-defined solutions for electric and hybrid-electric buses.

Additionally, at the conclusion of the DAS project ATTRP conducted a comparison of several different types of vehicle data acquisition systems relative to the data and reporting needs for electric and hybrid-electric buses. Systems included in the comparison with the ATTRP DAS were LabJack U3 LV, Battery DAQ Module-TM65-24 and the UTC Mechanical Engineering Experimentation Lab DAQ. Following the comparison of data acquisition systems, it was evident that the DAS is the most appropriate system available for monitoring and analyzing electric and hybrid-electric buses, especially when considering the significantly lower per unit cost for the ATTRP DAS. A table showing the comparison of data acquisition systems is included in Appendix IX.

ATTRP will continue to monitor the performance and data generation of the DAS units at all three demonstration sites in order to ensure continued optimal operation. Additionally, this report and other information related to DAS will be disseminated to other stakeholders with a need for this type of system to address performance and durability issues with electric and hybrid-electric buses.

VII. SUMMARY

The research program completed by ATTRP under TN-26-7031-01 has fulfilled the goals and objectives established for this project by assisting in the development of advanced technology and alternative fuel options for public transportation in support of the nation's efforts to reduce dependency on foreign oil and improve air quality. The research program included furthering knowledge and understanding of alternative bus transportation propulsion systems (including hydrogen engines and electric-drive hybrids), intelligent transportation systems, transportation requirements analysis and data acquisition applications to evaluate electric and hybrid propulsion performance.

Specifically, ATTRP provided technical assistance to a wide range of organizations and prepared technical reports on specific topics of need for three (3) agencies; played a leadership role in the industry by serving on the FTA Electric Drive Strategic Plan Steering Committee and serving as Editor-in-Chief for the World Electric Vehicle Journal Volume 2; supported the industry through the dissemination of research results at conferences, seminars and symposia; recommissioned and upgraded a unique and valuable resource in the Advanced Vehicle Test Facility (AVTF); completed a comprehensive campus transit plan for UTC that spawned several specific transit projects; deployed a Dynamic Message Sign (DMS) system in conjunction with CARTA and prepared a DMS Dual Power Engineering Analysis; and developed a Data Acquisition System (DAS) for electric and hybrid-electric buses. These research projects have wide ranging benefits to the industry and have positioned ATTRP to be a national leader in the future in advanced transit vehicle technologies and alternative fuels.

REFERENCES

[1]Franklin & Associates, May 1, 2006, *Test Track Site and Facilities Evaluation, SBC Project No. 540/05-01-06/*.

[2]DeVaney, David, November 13, 2006, *Broker Opinion of Value,* NAI Charter Commercial Real Estate Services.

[3]Energy Information Administration (EIA), November 7, 2008, "Weekly Retail Gasoline and Diesel Prices," http://www.eia.doe.gov/.

[4]Ibid

[5]American Public Transportation Association (APTA), June 2008, 2008 Public Transportation Factbook, 59th Edition.

[6]Ibid

[7]Ibid

[8]American Public Transportation Association (APTA), December 15, 2008. Volume 66, No. 41, page 19, *Major Trends for Buses: Hybrids, Eye Appeal, BRT,* Passenger Transport.

[9] Electric Drive Transportation Association (EDTA), *2008 Hybrid Electric Passenger Vehicle Sales By Model (October 2008)*, http://www.electricdrive.org, November 10, 2008.

[10]Ibid

[11]U.S. Department of Transportation, Research and Innovative Technology Administration (RITA), Bureau of Transportation Statistics, April 2007, *U.S. Automobile and Truck Fleets By Use (1997).*

[12]CALSTART, June 10, 2008, Testimony for the U.S. House Committee on Science and Technology, Energy and Environment Subcommittee.

[13]2002: U.S. Census Bureau, *2002 Economic Census: Vehicle Inventory and Use Survey*, *United States*, ECO2TV-US (Washington, DC: 2004).

[14]NAI Charter Real Estate, December 2008, *2008 Global Market Report, Chattanooga, Tennessee.*

[15]Energy Information Administration (EIS), http://www.eia.doe.gov/oiaf/aeo.

[16]BP Solar, 2009, http://www.bp.com/faq.do?categoryId=90195808.

APPENDICES

Appendix I

Task 2 List of Industry Activities Involving ATTRP

FTA Cooperative Agreement TN-26-7031-01
Task 2 Activities

1) On April 4, 2007, the ATTRP project team joined Congressman Zach Wamp at a kickoff event for TN-26-7031 that involved more than 40 government, university, business and community leaders.
2) Participation by Dan Simpson, ATTRP Chief Research Scientist, at the Mid South Parking and Transportation Association Conference held March 20-21. Mr. Simpson made a presentation entitled "Renewable Energy and Clean Transportation Research."
3) Participation by Jim Frierson, ATTI Executive Director, at the Alternative Fuel Vehicle Institute (AFVi) Conference held April 1-4.
4) Extensive involvement with conference planning activities for EVS-23 including:
   i. Lead responsibility in editing and publishing the World Electric Vehicle Association (WEVA) Journal in association with EVS-23;
   ii. Participation by Jim Frierson in the EVS-23 Conference Planning Committee; and
   iii. Preparation of abstracts by Jim Frierson and Paul Griffith for papers accepted for presentation at the EVS-23 Conference.
5) Participation by Mark Hairr in the conference "Mobilizing North Carolina: Where Air Quality, Energy and Transportation Meet," held April 18, 2007. Mr. Hairr made a presentation entitled "Current Trends: Neighborhood Electric Vehicles to Heavy Duty Hybrids."
6) Participation by Paul Griffith at the CalACT conference held April 24-27. Mr. Griffith made a presentation entitled "Alternative Fuels: Where Are We? Where are We Headed?"
7) Participation by Mark Hairr in the Fuel Cell South 2007 Conference on May 4, 2007. Mr. Hairr made a presentation entitled "Developing Hydrogen & Fuel Cell Driven Mass Transit Solutions."
8) Participation by Mark Hairr at the APTA Bus and Paratransit Operations Conference held May 6-9. Mr. Hairr made a presentation entitled "The Status of Alternative Fuels in Public Transportation Applications."
9) Technical assistance to Kittelson & Associates, a consulting firm engaged in examining advanced propulsion systems for the Baltimore Charles Street Streetcar project.
10) Participation by Dr. Ron Bailey and Mark Hairr of ATTRP and Jim Frierson and Gwen Bishop of ATTI at the Tennessee Valley Corridor Summit held May 29-30, 2007. Dr. Bailey made a presentation entitled "Advancing America's Energy Security."
11) Under the lead of Jim Frierson, participation in the Toyota Future Highway Hybrid Vehicle Exhibit during the Chattanooga Riverbend Festival held June 8-16, 2007.
12) Jim Frierson served as a principal contact and host for US Airways magazine staff who spent several weeks in Chattanooga preparing an extensive story on Chattanooga for the August 2007 issue. Part of the theme of the article focused

