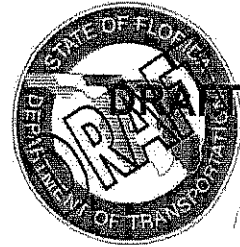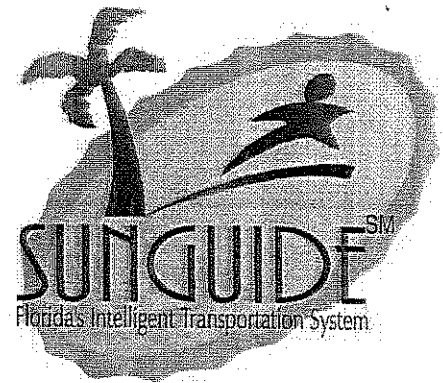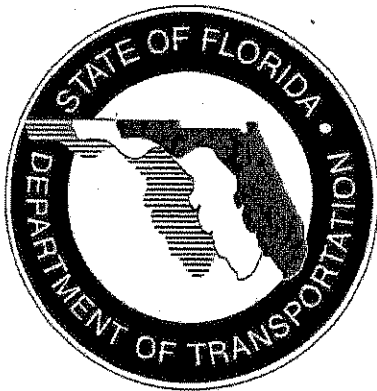Technical Memorandum

Florida Department of Transportation

Ramp Metering Firmware
Independent Verification and Validation Test Plan

June 14, 2007
Version 1.6.1

Prepared for:

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Revised: June 14, 2007

DOCUMENT CONTROL PANEL

File Name:	*070508FDOT RMF IVV Test Plan and Procedures V1_6_1.doc*	
File Location:		
Deliverable Number:		
Version Number:	Draft 1.6	

Name		**Date**
Created By:	Walt Townsend, Siemens ITS	3/12/07
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Modified By:	David Chang, PBS&J	3/21/07
	TJ Hapney, PBS&J	3/21/2007, 5/8/07
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Completed By:		

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List of Acronyms

C2C .... Center to Center

CCTV .... Closed Circuit Television

CPU .... Central Processing Unit

CRC .... Cyclic Redundancy Check

DMS .... Dynamic Message Sign

FDOT .... Florida Department of Transportation

HAR .... Highway Advisory Radio

ITS .... Intelligent Transportation Systems

IV&V .... Independent Verification and Validation

LAN .... Local Area Network

LED .... Light Emitting Diode

MDX .... Miami-Dade Expressway Authority

MIB .... Management Information Base

MIST .... Management Information System for Transportation

NTCIP .... National Transportation Communications for ITS Protocol

PDA .... Personal Digital Assistant

PM .... Performance Measures

RAM .... Random Access Memory

RMF .... Ramp Meter Firmware

RR .... Road Ranger

RWIS .... Road Weather Information System

RRPM .... Road Ranger Performance Measures

STMCSLS .... Statewide Transportation Management Center Software Library System

SwRI .... Southwest Research Institute

TERL .... Traffic Engineering Research Lab

TMC .... Transportation Management Center

VMS .... Variable Message Sign

1. Scope

This Test Plan defines the overall plan for the Independent Verification and Validation (IV&V) testing to verify the operation of the Florida Department of Transportation (FDOT) Ramp Meter Firmware (RMF) developed by Southwest Research Institute (SwRI) for use with the SunGuide^{SM} Software Ramp Metering Subsystem. The scope of these tests includes only the firmware, not the central software that makes up the Ramp Metering Subsystem itself, although the central software will be used as part of some of the tests.

Note that this document does not contain the actual test procedures, just the plan for the test process. Test procedures will be defined in a separate document.

1.1. Purpose

This test plan is intended as an independent verification that the RMF meets the SunGuide requirements for ramp metering and operates correctly with the SunGuide Ramp Metering System.

1.2. General Information

The SunGuide RMF was developed by SwRI to replace the original Washington State Department of Transportation (WSDOT) RMF, which was not available due to licensing issues. As a direct replacement for the WSDOT firmware, all functions, communications protocols, and the user interface should be the same as the original firmware. If there are questions about the correct functionality of the new firmware, it will be useful to compare its operation with that of the original firmware.

1.3. Project Background and Description

The FDOT is administering a program to develop and deploy SunGuide software. The SunGuide software is a set of intelligent transportation system (ITS) software modules that allows the control of roadway devices as well as information exchange across a variety of transportation agencies. The goal of the SunGuide software is to have a common software base that can be deployed throughout the state of Florida. The SunGuide software development effort is based on ITS software available from both the states of Texas and Maryland; significant customization of the software is being performed and new software modules are being developed.

Currently the SunGuide software system does not support ramp metering devices because the RMF was not available earlier. There are 23 SunGuide functional requirements that address the ramp metering function that were implemented in Release 2.0 of SunGuide and verified using the WSDOT firmware that was not licensed for SunGuide deployment in Florida. After SunGuide release 2.2, it was decided that new firmware would be developed and funded by the FDOT so that ownership of that firmware would reside with the FDOT. This Test Plan is to verify that the firmware developed by SwRI for the FDOT is fully compliant with the SunGuide ramp metering requirements.

SwRI was tasked to develop the FDOT Ramp Meter controller firmware. The functionality to be implemented is focused on the development of firmware that accepts and responds to commands from central system SunGuide software.

The development of the Ramp Meter controller firmware includes three operational modules: General 170E Operations Module, Data Surveillance Module, and the Metering Module.

The task of the General 170E Operations Module includes:

− Developing startup code to initialize central processing unit (CPU) and board;
− Developing basic functionality to communicate to the front panel, including light emitting diodes (LED), call lights and keypad;
− Developing interrupt service routine to read the eight detector upstream/downstream states at 120 Hz sample period;
− Developing real time interrupt routines to allow scheduling of functions for execution periodically or as a one time occurrence; and,
− Developing code to set and read time on the DS1744 real time clock module.

