Final Report
EXECUTIVE SUMMARY

Reporting Period: November 1996 - October 1999

Reference: *Executed contract - SPR No. 0707 / WPI 0510804 / State Job No. 99700-3371-119 / Contract No. BA590, "Technology And Standards Research For The State Traffic Engineering Research Laboratory ."*

Investigators:

Faculty

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Student assistants

This project has involved a total of seventeen (17) student assistants over the reporting period.

Current:

Graduate	– Tim Lynch (Lead Graduate Research Assistant)
	-- Lily Fang
Undergraduate	– Robert Hunter (Lead Undergraduate Research Assistant),
	-- Cedric Bouey, Alexis Morales, Robert Parkes, Andrew Saunders
Special	– Brandon Matthews

Past:

Adolfo Bello, Eric Brockmann, Ron Curtis, Amanda Dykes, Manxing Huang, Qinghui Lin, Hoa Pham, Thi Pham, Rob Pilkington

FDOT Managers:

Project manager – H. Eric Larson
Lab Engineer – Jeffrey M. Morgan

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Submitted with this report is a CD produced by the staff at TERL.

1. BACKGROUND

The primary factors that provided the impetus for embarking this research endeavor include:

- *Need*
  The impact of the Intelligent Transportation Systems (ITS) incentives and the Intermodal Surface Transportation Efficiency Act (ISTEA) resources for the advancement of transportation systems has led to many new and innovative traffic devices and systems being developed by industry. Knowing this, the Florida Department of Transportation (FDOT) recognized the need for a modern research and testing facility to review and evaluate the applicability and effectiveness of these new technologies for use on the state roadway system.

- *FDOT Vision*
  Alongside of facilitating the mission to provide safe, efficient, effective, and environmentally sound highway and surface transportation systems today and tomorrow, the traffic engineers of the FDOT envision that the establishment of the state-of-the-art technology research and testing laboratory has and will enable Florida to play a leading role in the development, testing and evaluation of theses state-of-the-art systems and equipment. Hence, with the operation of the Traffic Engineering Research Laboratory in it's 3rd year, the Florida DOT is poised to enter the twenty-first century with the tools necessary to play a leading role in the area of advanced transportation ITS technologies.

- *Education*
  It has become imperative to educate a new breed of transportation engineers with specialized skill and knowledge in microelectronics, communication systems, control systems, and computer engineering to cope with the planning, design, selection, testing, and maintenance of various ITS technologies for the next generation of transportation systems in Florida, and the United States as well. A joint effort between the FDOT and the FAMU-FSU College of Engineering (FAMU-FSU COE) has been taken to develop a research and testing facility that will present opportunities for educational programs with strong industrial contents, thereby effectively addressing the critical national issue of educating transportation engineers of tomorrow.

In view of the rapidly advancing transportation technologies, this project is envisioned to be a long-term endeavor in order to satisfy the FDOT needs adequately. The funding of this research project was initially approved by the FDOT for three years on October 1, 1996. The current research activities actually began to proceed in late November 1996 and the operation of the FDOT laboratory facility – The *Traffic Engineering Research Laboratory* – on Springhill Road in Tallahassee began its operation in May of 1997.

2. MISSION STATEMENT

The Traffic Engineering Research Laboratory or "TERL" as it is also called, exists as a joint research facility between FDOT and FAMU-FSU COE. The main objective is to conduct, support and nurture applied research, standards and specifications development along with providing help with the evaluation and testing of ITS and traffic engineering technologies. The TERL provides facilities and staff accessible to the federal and other state transportation agencies for characterization, testing, and evaluation of ITS equipment and subcomponents. These transportation agencies have open access to a traffic engineering database maintained by the TERL. Undergraduate and graduate education in transportation technologies and systems will be coordinated through FAMU-FSU COE.

3. RESEARCH PLAN

The original plan that defined the scope of research work was framed to achieve the mission of the TERL. It encompassed a set of fundamental objectives. Various tasks were identified and designed to address both the near-term as well as long-term research issues.

It may be emphasized that the original research work plan has been constantly modified to accommodate the recommendations initiated by FDOT project managers. The actual research tasks are usually performed to meet FDOT requirements as they arise.

3.1. Fundamental Objectives

(a) To conduct and support applied research, evaluation and testing pertaining to the development of standards and specifications used for the evaluation and testing and use of ITS and other traffic engineering technologies.

(b) To develop and maintain databases on traffic engineering and ITS technologies. Specifically, an Internet website will be created such that these databases will be accessible to the transportation engineers serving in the public transportation agencies. (This will be completed in the next phase of the project.)

(c) To design and implement computer-based instrumentation systems for evaluating and testing ITS and traffic engineering equipment and subcomponents. This will standardize the evaluation and testing procedures to ensure uniform component assessment, maximize accuracy, and minimize costs. Further, the development of computerized evaluation and testing workstations will present opportunities for implementing unique educational programs. (This will be completed in the next phase of the project.)