on Chattanooga's high quality of life and the role of clean energy initiatives in positioning the city as a unique "living laboratory."

13) Completed an assessment of the current status of the 22-foot electric bus market including a survey of vehicle manufacturers conducted by ATTRP with assistance from Paul Griffith.
14) Collaborated with the Chattanooga Metropolitan Airport regarding clean energy and transportation options;
15) Coordinated with several divisions within the Tennessee Department of Transportation (TDOT) including public transportation, research and planning to identify potential partnerships in clean transportation;
16) Provided technical assistance to Green Transit NC, a clean energy startup company in western North Carolina;
17) Provided technical assistance to Mountain Blue, a planned residential community in western North Carolina seeking clean transportation options;
18) Coordinated with the Electric Power Board (EPB) on electric vehicle charging and testing;
19) Conducted a presentation to the UTC GEAR UP Middle School Program for underserved inner city youth in Chattanooga;
20) Hosted high school students during TransWeek 2007 sponsored by the Center for Transportation Research at the University of Tennessee at Knoxville.
21) Hosted high school students participating in the UTC Center for Community Career Education program on July 9, 2007. ATTRP staff demonstrated advanced transportation technologies and conducted presentations on transit vehicle technology, alternative fuels and energy issues.
22) Participation by Paul Griffith, Independent Consultant, at the Advanced Capacitor World Summit 2007 held July 23-25. Mr. Griffith obtained valuable information on the potential use of capacitors in transit vehicles. Additionally, Mr. Griffith, in conjunction with Dr. Bailey and Dan Simpson (ATTRP Chief Research Scientist), authored a paper entitled "Inductive Charging of Ultracapacitor Electric Bus," examining the potential of using ultracapacitors and inductive charging in transit vehicles.
23) Jim Frierson and Dan Simpson conducted an on-site visit to Auburn University and its NCAT Test Track on August 20, 2007 to gain information that will be of value as the Chattanooga Vehicle Test Track is recommissioned. The group also discussed campus transportation, advanced technology vehicles and campus ITS applications.
24) Participation by Jim Frierson in the conference "Greening of the Campus VII," September 6-8, 2007 held at Ball State University in Muncie, Indiana.
25) Participation by Jim Frierson, Mark Hairr and Dan Simpson in the National Association of Development Officials (NADO) National Rural Transportation Conference held in Chattanooga September 26-28, 2007. ATTI and ATTRP staff hosted conference participants at the Test Track and at the UTC campus facility to discuss advanced transportation technologies of interest to this particular group.
26) Participation by Mark Hairr, ATTRP Research Program Director, at the American Public Transportation Association (APTA) Annual Conference held

October 7-10, 2007 in Charlotte, North Carolina. Mr. Hairr participated in a number of sessions regarding transit vehicle technology, ITS applications and university transit programs and also participated in the APTA Transportation and Universities Communities Conference Committee meeting in which he provided input on developing a transit research track as part of the APTA university transit conference planned for April 2008 in Reno. Additionally, Mr. Hairr met with a representative of North American Bus Industries (NABI) to discuss the status of the 30-foot hybrid Optima bus currently being tested at Altoona and also met with staff from ISE Corporation for an update on the latest hybrid drive systems being integrated into diesel and hydrogen powered vehicles.

27) Participation by Mark Hairr at the Tennessee Public Transportation Association (TPTA) Board meeting on October 16, 2007 to provide an update on advanced transit vehicle technologies and present an overview on ATTRP activities and initiatives.

28) Participation by Dr. Ron Bailey, Mark Hairr and Jim Frierson in the U.S. Department of Energy Day of Science held October 29, 2007 in Knoxville, Tennessee. The event was focused on linkages between DOE, colleges/universities and various technologies, including advanced vehicle research. ATTRP staff met with University of Tennessee at Knoxville representatives responsible for the biodiesel hybrid electric SUV entered in the U.S. Department of Energy Challenge X competition.

29) Participation by Mark Hairr and Dan Simpson, ATTRP Chief Research Scientist, in the Tri-State Regional Workforce meeting held November 8, 2007 at Chattanooga State Technical Community College. Mr. Hairr and Mr. Simpson conducted a presentation on ATTRP activities and the connections between research, technology and job creation in the Chattanooga metropolitan area.

30) Participation by Mark Hairr and Jim Frierson at the Tennessee Valley Corridor Southeast Partnership Event on Advanced Transportation and Homeland Security held at the Clemson University International Center for Automotive Research (ICAR) facility in Greenville, South Carolina, November 18-19, 2007. In addition to conference sessions regarding advanced transportation, on-site tours of the ICAR facility were provided showcasing the various types of vehicle technology research and testing that will be conducted at this new facility. The ATTRP team learned many important details regarding the development, operation and management of the ICAR test facility that will be of great assistance in recommissioning the vehicle test track in Chattanooga.

31) A presentation was conducted by Mark Hairr at the Chattanooga Engineer's Club on November 26, 2007 regarding the potential for deploying advanced transit vehicles on the UT Chattanooga campus in conjunction with CARTA.