The task of the Data Surveillance Module includes:
− Basic volume and occupancy calculations; and,
− Basic speed and length calculations.

The task of the Metering Module includes:
− Designing memory structures to represent lane data;
− Implementing calculation of the following rates;
  • Time of Day Metering Rate;
  • Traffic Metering Rate;
  • Intermediate Metering Rate; and,
− Developing the various adjustments (Queue Adjusted Metering Rate, Volume Adjustment, Advanced Queue Override, etc.).

Once all the modules are developed, the full integration will be conducted. The final delivery to the FDOT will be EPROM, source code and documentation, including Software Users Manual, Software Design Documentation, Software Integration Case Procedure, and Version Description Document.

2.   References

The following documents, of the exact issue shown, form a part of this document to the extent specified herein. In the event of a conflict between the documents referenced herein and the contents of this document, this document shall be considered the superseding requirement.

Statewide Transportation Management Center Software Library System: Requirements Specification, dated: June 3, 2003.

Florida Department of Transportation
Traffic Engineering and Operations Office
605 Suwannee Street, M.S. 90
Tallahassee, Florida 32399-0450
(850) 410-5600

State of Washington Model 170 Ramp Metering Controller User Manual, Program No. 175 dated: January, 1986

Washington State Department of Transportation
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PO Box 47344
Olympia, Washington 98504-7344
360.705.7281

3. Test Plan

The SunGuide requirements for the RMF will be verified using this test plan.

The IV&V testing is intended to be a separate test process independent of the firmware vendor's testing. SwRI will conduct a factory acceptance test (FAT) for the firmware in its lab in San Antonio.

If both the FAT and IV&V tests are successful, then the firmware will be ready for on-site field testing. See Section 5 for recommendations on field testing.

3.1. Test Philosophy

Since the Ramp Metering controllers drive signal heads that directly control traffic, it is important the firmware is thoroughly tested before field deployment. It is also important to note that testing the software in the field with bagged signal heads does not represent an accurate test environment. Since the vehicles are not stopping in response to the signal heads, the timing of the detector actuations is not correct. Ramp Meter operation must be tested in a lab environment with simulated inputs until reliable operation of the firmware is established.

3.2. Test Site

The IV&V testing of the RMF will take place at the Traffic Engineering Research Lab (TERL) in Tallahassee.

3.3. Requirements to be Verified

The component requirements identified for the RMF are listed in Table 3-1. Note that all requirements listed in this table are derived from User Requirement A001, System Requirement S006, and Subsystem Requirement TM021.

Table 3-1 SunGuide^{SM} Ramp Meter Firmware Requirements

REQ ID	Component	Element	Requirement Text
TM021			The SunGuide system shall provide a ramp metering firmware for controlling traffic flow onto a roadway from an on-ramp.
TM001H	TM001H		The Ramp Meter controller firmware shall control equipment consisting of standard transportation management hardware equivalent to the Model 170 controller.
TM002H	TM002H		The Ramp Meter controller firmware shall be developed for the 68HC11 processor.

REQ ID	Component	Element	Requirement Text
TM003H	TM003H		The Ramp Meter controller firmware shall support Model 170 controller keypad, LED display, indicators, communications input and output functionality
TM001C	TM001C		The Ramp Meter controller shall provide standardized communications similar to standard traffic controllers.
TM002C	TM002C		The Ramp Meter controller shall accept configurable input from detectors on the roadway.
TM001O	TM001O		The Ramp Meter controller shall allow use of a common access keypad for manual access to firmware parameters and controller operation.
TM002O	TM002O		The Ramp Meter controller shall accept pre-defined configurable firmware parameters.
TM002O1	TM002O	TM002O1	Firmware parameters shall be utilized for data collection and ramp metering algorithms.
TM003O	TM003O		The Ramp Meter controller shall allow firmware parameters to be downloaded from a central system or manually input from the keypad.
TM004O	TM004O		The Ramp Meter controller front panel shall provide controller metering and data collection status.
TM005O	TM005O		The Ramp Meter controller shall provide a manually configurable Clock and calendar function.
TM001L	TM001L		The Ramp Meter controller shall provide Surveillance functions.
TM001L1	TM001L	TM001L1	The Ramp Meter controller shall provide data collection surveillance services in a local mode.
TM002L	TM002L		The Ramp Meter controller shall meter traffic flow.
TM002L1	TM002L	TM002L1	The Ramp Meter controller shall meter a configurable number of lanes not to exceed three lanes.
TM002L2	TM002L	TM002L2	The Ramp Meter controller shall operate in a local or central command mode.
TM002L3	TM002L	TM002L3	The Ramp Meter controller local mode shall operate based on local traffic conditions and firmware parameters.

REQ ID	Component	Element	Requirement Text
TM002L4	TM002L	TM002L4	The Ramp Meter controller central command mode shall operate based on algorithms defined by the central system.
TM003L	TM003L		The Ramp Meter controller metering algorithms shall be defined for local mode.
TM004L	TM004L		The Ramp Meter controller shall allow configurable metering rates while in a central mode.
TM005L	TM005L		The Ramp Meter controller shall allow for manual starting, stopping and modifying the metering from central command.
TM006L	TM006L		The Ramp Meter controller shall meter in local mode when active and disconnected from central command.

3.4. Operational Test Cases

Table 3-2 shows the operational test cases that will be used to verify that the requirements are met. Each test case represents an area of functionality that must exist in order to meet one or more requirements. The table below indicates how the test cases are mapped to the requirements. In the next section the testing strategy required to verify each test case will be defined. Each test case will require one or more test steps to verify the required functionality.