(d) To collect and compile comprehensive information, pertaining to work done at the TERL, into an electronic handbook format such that it can be accessed interactively using a common Internet web browser. Currently this is in the Compact Disk (CD) version that this report is contained in and will be updated accordingly.

(e) To upgrade as well as further develop into a modern testing and evaluation facility, the existing FDOT Traffic Engineering Testing Laboratory , located at 2612 Springhill in Tallahassee, Florida.

4. OPERATION

Faculty Researchers:

Bing Kwan is in charge of the administration part of the project. He recruits student assistants for the project, prepares the payrolls, assigns the responsibilities of the student assistants, and checks the attendance and the research progresses of the student assistants. Bing Kwan also chairs the research team meetings held regularly at the TERL or at FAMU-FSU College of Engineering.

Leonard Tung manages the research at the TERL and also works in the following areas of research: NTCIP, Detectors, and Dynamic (Changeable) Message Signs (DMS). His schedule includes regular hours at the TERL, usually in the mornings for 8 to 12 hours per week.

Jim Zheng works in the area of testing for luminary technologies including LED signal heads, conventional signal heads and LED dynamic message signs. His schedule includes regular hours at the TERL, usually 3 to 4 hours per week.

Student Assistants:

The student assistants have been given various tasks involving the surveying, collecting and compiling of specifications and standards in the research areas of Light Emitting Diodes, Advanced Vehicle Detection, Dynamic (Changeable) Message Signs, NTCIP, and Intersection Testing Development. Weekly meetings of the entire research team are held where each student gives an oral (with multimedia) status report on their area. Student assistants are required to report the work done during the past week, problems encountered if any, and projection of the future activity. Students usually staff the TERL from 8 to 12 hours per week.

4.1. Mode of Operation

The FDOT Lab Engineer, Jeff Morgan, works each weekday with the research team to guide and direct the progress of the research being done. Meetings with the FDOT Project Manager, Eric Larson, also help to keep the research in line with the Department's goals and objectives.

The members of the research team are required to maintain the practices and procedures that have been established for the Research Lab as outlined in the TERL Administration portion of this report (cd version).

A reading file (notebook) containing all practices and procedures adopted by the TERL has been developed and is required to be read on a monthly basis by each student assistant.

5. RESEARCH TASKS

Our research efforts are currently concentrated in the following areas:

a) Advanced Traffic Signal Technology:
This area consists of the research and monitoring of light emitting diode (LED) vehicular traffic / pedestrian signals and other luminary technologies that may be applicable for this use. Lily Fang and Tim Lynch has been the lead student assistants in this area. Lily and Tim are working closely with and under the supervision of Dr. Zheng.

b) Advanced Vehicle Detection Technologies:
This area consists of the research and identification of application and performance standards for the various new vehicle detection technologies.
Ron Curtis was the lead student assistant in the area of Vehicle Detection till his resignation. Robert Hunter and Robert Parkes have since been assigned to the area of Vehicle Detection.

c) Advanced Dynamic Message Sign (DMS) Technologies:
This area consists of the research and identification of application and performance standards for new and existing dynamic message sign (DMS) technologies. Currently, there is no lead student assigned in this area. The task of LED DMS testing has been assigned to Lily Fang and Tim Lynch.

d) National Transportation Communications for ITS Protocol (NTCIP):
This area consists of the research and identification of NTCIP testing and performance standards of various devices, such as Traffic Controller and DMS, for ITS applications. Drew Saunders is the lead student assistant in this area till his resignation.

e) Special:
Robert Hunter also assists FDOT Engineer Jeff Morgan in the following areas: signal lamp re-certification; test equipment search; specification formatting, web page proofing, certification handbook, and the development of the first phase of the IAPL (Interactive Approved Product List, working with Brandon Matthews), an interactive version of the FDOT Approved Product List.

f) Technology Transfer:
Alexis A. Morales assists Mr. Morgan, Dr. Kwan and Dr. Tung in the area of technology transfer by maintaining and organizing the TERL filing system and compiling all information developed at the TERL into a user friendly interactive CD format. Cedric Bouey is also assigned in this area.

