CALIFORNIA DEPARTMENT OF TRANSPORTATION

ASWSC Phase III – D2 Testing and Deployment (Part 5 of 6 of collaborative presentation)

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Doug Galarus, Montana Tech

Acronyms

- CMS=Changeable Message Sign
- D2=Caltrans District 2
- ESS=Environmental Sensor Station
- RWIS=Roadway Weather Information System
- RPU=Remote Processing Unit (Weather Station Motherboard)
- SOCCS=Satellite Operations Center Command System

Reference Material

- Campbell RWIS Update (westernstatesforum.org) – 2016 WSF – Jeff Worthington
- Comparison of In-Pavement Versus Out-Of-Pavement Sensor Technologies (westernstatesforum.org) – 2016 WSF – Mike Beyer

ASWSC – Testing in D2 Lab

- District 2 Office located in Redding, CA.
- We share a dedicated EE lab for both the ITS Group and the Signals Group. (Separate from our office area).
- Multiple pieces of test equipment.
  - Simulations of most hardware in the field.
  - Analysis tools, fiber testing, etc…

TURNBULL LABS:

Accurate

Timely

Reliable

ASWSC – D2 Lab Equipment

CMS Sign Controllers:

Two model 170E.

Two model 2070E.

ASWSC – D2 Lab Equipment

We actually have an entire ITS Node (Roadside LAN)

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ASWSC – D2 Lab Equipment

ATC 2070LX Controller – ASWSC Platform

ASWSC – D2 Lab Equipment

RWIS station or simply ESS

ASWSC – D2 Lab Equipment

The Lab Notebook

ASWSC – D2 Lab Equipment

ASWSC – Testing in D2 Lab

- There is a regular test script routine I follow for each *release candidate* package Doug's team would provide.

  - LCD Panel Functionality
    - Sign tests (both 170 and 2070 CMS sign controllers)
    - RWIS Data
  - SOCCS HTML Functionality
    - Start/Stop controller
    - Sign testing, manual vs. automatic messages
    - User: Operator, User: Supervisor
  - Warning activations
    - Simulate weather conditions to trigger signs
  - Review log files
  - Simulate daylight savings time rollovers
  - Cold Boot, etc….

ASWSC – Testing in D2 Lab

- Due to time constraints I will just point out a couple of the more interesting experiences of testing in the lab;

  - Firmware updates on the ATC 2070 LX

  - How is weather simulated in the lab?

Firmware Updates on ATC 2070LX

- The Out-of-Box configuration requires a couple of updates to prep the hardware for ASWSC application installation.

Firmware Updates on ATC 2070LX

- The Out-of-Box configuration requires a couple of updates to prep the hardware for ASWSC application installation.
  - Update 1 Procedure
    - Insert USB stick into slot on back of controller
    - Autorun will execute the install script
    - LCD will show progress, prompting you when finished.
    - PROMPTLY remove the USB stick. (It may start process again.)