32) Participation by Dr. Ron Bailey, Mark Hairr and Jim Frierson in meetings with Dr. Kelly Tiller, Director of External Relations with the University of Tennessee at Knoxville Office of Bioenergy Programs, on November 29, 2007. Dr. Tiller made a presentation at UT Chattanooga regarding UT Knoxville's

partnership initiative to manufacture, distribute and sell cellulosic ethanol as a renewable, sustainable transportation fuel.

33) Participation by Dr. Ron Bailey, Mark Hairr, Dan Simpson, Jim Frierson and Paul Griffith at the 23rd Electric Vehicle Symposium (EVS-23) held at the Anaheim Convention Center December 2-5, 2007. This conference is the premier electric drive event in the international arena and included more than 1,000 conference delegates and 1,000+ participants at the Public Day and Ride & Drive events. ATTRP staff contributed significantly to the conference through serving on the International Steering Committee (ISC), assuming responsibility for managing the publication of the World Electric Vehicle Journal, and co-chairing a number of conference auditorium and small lecture sessions. ATTRP staff also authored and presented conference papers including Dr. Ron Bailey's "Deploying a Hydrogen Fuel Cell Bus," Mr. Frierson's "Interacting at Close Range with the Public and Decision Makers," and Mr. Griffith's "Inductive Charging of an Ultracapacitor Electric Bus." Additionally, Gwen Bishop played an important role in supporting pre-conference planning activities and performing a number of administrative tasks related to the Journal.

34) Participation by Woodlyn Madden, ATTRP student employee, in the Chattanooga Greenspokes Scavenger Hunt on December 8, 2007. This event was focused on alternative transportation and entailed bicycling enthusiasts visiting ATTRP throughout the day to hear presentations by Mr. Madden regarding advanced vehicle technology and ATTRP activities.

35) Participation by Dr. Ron Bailey, Mark Hairr, Dan Simpson and Jim Frierson in a meeting on December 12, 2007 with Eric Cromwell, President and CEO of the Tennessee Technology Development Corporation (TTDC), in order to discuss priorities for TTDC and potential collaboration between ATTRP and TTDC.

36) Participation by Mark Hairr and Jim Frierson in the *"buyit* downtown"* kickoff event on December 13, 2007 in downtown Chattanooga. In conjunction with CARTA and the RiverCity Company, ATTRP contributed to the event by presenting the benefits of the downtown electric bus system as an environmentally-friendly way to shop and contribute to the economic health of downtown Chattanooga.

37) Participation by Mark Hairr and Dan Simpson in reviewing and evaluating several semester-end (December 2007) engineering student team reports and presentations regarding advanced transportation technologies.

38) Participation by Mark Hairr at the American Society of Civil Engineers (ASCE) Chattanooga Branch meeting on January 15, 2008. Mr. Hairr made a presentation covering ATTRP work program activities and an overview of fuel cell technology in public transportation.

39) Served in the lead role in the demonstration of a new advanced technology vehicle, the Azure Dynamics cutaway hybrid vehicle. Led by Jim Frierson and Mark Hairr, the demonstration ran January 28-February 1, 2008 and included participation by the entire ATTRP staff. The demonstration was conducted in Chattanooga (including UTC campus and Moccasin Bend National Park),

Townsend, Sevierville, Gatlinburg, at the Knoxville Metropolitan Airport and at Maryville College in Blount County.

40) Participation by Mark Hairr, Program Development Chair, and Jim Frierson, Marketing and Promotion Chair, in the Electric Drive Transportation Association (EDTA) Conference Planning Committee via monthly conference calls.

41) Assistance by Mark Hairr and Jim Frierson to Western Carolina University (WCU) located in Cullowhee, NC with a preliminary assessment of the potential for electric or hybrid electric public transit shuttles to serve campus. ATTRP coordinated with the WCU Energy Manager on compiling information that can assist with an evaluation of various advanced transit vehicle technologies.

42) Participation by Mark Hairr at the American Public Transportation Association (APTA) Transportation and University Communities Conference held April 5-8, 2008 in Reno, Nevada. Mr. Hairr, in conjunction with Ilya Tabakh, Research Associate with the University of Kansas Transportation Research Institute, conducted a presentation regarding innovative bus charging concepts focusing on inductive charging. A copy of the presentation is attached in TEAM-Web.

43) Participation by Mark Hairr and Jim Frierson at the City of Chattanooga Green Committee Visioning Meeting held April 24, 2008 at the Chattanooga Convention Center. This event included more than 500 members of the community providing input on a variety of clean energy, environmental and transportation issues important to Chattanooga's sustainability initiatives. ATTRP was one of only a select number of exhibitors associated with this event.

44) Participation by Dr. Bailey and Mark Hairr in a meeting held May 1, 2008 with the local utility company, the Electric Power Board (EPB), to discuss areas of common interest, particularly initiatives that could capitalize on the ATTRP Advanced Vehicle Test Track in the area of plug-in hybrid vehicles, Vehicle-To-Grid (V2G) technology and smart meters.

45) Participation by Mark Hairr in the FTA Electric Drive Strategic Plan Public Meeting held May 6, 2008 and the FTA Electric Drive Strategic Plan Steering Committee held May 7, 2008 in conjunction with the APTA Bus and Paratransit Conference in Austin, Texas.

46) Participation by Paul Griffith at the California Public Transit Association Spring Conference held May 20, 2008 in Sacramento, California. Mr. Griffith made a presentation, "Powering the Small Bus: Where Are We Headed?" to provide the latest progress on advanced transit vehicle technology in the less than 30-foot vehicle category.

47) Participation by Dr. Bailey, Mark Hairr and Jim Frierson at the Chattanooga Technology Council meeting on May 21, 2008 in which CARTA ITS Manager, Kirk Shore, made a presentation of its ITS program including the DMS project being conducted in conjunction with ATTRP.