6. Near-Term Research Work

Proposed Research Issues and Tasks	FDOT Initiated Research Issues and Tasks	Actual Tasks Performed
Testing, detection, communications technologies • Literature search • Compiling information • Equipment selection • Design, installation, performance standards • Microloop arrays • Instrumentation	*Detection technologies* 1. *Non-intrusive vehicle detectors*: Passive acoustic, pulse ultrasonic, passive and active infrared, passive magnetic, radar, doppler microwave, video, magnetoresistors. 2. *Pedestrian detectors*: ADA, infrared, video. • Evaluate current detection technologies with respect to operation characteristics, installation, performance, maintenance requirements • Study expandability or upgrade requirements • Develop standard indexes in Florida • Collect input from manufacturers pertaining to technical and economic feasibility issues as well as compatibility issues • Draft standards, specifications, and procedures	*Detection technologies* • State DOTs contacts list • FDOT district contacts list • Vehicle detector specifications from state DOTs • Manufacturers information • Compiled specifications and standards for microwave, magnetic, and ultrasonic detectors • Survey on microloop detectors • Installation requirements of vehicle detection devices • Report on remote traffic microwave sensor (RTMS) for vehicle detection • Data are sorted, compiled, and stored in MS-EXCEL, MS-WORD, or Word-Perfect files

Proposed Research Issues and Tasks	FDOT Initiated Research Issues and Tasks	Actual Tasks Performed
Luminary technologies • Literature search • Compiling information • Design, installation, and performance standards	***Luminary technologies*** • Analyze the usage of Light Emitting Diode (LED) signals, in Florida, with respect to installation, performance, testing and future plan for their use • Study LED traffic signals pertaining to performance, standards, specifications, and comparison with incandescent lamped signals • Evaluate attractive technologies alternative to the LED signals	*LED signals, changeable / dynamic message signs (CMS/DMS)* • Compiled Nationwide DOT contact list • Compiled FDOT District contact list • Compiled LED DMS specifications from all manufacturers • Compiled DMS specifications from all state DOTs • Compiled specifications and standards for permanent mount DMS (PMDMS), truck (vehicle) mount DMS, and portable DMS • Data sorted, compiled, and stored in MS-EXCEL, MS-WORD, or WordPerfect files • Compiled PMDMS and TMDMS research reports • PMCMS draft Standards Report • Compiled nationwide survey on the usage of permanent mount dynamic message signs (PMDMS) • Performed re-certification of incandescent lamps for conventional signal heads • Instrumentation: optical test system for luminary technologies • Performed various tests on permanent mount DMS

Proposed Research Issues and Tasks	FDOT Initiated Research Issues and Tasks	Actual Tasks Performed
(Not originally set for first phase)	***National Transportation Communication ITS Protocol (NTCIP)*** • Literature search • Compiling information	*Florida NTCIP Compliance* • Study Simple Network Management Protocol (SNMP) Management Information Base (MIB) • Develop a Florida Management Information Base (MIB) for actuated traffic signal controllers (ASC) • Develop a user NTCIP Technical Glossary • Became proficient in the use the NTCIP Exerciser software for the testing of NTCIP compliance
Documentation • Progress reports • Electronic handbook	*Documentation* • Reports summarizing tasks performed	• Findings and results from various tasks are described in the ten (10) progress reports submitted to the FDOT. • Relevant information and results has been compiled and included in the electronic handbook – this final report.

7. Long-Term Research Work

Research Issue	Research Tasks	Remarks
ITS architecture	To provide assistance so that the FDOT can participate in this national effort more effectively.	
Communication protocol	To provide assistance for implementing multi-vendor compatibility for essential system communications.	Preliminary work completed
Global positioning system (GPS)	To investigate or examine the applications of GPS in transportation and safety areas.	
Traffic flow modeling	To study the applications of complex traffic models in advanced traffic information systems (ATIS).	
Automatic vehicle identification (AVI)	To study the multi-vendor compatibility issues for essential AVI.	
Detection techniques	1. To research and develop the specifications for the evaluation and the use of new vehicle detector technologies, such as ultrasonic, acoustic, microwave, video, etc. 2. To develop the standards for applications.	Preliminary work completed
LED signals and changeable message signs (CMS)	1. To research the specifications the evaluation and the use of traffic signals and CMS that incorporate LED technology. 2. To develop the standards for applications.	Completed
Changeable message signs (CMS)	1. To research testing and acceptance standards. 2. To research the specifications for evaluation and use of CMS (portable and permanent). 3. To research the operational standards. 4. To develop the standards for applications.	Completed

Research Issue	Research Tasks	Remarks
Precision requirement and video standards	To provide guidelines for acceptance of video detection and surveillance systems.	
Use of solar energy	To research the specifications for the evaluation and the use of solar-powered traffic control equipment, such as arrow boards, CMS's, flasher, traffic signals, etc.	
Environmental test standards	To research new standards for some new technology equipment.	
Closed circuit television (CCTV)	To research standards for cameras, cable, amplifiers, etc.	
Fiber optics	To research specifications for the different uses of fiber optics (glass and plastic), including long and short haul communications, CMS, vehicular and pedestrian signals.	
Radio systems and Equipment	1. To research the specifications for the different uses of radio equipment, motorist aid call boxes, portable traffic signal systems, CMS, pre-emption equipment, etc. 2. To study the coordination of radio frequency.	
Communication mediums	To research the specifications for the different types of communication mediums, such as wire pair, coaxial cable, submarine cable, optical fiber, microwave, satellite, cellular radio, infrared, and spread spectrum systems.	
Modems	To research and develop the specifications for the use of modems in traffic control device and systems standards.	
PC / Laptop computer upload and download	To research the specifications for the different types of computers and communications used for interfacing with NEMA/170/2070 and TS-2 controllers, AVI equipment, vehicle count stations, CMS, etc.	