Table 3-2 Operational Test Cases

REQ ID	Requirement Text	Verify by Inspection	OP-1: Detector Input Config	OP-2: Access Config Data from Front Panel	OP-3: Basic Ramp Metering Operation (local)	OP-4: Data Collection	OP-5: Parameter Download	OP-6: Set and Test clock	OP-7: Meter in Central Mode	OP-8: Local Traffic Responsive metering	OP-9: Verify switch to local mode on comm fail
TM021	The SunGuide system shall provide a ramp metering firmware for controlling traffic flow onto a roadway from an on-ramp.	X									
TM001H	The Ramp Meter controller firmware shall control equipment consisting of standard transportation management hardware equivalent to the Model 170 controller.	X									
TM002H	The Ramp Meter controller firmware shall be developed for the 68HC11 processor.	X									
TM003H	The Ramp Meter controller firmware shall support Model 170 controller keypad, LED display, indicators, communications input and output functionality	X									

REQ ID	Requirement Text	Verify by Inspection	OP-1: Detector Input Config	OP-2: Access Config Data from Front Panel	OP-3: Basic Ramp Metering Operation (local)	OP-4: Data Collection	OP-5: Parameter Download	OP-6: Set and Test clock	OP-7: Meter in Central Mode	OP-8: Local Traffic Responsive mode on metering comm fail	OP-9: Verify switch to local
TM001C	The Ramp Meter controller shall provide standardized communications similar to standard traffic controllers.	X									
TM002C	The Ramp Meter controller shall accept configurable input from detectors on the roadway.		X								
TM001O	The Ramp Meter controller shall allow use of a common access keypad for manual access to firmware parameters and controller operation.			X							
TM002O	The Ramp Meter controller shall accept pre-defined configurable firmware parameters.			X							
TM002O1	Firmware parameters shall be utilized for data collection and ramp metering algorithms.				X	X					

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REQ ID	Requirement Text	Verify by Inspection	OP-1: Detector Input Config	OP-2: Access Config Data from Front Panel	OP-3: Basic Ramp Metering Operation (local)	OP-4: Data Collection	OP-5: Parameter Download	OP-6: Set and Test clock	OP-7: Meter in Central Mode	OP-8: Local Traffic Responsive metering	OP-9: Verify switch to local mode on comm fail
TM003O	The Ramp Meter controller shall allow firmware parameters to be downloaded from a central system or manually input from the keypad.						X				
TM004O	The Ramp Meter controller front panel shall provide controller metering and data collection status.				X	X					
TM005O	The Ramp Meter controller shall provide a manually configurable Clock and calendar function.							X			
TM001L	The Ramp Meter controller shall provide Surveillance functions.					X					
TM001L1	The Ramp Meter controller shall provide data collection surveillance services in a local mode.					X					
TM002L	The Ramp Meter controller shall meter traffic flow.				X						

REQ ID	Requirement Text	Verify by Inspection	OP-1: Detector Input Config	OP-2: Access Config Data from Front Panel	OP-3: Basic Ramp Metering Operation (local)	OP-4: Data Collection	OP-5: Parameter Download	OP-6: Set and Test clock	OP-7: Meter in Central Mode	OP-8: Local Traffic Responsive metering on comm fail	OP-9: Verify switch to local mode on comm fail
TM002L1	The Ramp Meter controller shall meter a configurable number of lanes not to exceed three lanes.				X						
TM002L2	The Ramp Meter controller shall operate in a local or central command mode.				X				X		
TM002L3	The Ramp Meter controller local mode shall operate based on local traffic conditions and firmware parameters.				X					X	
TM002L4	The Ramp Meter controller central command mode shall operate based on algorithms defined by the central system.								X		
TM003L	The Ramp Meter controller metering algorithms shall be defined for local mode.										X

REQ ID	Requirement Text	Verify by Inspection	OP-1: Detector Input Config	OP-2: Access Config Data from Front Panel	OP-3: Basic Ramp Metering Operation (local)	OP-4: Data Collection	OP-5: Parameter Download	OP-6: Set and Test clock	OP-7: Meter in Central Mode	OP-8: Local Traffic Responsive metering	OP-9: Verify switch to local mode on comm fail
TM004L	The Ramp Meter controller shall allow configurable metering rates while in a central mode.								X		
TM005L	The Ramp Meter controller shall allow for manual starting, stopping and modifying the metering from central command.								X		
TM006L	The Ramp Meter controller shall meter in local mode when active and disconnected from central command.										X

4. Requirements Testing

The test strategies required to verify each operational test case are described below.

In general, all operational test cases require the following equipment:

- 170 controller
- RMC firmware
- 334 Ramp Metering cabinet
- 170 I/O tester
- Serial Port Server for connection to SunGuide
- An operational SunGuide system with Ramp Metering Subsystem installed and configured
- Test switches on demand, passage, and queue detector inputs for two lanes
- Detector simulator on at least one mainline detector input pair
- C20 wrap-around connector (needed for correct speed/length calculations)

4.1. OP-1: Detector Input Configuration

REQ ID	Component	Element	Requirement Text
TM002C	TM002C		The Ramp Meter controller shall accept configurable input from detectors on the roadway.

Test Strategy:

Demonstrate configuration of ramp and mainline detector inputs.

Preconditions:

1. Open the Ramp Meter Control screen, and press the "Send Firmware Parameters" button to ensure that all parameters have been downloaded.
2. Open the Firmware Parameters screen for the ramp meter, select the Loop Function Codes page, and make sure the loops are configured as follows:

Loop	Function
1	Mainline roadway metering station loop
2	Mainline roadway metering station loop
3-16	Loop not assigned
17	Ramp Demand Lane 1
18	Ramp Passage Lane 1
19	Ramp Queue loop Lane 1
20	Ramp Demand Lane 2
21	Ramp Passage Lane 2
22	Ramp Queue loop Lane 2

If any corrections are required, press the "Save and Send to Controller" button after all changes have been made.