48) Participation by Mark Hairr in the Electric and Plug-In Hybrid Vehicle Conference sponsored by American Business Conferences. The conference was held in Troy, Michigan May 27-29, 2008 and included a number of leading

researchers, vehicle manufacturers, electric and hybrid electric infrastructure experts and others. Jim Frierson played a key role in assisting with the development of the conference agenda to ensure participation by the leading international authorities in the field of electric and hybrid electric vehicle technologies.

49) Participation by Dr. Bailey in the Tennessee Valley Corridor 2008 National Summit held in Huntsville, Alabama May 28-30, 2008. The Summit included participation by U.S. Senator Bob Corker (R-TN), U.S. Senator Jeff Sessions (R-AL), U.S. Congressman Zach Wamp (R-TN), U.S. Congressman Bud Cramer (D-AL) and numerous other national leaders in energy, economic development and advanced transportation technologies.

50) Participation by Dr. Bailey and Mark Hairr in a meeting with instructors and students with the Chattanooga State Technical Community College (CSTCC) Transportation Technology Program to discuss areas of mutual interest and prospects for partnerships involving the ATTRP Advanced Vehicle Test Track located adjacent to the CSTCC campus.

51) Participation by Mark Hairr on a conference call held on June 10, 2008 with Josh Cohen, President and Owner of TransLoc, a firm which specializes in real-time transit technology. The main topics covering were real-time passenger sign systems and other ITS transit applications focused on university and college campuses. TransLoc has real-time passenger information systems operating at North Carolina State University, Emory University, Auburn University and Harvard University among others.

52) Participation by Mark Hairr in the Tennessee Valley Authority (TVA) Forum on Hybrid and Electric Vehicles held on June 16, 2008 in Nashville, Tennessee. The forum was hosted by U.S. Senator Lamar Alexander (R-TN) and U.S. Congressman Bud Cramer (D-AL) and included representatives of several electric and hybrid vehicle manufacturers and component suppliers.

53) Participation by Paul Griffith in the “Well-to-Wheels Emissions” Webinar conducted June 24, 2008 by the Alternative Fuel Vehicle Institute (AFVi).

54) Provided technical assistance to the York County, Maine Community Action Committee regarding hybrid vehicle technology in the small transit vehicle class (less than 30-foot).

55) Provided technical assistance to the Gettysburg National Military Park regarding electric tram technology appropriate for visitor and passenger shuttling within the Park.

56) Conducted a presentation entitled, “Is There a HEV, PHEV or FCEV in Your Future?” by Dr. Bailey and Mark Hairr at the Chattanooga Engineers’ Club on July 7, 2008. The presentation covered energy sources and trends, air quality issues and vehicle technology trends.

57) Participation by Mark Hairr at the FTA Electric Drive Strategic Plan Steering Committee meeting July 30, 2008 in Washington, D.C. The meeting included finalizing the program vision, program plan and implementation and management elements of the overall Plan. The final Plan is scheduled to be presented at the APTA Annual Conference in early October 2008.

58) Participation by Dr. Bailey and Mark Hairr at the Enterprise Center Plug-In Vehicle Meeting which included Tom Reddoch, Director of Power Delivery and Utilization with the Electric Power Research Institute (EPRI) and Will Pinkston, Senior Advisor for Tennessee Governor Phil Bredesen. The meeting covered the latest trends and initiatives in the plug-in vehicle industry and included a wide range of participants including representatives from the federal legislative delegation, utilities, public transportation and other local stakeholders.

59) Participation by Dr. Bailey and Mark Hairr at Tennessee Senator Bob Corker's press conference on August 4, 2008 regarding the latest federal energy policy proposals.

60) Participation by Mark Hairr in a meeting on August 25, 2008 with CARTA and representatives of the City of Cookeville, Tennessee who are examining various alternative fuel options for public transportation that would serve Tennessee Tech University and dense commercial areas of the city.

61) A radio interview was conducted on September 17, 2008, with Mark Hairr by WUTC, the campus public radio station, to discuss the latest alternative vehicle technologies and the WEV Journal which ATTRP is editing and managing the publication of four issues beginning in the fall of 2008.

62) Participation by Mark Hairr at the East Tennessee Smart Energy Odyssey held at Miller Plaza in downtown Chattanooga on October 3, 2008. This event was sponsored by the National Alternative Fuels Training Consortium, the Chattanooga Green Committee and the East Tennessee Clean Fuels Coalition and showcased the latest technologies related to energy efficiency, advanced transportation and other clean energy initiatives.

63) Participation by Dr. Bailey and Mark Hairr at the Chattanooga Manufacturers Association Annual Meeting on October 28, 2008. The event featured a keynote address by Daniel C. Esty, Professor of Environmental Law and Policy at Yale University and co-author of *Green to Gold*.

64) Participation by Dr. Bailey, Mark Hairr and Woody Madden at the UTC GIS Open House event on November 20, 2008. The ATTRP staff met with the GIS Lab Director to discuss modeling and simulation of alternative fuel vehicles using GIS data. Through the meeting, ATTRP identified GIS software (e.g., ArcGIS) and other resources available to support several of its transit research activities.

65) Participation by Dr. Bailey and Mark Hairr at the Tennessee Valley Corridor Southeast Partnership Event held in Asheville, NC on November 4, 2008. The event hosted by Congressman Zach Wamp and Congressman Heath Shuler included sessions on green technologies, climate change and other issues of relevance to ATTRP's research program.

66) Participation by Dr. Bailey and Mark Hairr at the Electric Drive Transportation Association (EDTA) 2008 Conference held in Washington, DC, December 2-4, 2008. ATTRP staff played a major role in the conference proceedings and conference planning as Dr. Bailey moderated the session entitled "Advanced Systems: The Keys to a New Transportation Sector," and Mark Hairr served as Chair of the Conference Agenda Planning Committee. The conference attracted approximately 700 participants and included a Ride-and-Drive Event as well as

sessions on energy policy, fuel cell technology, advanced components and next-generation hybrid vehicles.