8. Work Has Been Accomplished in the Following Areas

8.1. Advanced Traffic Controller (ATC) Model 2070 Controllers
- a) Florida 2070 ATC Minimum Standards Report
- b) Model 2070 Traffic Controller Technical Glossary

8.2. Certification
- a) Approved Product List
  - 1) Non-Interactive Approved Product List
  - 2) Interactive Approved Product List
- b) Certification Summary Reports
  - 1) Statewide Re-certification of Signal Lamps
  - 2) Certification Handbook
  - 3) Contractor Internet Access Survey
  - 4) Florida Maintaining Agency Contacts
  - 5) Nationwide Signal Contractor Pre-qualification Survey
  - 6) Statewide Signal Contractor List
  - 7) Temporary Permit History Report
  - 8) Worldwide Transportation Agency Links
  - 9) US DOT Contact List

8.3. Dynamic Message Signs (DMS)
- a) Permanent Mount DMS Standards Report
- b) Truck (Vehicle) Mount DMS Standards Report

8.4. National Transportation Communication ITS Protocol (NTCIP)
- a) Management Information Base (MIB) for actuated traffic signal controller (ATC) in Florida
- b) NTCIP Technical Glossary

8.5. Signal Illumination Technology – Light Emitting Diodes (LED)
- a) Design of an optical system for testing the chromaticity and the intensity of signal heads
  - 1) The procedures for testing chromaticity
  - 2) The procedures for testing intensity
- b) Intensity study of signal heads
  - 1) Precision Solar LED traffic signals
  - 2) Dialight LED traffic signals
  - 3) Ecolux LED traffic signals (8 inch and 12 inch)
  - 4) Econolite LED traffic signals
  - 5) 3-M traffic signals (High Visibility Lens System Model 150)
  - 6) Conventional (incandescent) traffic signals
  - 7) McCain pedestrian signals
  - 8) Various neon pedestrian signs
  - 9) Changeable (Dynamic) Message Signs (DMS)
  - 10) Variation of voltage and its effects on conventional and LED signals
  - 11) Light Degradation
  - 12) Tested various candela and chromaticity test measurement devices
  - 13) LED signal and maintaining agencies survey
  - 14) Candela dependency on distance simulation (8 inch and 12 inch LED traffic signal)
- c) Chromaticity study
  - 1) Test results with the Minolta colorimeter
  - 2) 8" Ecolux Red LED signal at different distances
  - 3) 12" Precision Solar Controls Red LED traffic signal at different distances
  - 4) 12" Precision Solar Controls Amber LED traffic signal at different distances
  - 5) 12" Precision Solar Controls Green LED traffic signal
  - 6) 12" deMco Red Conventional traffic signal

7) 12" deMco Amber Conventional traffic signal
8) 12" deMco Green Conventional traffic signal
9) 12" 3M Red traffic signal
10) 12" 3M Amber traffic signal
11) 12" 3M Green traffic signal
12) Test results with PR-650 Spectrascan Colorimeter
13) McCAIN solid pedestrian signal
14) McCAIN hand signal
15) Ecolux 12" red LED, model: D12 RA4-A4 and D12 RA5.

8.6. Advanced Vehicle Detection
a) Detection Features (Summary of Minnesota Guidestar)
b) Developed Draft Standards Reports
1) Acoustic Detectors
2) Infrared Detectors
3) Magnetic Detectors
4) Microwave Detectors
5) Radar Detectors
6) Ultrasonic Detectors
7) Video Detectors
c) Detection Devices Tested
1) Installation of the Microloop Detector by 3M (Preliminary Report Included)

8.7. Technology Transfer
a) TERL Compact Disk
b) TERL Newsletter
c) TERL Website
d) Addition of material in the Traffic Engineering Manual

8.8. Vehicle Detection Testing Development
a) Detection system that connects the TERL and the mast-arm installed outside the lab facility
b) Research on installation requirements of various detecting devices available to the TERL; including a video detection system with two cameras, one microwave detector, one infrared detector, and one magnetic detector (to be installed on the mast arm for testing)
c) Design a detection system that integrates various technologies for systematic evaluation of specific detection devices
d) preparation of the intersection testing site for various studies