3. In the Firmware Parameters screen, select the Speed Trap Table. Make sure that Speed Trap 1 is configured as follows:

Upstream Loop Number	1
Downstream Loop Number	2
Trap Length	17
Effective Loop Length	7

Test Steps:

Step	Result	
1. From the Base Display Mode, press C-1-0	Verify code displayed is 144	✓
2. Press the A key to verify the next setting	Verify code displayed is 144	✓
3. From the Base Display Mode, press C-2-0 and verify the loop function codes	Verify that the code displayed is 129	✓
4. Press the A key to step through successive entries	Verify that the codes displayed are as follows: 1: 145 2: 161 3: 130 4: 146 5: 162	✓
5. Return to the Base Mode and press C-3-8 (Speed Trap 1 upstream loop number)	Verify that the value displayed is 1	✓
6. Press the A key to move through successive parameters and verify the next three parameters.	Verify the values displayed are: 1: 2 2: 17 3: 7	✓

4.2. OP-2: Access Config Data from Front Panel

REQ ID	Component	Element	Requirement Text
TM001O	TM001O		The Ramp Meter controller shall allow use of a common access keypad for manual access to firmware parameters and controller operation.
TM002O	TM002O		The Ramp Meter controller shall accept pre-defined configurable firmware parameters.

Test Strategy:

Verify that front panel keypad can be used to view and modify configuration data.

Test Steps:

Step	Result	
1. From base display, enter C-6-D	Display should show the value of the Maximum Speed parameter = 100	/
2. Change the Maximum Speed parameter to 95 and press E	New value for configuration parameter is accepted	✓
3. Return to the Base Display, then press C-6-D again	Display should show 95	✓

4.3. OP-3: Basic Ramp Metering Operation (local)

REQ ID	Component	Element	Requirement Text
TM002O1	TM002O	TM002O1	Firmware parameters shall be utilized for data collection and ramp metering algorithms.
TM004O	TM004O		The Ramp Meter controller front panel shall provide controller metering and data collection status.
TM002L	TM002L		The Ramp Meter controller shall meter traffic flow.
TM002L1	TM002L	TM002L1	The Ramp Meter controller shall meter a configurable number of lanes not to exceed three lanes.
TM002L2	TM002L	TM002L2	The Ramp Meter controller shall operate in a local or central command mode.
TM002L3	TM002L	TM002L3	The Ramp Meter controller local mode shall operate based on local traffic conditions and firmware parameters.

Test Strategy:

Verify basic local ramp metering operation, including:
- Signal output sequencing;
- Demand and passage detector inputs;
- Queue detector inputs; and,
- Time of Day operation.

Preconditions:
1. Verify that the default Ramp Lane Data has been downloaded to the controller.
2. Make sure that the TOD table in the controller is set as follows (can be entered at keyboard with the keystrokes shown, or through the SunGuide GUI):

Entry	Parameters	Keystrokes
1	00:00, rate 0	9-0-1 0-0-0-0-0-0-0-E Then use numeric keys to toggle lights 1-7 on A: move to next entry

2	08:00, rate 7.0 *	0-8-0-0-4-6-E ** Toggle lights 1-7 on A
3	18:00, rate 8.0	1-8-0-0-5-0-E Toggle lights 1-7 on A
4	23:59, rate 0	2-3-5-9-0-0-E Toggle lights 1-7 on A

* Note that a rate of 7.0 is entered as "70" in SunGuide.

** Note that rates are entered in hex when entered from the keypad

Test Steps:

Step		Result	
1.	Configure meter as follows: • Set mode to Ramp Meter (C-6-4 = 1 • Set meter to one-lane operation (C-6-6 = 1) • Set control switch to TOD (C-6-8 = 1) • Return to the Base Display • If the time is not set, set the time (see OP-6)	• Controller goes through startup sequence • Phase display shows "1" • Interval display shows "A" • Call/Active lights 0,1 and 5 are on • Timing/data display shows a cycle timer • All lanes indicate red • "Metering on" indication turned on	
2.	Activate and release the demand detector on lane 1	• Ramp lane 1 indication turns green and stays green until next step. • Call/active light 1 goes off and 3 turns on while signal is green	
3.	Activate and hold the passage detector on lane 1	• Ramp lane 1 indication turns red • Call/active light 3 turns off and light 1 turns on.	
4.	Release the passage detector on lane 1	• No change	
5.	Set C-0-E to 1, and examine the Intermediate Metering Rate (E-7-6) and the Adjusted Metering Rate (E-7-8)	• Should both be 7.0	
6.	Activate the demand detector and then the passage detector on lane 1. Observe the cycle time the controller uses. (cycle time in seconds = 60/rate in vpm)	• Verify that the controller counts the correct cycle time for the rate of 7.0 (8.5 seconds)	

Step		Result	
7.	Activate a queue detector on lane 1 and wait at least 2 minutes. Then examine the Queue Adjusted Metering Rate	• The interval display should change to B • Verify that the Adjusted Metering Rate (E-7-8) has increased by the first queue adjustment value (F-1-2-1) (2.0), resulting in a rate of 9.0	✗
8.	Release the queue detector and wait for the meter to leave queue adjust mode (at least two minutes)	• The interval display should change back to A	✓
9.	Configure meter for two-lane operation (C-6-6).	• Both lanes should show red	✓
10.	Activate and release the demand detector on lane 1	• Ramp lane 1 indication turns green (and stays green until next step) • Call/active light 1 goes off and 3 turns on while signal is green	✓
11.	Activate and release the passage detector on lane 1	• Ramp lane 1 indication turns red • Call/active light 3 turns off and light 1 turns on.	✓
12.	Press the "2" key to display lane 2 on the front panel	• Phase display shows "2" • Interval display shows "A"	✓
13.	Activate and release the demand detector on lane 2	• Ramp lane 2 indication turns green (and stays green until next step) • Call/active light 1 goes off and 3 turns on while signal is green	✓
14.	Activate and hold the passage detector on lane 2	• Ramp lane 2 indication turns red • Call/active light 3 turns off and light 1 turns on.	✓
15.	Release the passage detector on lane w	• No change	✓
16.	Activate the demand detectors on lanes 1 and 2 at the same time and hold for at least 2 seconds	• One lane should turn green immediately; the other lane should wait ½ second before turning green.	✓
17.	Activate the demand detector on lane 1 twice without activating the passage detector	• The "detector fail" LED on the front panel should come on, and the passage detector will be treated as failed	✓