Appendix II

Task 2 Technical Assistance Evaluation Instrument

TECHNICAL ASSISTANCE EVALUATION
Center for Energy, Transportation & the Environment
The University of Tennessee at Chattanooga

This evaluation of technical assistance provided to your organization by the Center for Energy, Transportation and the Environment (CETE) at the University of Tennessee at Chattanooga is intended to assist with measuring the effectiveness of CETE technical services provided under Federal Transit Administration (FTA) Cooperative Agreement TN-26-7031. The survey relates to a project completed for your organization by CETE, specifically a report entitled **"*Insert Report Title*"** dated ***Insert date***.

Your assistance is greatly appreciated in the evaluation of this aspect of CETE's program. Please respond to the best of your ability to the following questions.

Please rank your opinions on a scale from 5 to 1, with 5 being "Very Satisfied" and 1 being "Very Dissatisfied." Place an "X" mark in the gray cell under your rank. Once you have completed the entire survey along with your contact information, please save the file and email as an attachment to Mark Hairr, CETE Research Program Director, at mark-hairr@utc.edu.

1) Overall, how satisfied were you with the report completed by CETE?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied

2) How satisfied were you with the technical expertise provided during the course of the project?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied

3) How satisfied were you that complex, technical concepts were communicated in a clear and understandable manner during the course of the project?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied

4) How satisfied were you with the timeframe for completion of the project?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied

5) How satisfied were you that the final report met the goals and objectives established for the project?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied

6) How satisfied were you with the ability of the CETE staff to respond effectively to changes, modifications or additional requirements during the course of the project?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied

Would you recommend CETE to another organization with a need for similar technical assistance?

Yes	No

Other comments may be provided in the space below.

Your Name	
Title	
Organization	
Street #	
Suite #	
City	
State	
Zip	
Telephone #	
Email	
Fax #	

Thank you for your assistance.

Appendix III

Task 2 Technical Assistance Evaluation Results

TECHNICAL ASSISTANCE EVALUATION
Center for Energy, Transportation & the Environment
The University of Tennessee at Chattanooga

This evaluation of technical assistance provided to your organization by the Center for Energy, Transportation and the Environment (CETE) at the University of Tennessee at Chattanooga is intended to assist with measuring the effectiveness of CETE technical services provided under Federal Transit Administration (FTA) Cooperative Agreement TN-26-7031. The survey relates to a project completed for your organization by CETE, specifically a report entitled **"Alternative Fuel Options for ValleyRide"** dated October 4, 2007.

Your assistance is greatly appreciated in the evaluation of this aspect of CETE's program. Please respond to the best of your ability to the following questions.

Please rank your opinions on a scale from 5 to 1, with 5 being "Very Satisfied" and 1 being "Very Dissatisfied." Place an "X" mark in the gray cell under your rank. Once you have completed the entire survey along with your contact information, please save the file and email as an attachment to Mark Hairr, CETE Research Program Director, at mark-hairr@utc.edu.

1) Overall, how satisfied were you with the report completed by CETE?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied
X				

2) How satisfied were you with the technical expertise provided during the course of the project?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied
X				

3) How satisfied were you that complex, technical concepts were communicated in a clear and understandable manner during the course of the project?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied
X				

4) How satisfied were you with the timeframe for completion of the project?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied
X				

5) How satisfied were you that the final report met the goals and objectives established for the project?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied
X				

6) How satisfied were you with the ability of the CETE staff to respond effectively to changes, modifications or additional requirements during the course of the project?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied
X				

Would you recommend CETE to another organization with a need for similar technical assistance?

Yes	No
X	

Other comments may be provided in the space below.
The project team responded very promptly, understood instantly the types of questions I had, was able to steer my concepts into concrete and discernable areas of study and provided a report that was written in terms that were easily understood by "layman" in terms of the engineering aspects but at a level that recognized and respected the experience and expertise of the end users.

Your Name	Robert (Bobby) A. Schneider, PhD
Title	General Manager
Organization	ValleyRide
Street #	4788 S. Orchard St.
Suite #	
City	Boise
State	ID
Zip	83705
Telephone #	208.336.1019 X4112
Email	bschneider@valleyride.org
Fax #	208.336.9048

Thank you for your assistance.

TECHNICAL ASSISTANCE EVALUATION
Center for Energy, Transportation & the Environment
The University of Tennessee at Chattanooga

This evaluation of technical assistance provided to your organization by the Center for Energy, Transportation and the Environment (CETE) at the University of Tennessee at Chattanooga is intended to assist with measuring the effectiveness of CETE technical services provided under Federal Transit Administration (FTA) Cooperative Agreement TN-26-7031. The survey relates to a project completed for your organization by CETE, specifically a report entitled **"Alternative Fuel Vehicle Options for Cades Cove Shuttle"** dated November 28, 2007.

Your assistance is greatly appreciated in the evaluation of this aspect of CETE's program. Please respond to the best of your ability to the following questions.

Please rank your opinions on a scale from 5 to 1, with 5 being "Very Satisfied" and 1 being "Very Dissatisfied." Place an "X" mark in the gray cell under your rank. Once you have completed the entire survey along with your contact information, please save the file and email as an attachment to Mark Hairr, CETE Research Program Director, at mark-hairr@utc.edu.

1) Overall, how satisfied were you with the report completed by CETE?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied
5				

2) How satisfied were you with the technical expertise provided during the course of the project?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied
5				

3) How satisfied were you that complex, technical concepts were communicated in a clear and understandable manner during the course of the project?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied
5				

4) How satisfied were you with the timeframe for completion of the project?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied
5				

5) How satisfied were you that the final report met the goals and objectives established for the project?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied
5				

6) How satisfied were you with the ability of the CETE staff to respond effectively to changes, modifications or additional requirements during the course of the project?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied
5				

Would you recommend CETE to another organization with a need for similar technical assistance?