Step		Result	
18.	Turn the lane 1 demand detector on and leave it on	• Lane one should go green for 1.5 seconds every cycle (because the passage detector is failed)	/
19.	Release the Lane 1 Demand detector, then activate and release the passage detector on lane 1	• Detector Fail LED should go off. Lane should stop cycling and stay in red.	✓

4.4. OP-4: Data Collection

REQ ID	Component	Element	Requirement Text
TM002O1	TM002O	TM002O1	Firmware parameters shall be utilized for data collection and ramp metering algorithms.
TM004O	TM004O		The Ramp Meter controller front panel shall provide controller metering and data collection status.
TM001L	TM001L		The Ramp Meter controller shall provide Surveillance functions.
TM001L1	TM001L	TM001L1	The Ramp Meter controller shall provide data collection surveillance services in a local mode.

Test Strategy:

Verify volume, occupancy, and speed data collected by mainline detectors.

Preconditions
1. Verify that Speed Trap 1 is configured as follows:
   • Upstream detector number = 1
   • Downstream detector number =2
   • Loop length = 7
   • Loop spacing =17
2. Set the detector simulator as follows:
   • Vehicle Length =18
   • Vehicle Speed = 47
   • VPH = 1800
   • Loop Length = 7
   • Loop Spacing = 17
3. Make sure SunGuide is set up to upload detector data (See Appendix A).

Test Steps:

Step		Result	
1.	Connect a detector simulator to C1 pins 39 and 40, and generate inputs with parameters listed above.	Wait two minutes, then verify the following values in page E/118 (set C-0-E to 118): • E-7-B (speed high) = 129 [1] • E-7-C (speed low) = 214 [1] • E-7-D (length) = 180 • E-1-6 (volume) = 80 [2] • E-1-7 (occupancy) = 218 [3] Note: Errors of up to 5% are acceptable for these values.	✓
2.	Display the TSS data uploaded from this controller in SunGuide	• Wait until an "RmsRMC" message is logged in the StatusLogViewer. • Verify that the message contains: <Zone:1 V:10 S:47 O:20	✓

[1] Speed is calculated as $(((\text{low two bits of E-7-B}) * 256) + (\text{E-7-C})) / 10$

[2] Volume starts in bit 4 of this memory location, so divide the value in E-1-6 by 8 to get the actual 20-second volume.

[3] Occupancy is reported in terms of 60 Hz scans per 20 seconds, so divide this value by 1200 to get the occupancy in percent.

4.5. OP-5: Parameter Download

REQ ID	Component	Element	Requirement Text
TM003O	TM003O		The Ramp Meter controller shall allow firmware parameters to be downloaded from a central system or manually input from the keypad.

Test Strategy:

Verify that configuration parameters can be downloaded from the central system.

Test Steps:

Step		Result	
1.	Examine parameter at F/1-1-1	Value should be 15.0	✓
2.	On the Ramp Lane Parameters screen, examine the "Meter Rate associated with the first mainline occupancy level" entry for Lane 1.	Value should be 150	✓
3.	Change the value of the parameter to 151 and press "Save and Send to Controller"	Parameter at F/1-1-1 should change to 15.1	✓

4.6. OP-6: Set and Test Clock

REQ ID	Component	Element	Requirement Text
TM005O	TM005O		The Ramp Meter controller shall provide a manually configurable Clock and calendar function.

Test Strategy:

Verify local clock operation, including:
- Set clock manually (from front panel keypad); and,
- Set clock from central.

Test Steps:

Step		Result	
1.	Set the clock to something other than the correct time. 　To set the time to 7:05:00 AM Thursday, enter the following from the base display: 8-0 (clock display comes up) 0-7-0-5-0-5-E Then enter B to return to the base display and 8-0 to return to the clock display	Clock is displayed running with the incorrect time.	✓
2.	From the Ramp Meter Control screen, set the ramp meter offline and then back online.	Clock changes to correct time.	✓

4.7. OP-7: Meter in Central Mode

REQ ID	Component	Element	Requirement Text
TM002L2	TM002L	TM002L2	The Ramp Meter controller shall operate in a local or central command mode.
TM002L4	TM002L	TM002L4	The Ramp Meter controller central command mode shall operate based on algorithms defined by the central system.
TM004L	TM004L		The Ramp Meter controller shall allow configurable metering rates while in a central mode.
TM005L	TM005L		The Ramp Meter controller shall allow for manual starting, stopping and modifying the metering from central command.

Test Strategy:

1. Demonstrate central mode ramp metering operation.
2. Demonstrate manual control of operation from central.

Preconditions:

1. Make sure SunGuide is configured to run Fuzzy Ramp Metering (See Appendix A).

Test Steps:

Step		Result	
1.	In Ramp Meter global parameters, set meter control switch to central operation	Ramp meter changes to central/fuzzy mode	X
2.	On RMC control screen, set meter mode to fuzzy	Lanes change to a different rate between 4 and 20.	
3.	Enter a 5 in each of the rate fields in the "set rate" dialog and set.	Ramp meter lanes change to a rate of 5.00.	✓

[handwritten margin note: Ar did not work since subsystem was not ready correctly]

4.8. OP-8: Local Traffic Responsive metering

REQ ID	Component	Element	Requirement Text
TM002L3	TM002L	TM002L3	The Ramp Meter controller local mode shall operate based on local traffic conditions and firmware parameters.
TM003L	TM003L		The Ramp Meter controller metering algorithms shall be defined for local mode.

Test Strategy:

Demonstrate local traffic responsive metering (changing metering rate based on local mainline detector data).

Preconditions:

Verify that Ramp Lane Data matches screenshots in Appendix B.

Set Detector Simulator as follows:
- Vehicle Length =18
- Vehicle Speed = 47
- VPH = 1800
- Loop Length = 7
- Loop Spacing = 17

This results in an occupancy of 18.2%

Test Steps:

Step		Result	
1.	Set control mode to Local on RMC control screen	Meter status reports local mode	✓
2.	Enable detector simulator at above parameters.	Wait for two minutes. Set C-0-E to 1. Verify that TMR (E-7-3) equals 10.5 (some jitter is acceptable)	✓
3.	Check Intermediate Metering Rate (IMR) ↳ *change* TOD *to* 15.0	Examine IMR (E-7-6) and verify that it is the same as the TMR	✓
4.	Activate Demand and Passage detectors on lane one and examine the cycle time being used	Cycle time should be 60/IMR	✓
5.	Change detector simulator to 54 mph to create an occupancy of 15.8	Wait two minutes. Verify that TMR (E-7-3) is between 13.5 and 15.	✓

96
265°

4.9. OP-9: Verify switch to local mode on comm fail

REQ ID	Component	Element	Requirement Text
TM006L	TM006L		The Ramp Meter controller shall meter in local mode when active and disconnected from central command.

Test Strategy:

Verify that controller switches to local mode operation when communication with central is disconnected.

Preconditions:
- Ramp meter should be under Central control.
- Ramp metering status is not set to Off.

Test Steps:

Step		Result	
1.	Disconnect the communications link and wait 60 seconds	• Call/Active light 6 (telemetry) should go off • Call/Active light 4 (local mode) should go on.	✓
2.	Activate the demand detector on lane 1	• Ramp lane 1 indication turns green (and stays green until next step) • Call/active light 1 goes off and 3 turns on while signal is green	✓
3.	Activate the passage detector on lane 1	• Ramp lane 1 indication turns red • Call/active light 3 turns off and light 1 turns on.	✓

5. Field Test Recommendations

After the FAT and IV&V testing are complete, the firmware will be field tested onsite. Field testing should be performed at a single ramp until satisfactory operation is established. Once the transportation management center (TMC) staff is comfortable with the reliability of the firmware, it can then be deployed to the remainder of the ramps.

The basic test strategy for the field test will be as follows:

During a period of light traffic on the target ramp:
- Pre-configure a 170 controller at the TMC and:
  o Verify basic operation with an I/O tester;
  o Verify communications with SunGuide
  o Verify correct configuration of SunGuide RM Subsystem
- Install 170 controller in cabinet onsite;
- Verify communications with central with metering disabled;
- Verify basic local ramp metering operation, with metering set at a fairly high rate so that queuing is not an issue;
- Let ramp meter operate for at least 30 minutes with staff observing onsite;
- Adjust local timing parameters as required (some parameters may have to be adjusted uniquely for each ramp);
- Once basic ramp operation is established, TMC staff can switch the ramp meter to central (Fuzzy) control, while onsite staff is still there to observe; and,
- Observe ramp operation under central control for at least 30 minutes.

Once basic operation under local and central control is established, additional tests can be performed:
- Observe ramp meter operation during a period when traffic is heavy enough to cause a queue to occur. Test the queue override functions;
- Operate the ramp meter in local and central traffic responsive modes. Adjust parameters as necessary;
- In local traffic responsive mode, it should be possible to observer the metering rate decrease as mainline traffic occupancy increases; and,
- In Central traffic responsive mode, it should be possible to observer the metering rate decrease as occupancy at the Upstream and Downstream detector sites increases.

Other suggestions:
- These tests should be spread out over a period of days, not run all at once; and,
- If a camera is available that can see the ramp meter, then testing can be done remotely once basic operation is established with onsite observation. Note that the camera should have a view of the queuing area in addition to the ramp meter itself.

Appendix A - SunGuide Configuration

The following instructions show how to configure the lanes and detectors in the Ramp Metering subsystem to enable fuzzy operation.

1.   Select TSS | Detectors from menu list.
2.   Click Add.
3.   Enter Detector Name.
4.   Use WSDOT Driver for Driver Name.
5.   Protocol N/A.
6.   Enter Port Server IP and Port Number of Ramp Meter Controller.
7.   Enter Ramp Meter Controller Drop Address in Address field.
8.   Record Detector Name for Use in subsequent steps. Ramp Meter Controller Name must match Detector Name

1. Select TSS | Detector Maps from menu list.
2. Select Detector created earlier.
3. Click Map button.
4. Click Add Link button.
5. Add descriptive text to end of link name that is automatically generated (for example ML for Mainline) – or create an arbitrary name.
6. Enter Speed Limit.
7. Click OK.
8. Repeat steps 1-4 for Ramp Queue (RQ), and Advance Queue (AQ).
9. Select Mainline Link in "Links" list.
10. Click Add Lane.
11. Use existing name in Lane Name field.
12. Enter Zone Number. This is the corresponding detector number from the Ramp Meter Controller.
13. Enter arbitrary description for zone.
14. Click OK.
15. Repeat steps 6-11 for Ramp Queue (RQ), and Advance Queue (AQ).
16. Click Save and Exit.