Yes	No
yes	

Other comments may be provided in the space below.
We greatly appreciated your help for our Cades Cove project. Your advice was invaluable and has had a real impact on the project.

Your Name	Alissa McMahon
Title	Program Analyst
Organization	National Parks Conservation Association
Street #	706 Walnut St
Suite #	200
City	Knoxville
State	TN
Zip	37902
Telephone #	865.329.2424
Email	amcmahon@npca.org
Fax #	865.329.2422

Thank you for your assistance.

TECHNICAL ASSISTANCE EVALUATION
Center for Energy, Transportation & the Environment
The University of Tennessee at Chattanooga

This evaluation of technical assistance provided to your organization by the Center for Energy, Transportation and the Environment (CETE) at the University of Tennessee at Chattanooga is intended to assist with measuring the effectiveness of CETE technical services provided under Federal Transit Administration (FTA) Cooperative Agreement TN-26-7031. The survey relates to a project completed for your organization by CETE, specifically a report entitled **"CARTA Electric Bus Battery Analysis"** dated March 26, 2008.

Your assistance is greatly appreciated in the evaluation of this aspect of CETE's program. Please respond to the best of your ability to the following questions.

Please rank your opinions on a scale from 5 to 1, with 5 being "Very Satisfied" and 1 being "Very Dissatisfied." Place an "X" mark in the gray cell under your rank. Once you have completed the entire survey along with your contact information, please save the file and email as an attachment to Mark Hairr, CETE Research Program Director, at mark-hairr@utc.edu.

1) Overall, how satisfied were you with the report completed by CETE?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied
X				

2) How satisfied were you with the technical expertise provided during the course of the project?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied
X				

3) How satisfied were you that complex, technical concepts were communicated in a clear and understandable manner during the course of the project?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied
X				

4) How satisfied were you with the timeframe for completion of the project?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied
X				

5) How satisfied were you that the final report met the goals and objectives established for the project?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied
X				

6) How satisfied were you with the ability of the CETE staff to respond effectively to changes, modifications or additional requirements during the course of the project?

5	4	3	2	1
Very Satisfied	Somewhat Satisfied	No Opinion	Somewhat Dissatisfied	Very Dissatisfied
X				

Would you recommend CETE to another organization with a need for similar technical assistance?

Yes	No
X	

Other comments may be provided in the space below.
WE ARE VERY PLEASED WITH ALL ASPECTS OF THE WORK PERFORMED BY CETE AND WOULD ENTHUSIASTICALLY RECOMMEND THEIR SERVICES TO OTHER ORGANIZATIONS.

Your Name	RON D. SWEENEY
Title	GENERAL MANAGER
Organization	CHATTANOOGA AREA REGIONAL TRANSPORTATION AUTHORITY (CARTA)
Street #	1617 WILCOX BLVD
Suite #	
City	CHATTANOOGA
State	TN
Zip	37406
Telephone #	423 629 1411
Email	RONSWEENEY@GOCARTA.ORG
Fax #	423 698 2749

Thank you for your assistance.

Appendix IV

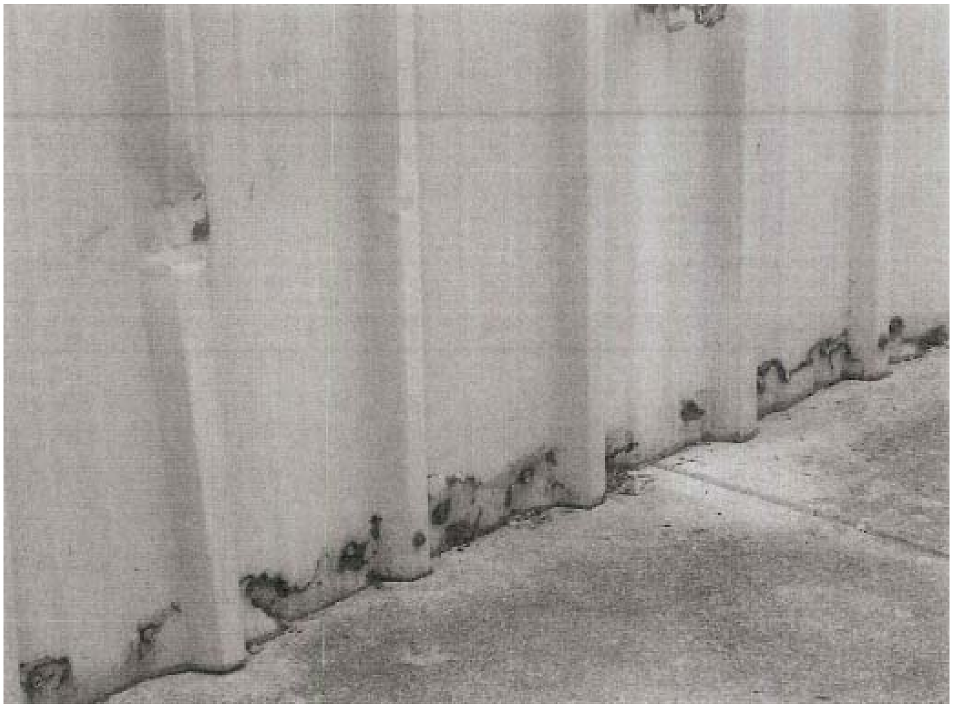
Task 3 Before and After Photographs of the AVTF

Before

After

Before

After



Before

After

Before

After

Before

After

Before

After

Appendix V

Task 3 Enterprise Center Endorsement Letter for AVTF Plans

the enterprise center

January 26, 2009

Mr. Mark E. Hairr
Research Program Director
Advanced Technologies for Transportation Research Program
University of Tennessee at Chattanooga
615 McCallie Avenue
214 EMCS Bldg., Dept. 2522
Chattanooga, TN 37403-2598

Dear Mr. Hairr:

On behalf of The Enterprise Center, I am pleased to report that I have reviewed and I endorse the Advanced Vehicle Test Facility (AVTF) Improvements Plan dated September 30, 2008 and the AVTF Business Plan dated December 31, 2008. These plans completed as part of Federal Transit Administration (FTA) research project TN-26-7031-01 are important resources in guiding initial test facility improvements and providing marketing, operating and financial strategies to ensure the sustainability of the facility in the future.