1. Select RMS | RMC Controllers from menu list.
2. Click Add.
3. Enter Controller Name that Matches Detector Name
4. Select "Bitran-170" Driver
5. Type "Bitran-170" in Protocol field.
6. Select Address Type "Port Server"
7. Enter all remaining fields to match corresponding detector.
8. Enter "8" in the Data Bits field.
9. Enter appropriate information for Mile Post location and Cross Street.
10. Select Correct Number of Metering Lanes for Ramp Meter (number of lanes on ramp).
11. Click Save and Exit.
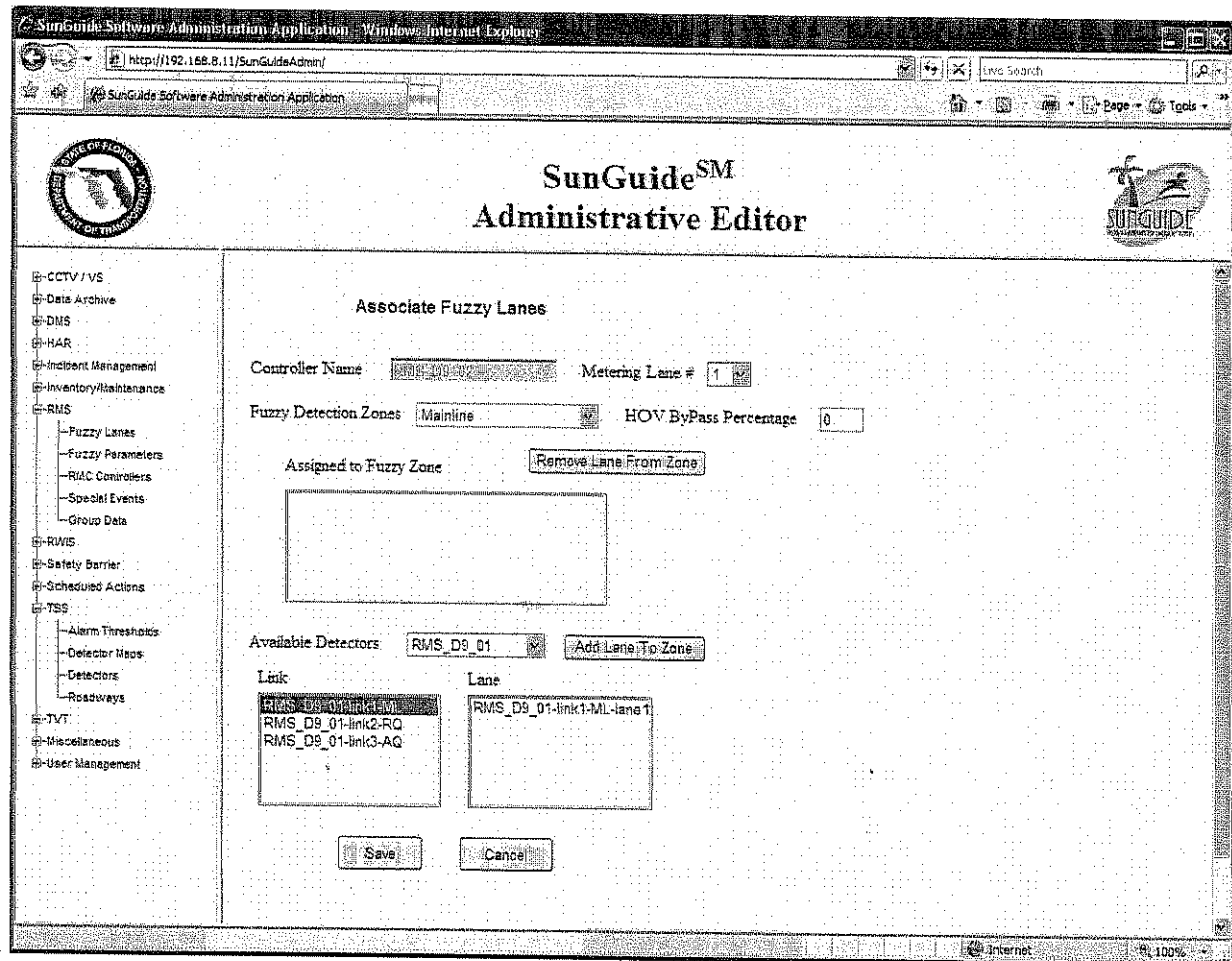
1.   Select RMS | Fuzzy Lanes Controllers from menu list.
2.   Select Controller created earlier.
3.   Click Configure
4.   Select Detector shown in Assigned to Fuzzy Zone list.
5.   Click Remove Lane From Zone.
6.   Verify that Mainline is selected in "Fuzzy Detection Zones" pull-down.
7.   Select Detector created earlier in "Available Detectors" list.
8.   Select ML link in "Link" list.
9.   Click on Lane displayed in "Lane" list.
10.   Click "Add Lane to Zone".
11.   Select "Ramp Queue" in "Fuzzy Detection Zones" pull-down.
12.   Highlight RQ link in "Link" list.
13.   Highlight the Lane displayed in the "Lane" list.
14.   Click "Add Lane To Zone"
15.   Select "Advance Queue" in "Fuzzy Detection Zones" pull-down.
16.   Highlight AQ link in "Link" list.
17.   Highlight the Lane displayed in the "Lane" list.
18.   Click "Add Lane To Zone"
19.   Select "DownStream" in "Fuzzy Detection Zones" pull-down.

20. Select appropriate downstream detector (cannot be ramp meter detectors) in the "Available Detectors" pull-down list.
21. Highlight the appropriate Link in "Link" list.
22. Highlight the appropriate Lane displayed in the "Lane" list.
23. Click "Add Lane To Zone"
24. Select "UpStream" in "Fuzzy Detection Zones" pull-down.
25. Repeat Steps 20-23 with appropriate selections.
26. Click Save

Note: For actual deployment of system, the administrator may need to enter multiple links and/or lanes to each Fuzzy Zone. An HOV Bypass Percentage may also be entered if HOV lanes are present.

Appendix B - Ramp Meter Database

The following screenshots show the ramp meter configuration settings used for this test.

	Lane 1	Lane 2	Lane 3
Percentage of MeterRateAdj for lane (if 0 = no split)	100	100	0
Meter rate associated with the first mainline occupancy level	150	150	0
Meter rate associated with the second mainline occupancy level	120	120	0
Meter rate associated with the third mainline occupancy level	90	90	0
Meter rate associated with the fourth mainline occupancy level	70	70	0
Meter rate associated with the fifth mainline occupancy level	50	50	0
First mainline occupancy level in local algorithm	15	15	0
Second mainline occupancy level in local algorithm	17	17	0
Third mainline occupancy level in local algorithm	19	19	0
Fourth mainline occupancy level in local algorithm	21	21	0
Highest mainline occupancy level in local algorithm	23	23	0
Maximum allowable meter rate	200	200	0
Minimum allowable meter rate	40	40	0
Occupancy threshold to start queue adjustment	30	30	0
Occupancy threshold to end queue adjustment	25	25	0
Time queue occupancy > QTOCC1 before adding V1 (min)	10	10	0
Time queue occupancy > QTOCC1 before adding V2 (min)	30	30	0
Queue adjustment meter rate increment for T2	20	20	0
Queue adjustment meter rate increment for T3	40	40	0
Advance queue occupancy threshold for override	25	25	0
Advance queue occupancy timer (sec)	60	60	0
Advance queue override (vpm)	80	80	0
Long stop passage occupancy time to trigger green (sec)	20	20	0
Violator delay added to red timer (sec)	0	0	0
Normal yellow duration at ramp (sec)	0	0	0
HOV delay added to red timer (sec)	0	0	0
Short stop queue occupancy to trigger green	15	15	0
Start of metering queue headway gap length (sec)	30	30	0

First window: Time Of Day Table

Title bar: Ramp Meter Controller Firmware Params – Windows Internet Explorer

Address: http://192.168.8.11/OperatorMapAX/Data/RM/dialogs/firmware.html?windowid=rm-rms-firmware

Ramp Meters — Find on Map
RMS-D9-T1

Filter
All Rmcs

	Hour	Minute	InUse	Sun	Mon	Tue	Wed	Thu	Fri	Sat	MeteringRate
Entry 1	0	0	☑	☑	☑	☑	☑	☑	☑	☑	0
Entry 2	8	0	☑	☑	☑	☑	☑	☑	☑	☑	70
Entry 3	18	0	☑	☑	☑	☑	☑	☑	☑	☑	80
Entry 4	23	59	☑	☑	☑	☑	☑	☑	☑	☑	0
Entry 5	0	0	☐	☑	☑	☑	☑	☑	☑	☑	0
Entry 6	0	0	☐	☑	☑	☑	☑	☑	☑	☑	0
Entry 7	0	0	☐	☑	☑	☑	☑	☑	☑	☑	0
Entry 8	0	0	☐	☑	☑	☑	☑	☑	☑	☑	0
Entry 9	0	0	☐	☑	☑	☑	☑	☑	☑	☑	0
Entry 10	0	0	☐	☑	☑	☑	☑	☑	☑	☑	0

Time Of Day Table | Save Parameters | Save and Send To Controller

Done — Internet — 100%

Second window: Loop Function Codes

Title bar: Ramp Meter Controller Firmware Params – Windows Internet Explorer

Address: http://192.168.8.11/OperatorMapAX/Data/RM/dialogs/firmware.html?windowid=rm-rms-firmware

Ramp Meters — Find on Map
RMS-D9-T1

Filter
All Rmcs

Loop 1	Mainline roadway metering station loop
Loop 2	Mainline roadway metering station loop
Loop 3	Loop not assigned
Loop 4	Loop not assigned
Loop 5	Loop not assigned
Loop 6	Loop not assigned
Loop 7	Loop not assigned
Loop 8	Loop not assigned
Loop 9	Loop not assigned
Loop 10	Loop not assigned
Loop 11	Loop not assigned
Loop 12	Loop not assigned
Loop 13	Loop not assigned
Loop 14	Loop not assigned
Loop 15	Loop not assigned
Loop 16	Loop not assigned
Loop 17	Ramp Demand Lane 1
Loop 18	Ramp Passage Lane 1
Loop 19	Ramp Queue loop Lane 1
Loop 20	Ramp Demand Lane 2
Loop 21	Ramp Passage Lane 2
Loop 22	Ramp Queue Lane 2
Loop 23	Loop not assigned
Loop 24	Loop not assigned
Loop 25	Loop not assigned
Loop 26	Loop not assigned

Loop Function Codes | Save Parameters | Save and Send To Controller

Done — Internet — 100%

30

Appendix C – Ramp Meter Modes of Operation

For reference, the following table shows the ramp meter's various modes of operation:

Modes of Operation

Control Switch	Metering Status		
	Local	**Fuzzy**	**Offline**
Central	• Central LED on • MR = Min (TMR, BOTMR)	• Central LED on • MR = Fuzzy Rate	• Local LED on • MR = Min(TMR, TOD)
TOD	• Local LED on • MR = Min(TMR, TOD)	• N/A. Meter ignores fuzzy command in TOD mode.	

- Local Mode is also called Standby mode in the WSDOT documentation.
- Central mode is also called Remote mode in the WSDOT documentation.
- MR = Metering Rate
- TMR = Traffic Metering Rate (determined by local mainline detector occupancy).
- TOD = Time of Day Rate (from TOD schedule).
- Fuzzy Rate = rate determined by fuzzy logic algorithm in SunGuide RM service.
- BOTMR = Bottleneck metering rate. Not used in SunGuide (or WSDOT).
- Control Switch (Central/TOD) is in Ramp Meter Local Parameters, Global Data page.
- Metering Status Control (Local/Fuzzy) is on the RM Control Screen in SunGuide.

Florida Department of Transportation
Ramp Metering Firmware
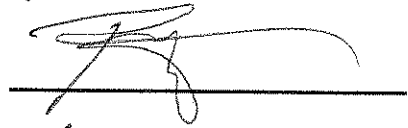# Independent Verification and Validation Test

Date: June 14, 2007
Time: 9 AM to 12 Noon
Location: Traffic Engineering Research Lab, Tallahassee
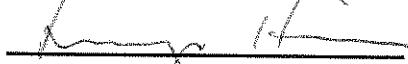

Test Conducted by: Walt Townsend _____

                     Ron Meyer   _____
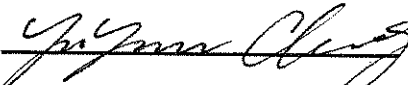
Test Witnessed by: Rory Santana   _____

                     Liang Hsia   _____

Test Observed by: Trey Tillander _____

                     Les Jacobson   _____

                     David Chang   _____

                     Alejandro S. Canosa _____