It is clear that the AVTF serves as a unique research and testing facility and is a critical piece of infrastructure that supports a wide range of the research activities of the Advanced Technologies for Transportation Research (ATTRP) program. This facility returns to operation at an important point in time as our nation focuses more on clean vehicle technology and renewable energy solutions. Chattanooga has long served as a "living laboratory" for advanced technologies and the AVTF has positioned ATTRP to serve as a national leader in testing emerging clean vehicle technologies. I am pleased to see that ATTRP has already moved forward in using the track recently for several projects and events such as UTC engineering student projects and demonstrations of electric and hybrid electric transit vehicles. These initial research activities provide a strong foundation upon which to increase activity at the AVTF.

In closing, I believe that conditions are favorable at this time for increased use of the AVTF as ATTRP continues to expand its research program and enlist additional project partners. The current emphasis in the U.S. on clean energy technologies, alternative fuels and energy independence, particularly in the transportation sector, provides a climate in which ATTRP can flourish and contribute greatly to meeting national goals in clean energy research.

I look forward to continuing our work together on maximizing the potential of the AVTF. This facility will certainly strengthen Chattanooga's position as a national leader in advanced clean vehicle technologies.

Sincerely,

J. Wayne Cropp
President and CEO

1250 MARKET STREET • SUITE 3020 • CHATTANOOGA, TN 37402 • TEL: 423-425-3770 • FAX: 423-757-4945

Appendix VI

Task 4 Table 7 Notes

Notes to Table 7

* Recommendation Numbers (i.e., 8.1 through 9.6) refer to designation in UTC Campus Transit Plan
(a) Based on an incremental cost for biodiesel vs. diesel of 25¢/gallon for 50,000 gallons used annually. (b) Based on quote provided May 20, 2008 for a 25-foot, 20-passenger series hybrid cutaway (Dean McGrew, Vice President of Azure Dynamics)
(c) Per vehicle—does not include charging and/or fueling equipment. Based on ATTRP analysis for hybrid and hydrogen ICE cutaway vehicles conducted spring 2008
(d) Per vehicle—does not include charging and/or fueling equipment. Based on cost of 22-foot hydrogen fuel cell bus manufactured by Ebus for the University of Delaware and the University of Texas
(e) Based on project plan and cost estimates associated with inductive charging project at the University of Kansas, May 2008
(f) Based on CARTA ITS cost estimates (spring 2008)
(g) Based on CARTA ITS cost estimates (spring 2008)
(h) Based on CARTA ITS cost estimates (spring 2008)
(i) Based on CARTA ITS cost estimates (spring 2008). Includes a complete replacement of CARTA's fare collection system with a new electronic fare system incorporating smart cards
(j) Recommended modification would be budget neutral
(k) Based on one vehicle, 8 hours/day, 200 days/year (fall & spring semesters), $75/hour
(l) Based on two vehicles, 8 hours/day, 200 days/year (fall & spring semesters), $80/hour
(m) Based on one vehicle, 8 hours/day, 200 days/year (fall & spring semesters), $80/hour
(n) Based on ATTRP project funding request, November 2007
(o) Per bus stop. Based on review of enhanced bus stops at various U.S. public transportation systems
(p) For increased marketing staff time and materials in year one
(q) For year-one start-up of program (staff and materials budget)

Appendix VII

Task 4 UTC Campus Transit Plan Advisory Committee Endorsement Letter

UTC CAMPUS TRANSIT PLAN
Advisory Committee

July 25, 2008

Mark E. Hairr
Research Program Director
ATTRP
615 McCallie Avenue
214 EMCS Bldg.
Chattanooga, TN 37403-2598

RE: Endorsement of UT Chattanooga Campus Transit Plan

Dear Mr. Hairr,

On behalf of the UTC Campus Transit Plan Advisory Committee, we wish to extend our endorsement of the UTC Campus Transit Plan completed by the Advanced Technologies for Transportation Research Program (ATTRP) on June 30, 2008. The Plan effectively addresses the original goals and objectives identified at the beginning of the planning process, namely focusing on the transit system in the context of overall campus transportation issues and recommending a number of strategies for ensuring that transit and related alternative modes of transportation are viable options in the future. Building on the strengths of the research team, a special focus of the plan was placed on identifying advanced vehicle technologies and Intelligent Transportation Systems (ITS) that will support campus sustainability initiatives.

The UTC Campus Transit Plan Advisory Committee was made up of a wide range of stakeholders representing the UT Chattanooga faculty, staff and students; the regional public transportation organization (CARTA); downtown interests (RiverCity Company), and the regional transportation planning agency. The Advisory Committee met regularly during the development of the Transit Plan and provided important feedback and input along the way. This input from the Advisory Committee was combined with an extensive public input and market research effort that produced a Plan that is truly reflective of the needs and desires of the campus community. We are appreciative that the recommendations in the Plan are unique and tailored specifically to our campus so as to ensure the highest chance of success in building transit ridership.

UT Chattanooga recently completed a Strategic Plan that has a strong focus on technology and research initiatives that build upon the strengths of the University and the city of Chattanooga. The Strategic Plan calls for a connection between the University and the "environmental city" of Chattanooga and includes a goal of becoming the most environmentally sustainable campus in the state of Tennessee. The Transit Plan will play an important role in assisting the University in moving forward toward this goal by stressing the integration of clean energy and advanced transportation technologies.

Thank you for your work on the UTC Campus Transit Plan and providing a strong foundation upon which to make future transit improvements and enhancements.

Sincerely,

Cindee Pulliam

Cindee Pulliam
UTC Campus Transit Plan Co-Chair
Director of UT Chattanooga Auxiliary Services

Jill Veron

Jill Veron
UTC Campus Transit Plan Co-Chair
CARTA Director of Planning

Appendix VIII

Task 5 CARTA Endorsement Letter

for DMS Project

Chattanooga Area Regional Transportation Authority

January 26, 2009

Mr. Mark E. Hairr
Research Program Director
Advanced Technologies for Transportation Research Program
University of Tennessee at Chattanooga
615 McCallie Avenue
214 EMCS Bldg., Dept. 2522
Chattanooga, TN 37403-2598

Dear Mr. Hairr,

This letter is to confirm the successful implementation of the Dynamic Message Sign (DMS) system in conjunction with CARTA under FTA research project TN-26-7031-01, Task 5. This project resulted in the deployment of a real-time electronic passenger information system on campus and at other strategic locations important to university passengers. This project is a critical element in CARTA's comprehensive ITS system and responds directly to passenger needs for more information at high-traffic bus stops. Additionally, the project included the completion of an ATTRP engineering analysis examining the prospects for future dual power DMS units that utilize both solar and grid-connected power.

The real-time passenger information system improves customer satisfaction in such a manner as to stimulate increased ridership on campus-related transit services. DMS communicates real-time arrival and departure information to passengers via electronic bus stop signs, the internet and wireless hand-held devices such as mobile phones and Personal Digital Assistants (PDAs). The system greatly increases customer access to real-time information by allowing for user-defined views and automated notification of bus arrival times on hand-held devices. This real-time system not only communicates precise arrival and departure times, but also provides passengers with critical information regarding service interruptions, emergencies and other important public service announcements and campus-related event notices. The system calculates the arrival time of buses for specific routes and stops and provides definitive information for passengers addressing the uncertainty that often exists at bus stops for passengers. The DMS system deployed on campus and at other strategic locations is part of an overall passenger information system that allows passengers to track bus movements via the internet (see "Bus Route Tracker" section of CARTA website at www.gocarta.org).

Chattanooga's Driving Force.

The implementation of the DMS system was completed prior to December 31, 2008. All sign units located at bus stops were tested for operability, accuracy and reliability during the test period. Additionally, the DMS system was evaluated by the CARTA Technology Director to ensure proper integration with CARTA's overall ITS system. Additionally, the DMS Dual Power Engineering Analysis effectively addresses the prospects for deploying DMS units with grid-connected and solar power systems which should prove a benefit to future expansion of the DMS system on the CARTA route system.

Thank you for your efforts in completing this important ITS project in partnership with CARTA. We look forward to continuing our work together in the future.

Sincerely yours,

Thomas W Dugan

Thomas W. Dugan
Executive Director

Appendix IX

Task 6 DAS Comparison Table

Comparison of Vehicle Data Acquisition Systems

	DAS	LabJack U3	BatteryDAQ TM65-24	UTC DAQ
Compatible with battery-electric buses	Yes	Yes	Yes	Yes
Compatible with hybrid-electric buses	Yes	Yes	Yes	Yes
Number of data channels	9	Up to 16	Up to 51	Up to 16
Individual monitoring of sep. battery strings	Yes	Yes	Yes	Yes
Monitoring of battery temperature	Yes	Yes	Yes	Yes
Monitoring of genset voltage and current	Yes	No	No	Yes
High-voltage present in driver area	No	No	No	No
Sensitivity to system crashes	Low	Moderate	Low	High
Automatic crash recovery	Yes	No	Yes	No
Meter memory	1 giga-byte	n/a	Unavailable	n/a
Laptop required for stored data download	No	Yes	Yes	Yes
Laptop required for real-time monitoring	No	Yes	No	Yes
Date of development	2007	2008	Unavailable	1997
Operating system requirement	Windows XP or Vista	Flexible*	Windows 95 - Vista	Windows XP or Vista
Operating system support status	Supported	Supported	Supported	Supported
Charge profiles accessible after-the-fact	Yes	n/a	n/a	Yes
Drive profiles accessible after-the-fact	Yes	n/a	n/a	Yes
Evaluate low-power events after-the-fact	Yes	n/a	Yes	Yes
Battery ampere-hour data compiled	Yes	n/a	Yes	Yes
Number of y-axis plot variables	6	n/a	n/a	Multiple
Cost	$890	$150	Unavailable	$5,195

* - Open Source Development

Metric Conversion Chart

Distance		
1 inch	= 2.54 centimeters	= 25.4 millimeters
1 foot	= 0.305 meter	= 30.48 centimeters
1 yard	= 0.9144 meter	
1 mile	= 1.61 kilometers	= 5,280 feet
1 kilometer	= 1,000 meters	= 0.6214 mile
1 meter	= 100 centimeters	= 1,000 millimeters
1 meter	= 3.28 feet	
1 centimeter	= 0.3937 inch	= 10 millimeters
1 millimeter	= 0.039 inch	= 0.1 centimeter
1 micron	= 10^{-4} centimeter	= 10^{-6} meter
10^{-6} meter	= 1micrometer	
Volume		
1 kiloliter	= 1,000 liters	= 1 cubic meter
1 liter	= 1,000 milliliters	= 1,000 cc
1 milliliter	= 1 cc (exactly 1.000027 cc)	
1 fluid ounce	= 29.57 milliliters	
1 US gallon	= 3.785 liters	
1 Imperial gallon	= 4.546 liters	
Weight		
1 kilogram	= 1,000 grams	= 2.2 pounds
1 gram	= 1,000 milligrams	= 0.035 ounce
1 milligram	= 1,000 micrograms	= 1/1,000 gram
1 microgram	= 10^{-6} grams	= 1/1,000 milligram
1 nanogram	= 10^{-9} grams	= 1/1,000 microgram
1 pound	= 0.45 kilogram	= 16 ounces
1 ounce	= 28.35 grams	

Federal Transit Administration
Office of Research, Demonstration and Innovation
U.S. Department of Transportation
1200 New Jersey Avenue, SE
Washington, DC 20590

www.fta.dot.gov/research

Report No. FTA-TN-26-7031-01-2009.1