Firmware Updates on ATC 2070LX

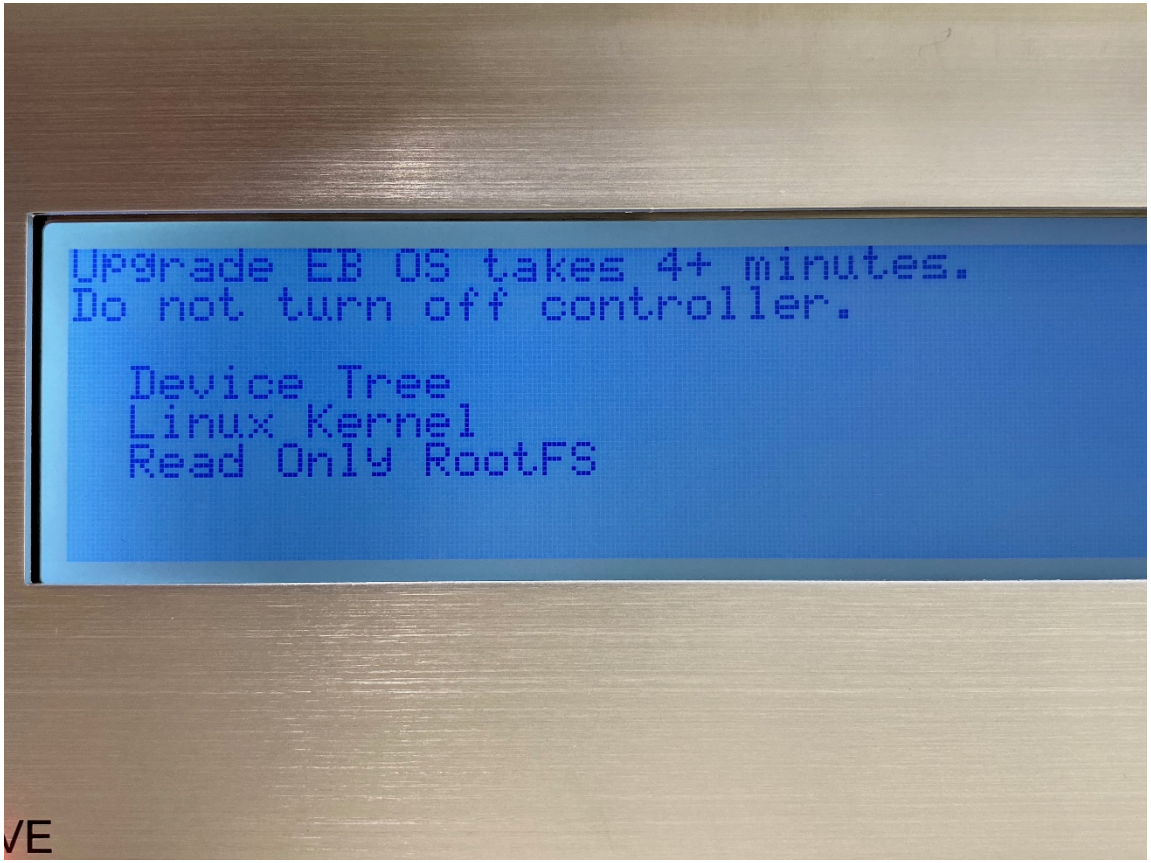

Photo of LCD panel of ATC2070LX controller during firmware update 1.

Firmware Updates on ATC 2070LX

- The Out-of-Box configuration requires a couple of updates to prep the hardware for ASWSC application installation.
  - Update 2 Procedure?
    - Insert USB stick into slot on back of controller
    - Autorun will execute the install script
    - LCD will show progress, prompting you when finished.
    - PROMPTLY remove the USB stick. (It may start process again.)

Firmware Updates on ATC 2070LX

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    - RESULT = I BRICKED THE CONTROLLER!

Firmware Updates on ATC 2070LX

- BRICKED = No Factory Reset Button

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- Made contact with Dan Brandesky at Econolite
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Firmware Updates on ATC 2070LX

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- Made contact with Dan Brandesky at Econolite
  - Provided me with an Econolite U-Boot OS Restoration Process. Just to get the idea….
    - Need TFTP Server Software
    - Need Network connection and Serial Connection
    - Identify Mac Address physically printed on CPU card
    - Enter Uboot
    - Erase a few memory locations
    - Copy a few binary files
    - Install new EBOS (Engine Board Operating System)

Firmware Updates on ATC 2070LX

Econolite ATC Engine Board Operating System Restoration Procedures

Version 1.0, 10/16/2019

Boot into U-Boot

- Connect a controller via serial console: 115200 baud, 8/N/1 parity
  - 2070 controllers will require a 2070 console cable, which consists of a standard RS232 null modem cable with an added jumper between pins 1 and 5 on the connector that connects to the C50S port
- Power off controller
- Hold **u** on the keyboard
- While continuing to hold **u** on the keyboard, power on the controller
- Within 3-10 seconds, the U-Boot prompt will display =>
- Release the **u** key

Clear the Controller Application Software

- Boot into U-boot
- Run the following commands:

```
protect off all
erase 0xfc080000 0xffffffff
```

Partial screenshot of restore procedure.

Firmware Updates on ATC 2070LX

Clear the Controller Application Software

- Boot into U-boot
- Run the following commands:

```
protect off all
erase 0xfc080000 0xffffffff
```

Install Engine Board Operating System (EBOS)

Deploy Desired Files via TFTP Server

- Obtain the desired EBOS
- Start a tftp server instance with the extracted EBOS package in its working directory

Load and Apply Files from TFTP server

- Boot controller into the U-Boot shell
- Run the following commands. ***Make sure you substitute relevant values for your configuration!***
    - ***Substitute the MAC addresses shown on the engine board for the "xx" values below***; the first MAC address shown on the engine board label should be used for eth1addr, the second for ethaddr.
    - ***gatewayip, ipaddr, netmask, and serverip should all be substituted for values relevant to your configuration.*** For ideal results, connect the controller directly to the computer

Partial screenshot of restore procedure, continued…

Firmware Updates on ATC 2070LX

- Revisiting the two Firmware updates…
  - Update 2 Correct Procedure (Different than Update 1)
    - Start a console session with putty on your laptop.
    - Insert USB stick into USB slot.
    - Autorun will execute the install script.
    - Firmware status is displayed on the *console session* through putty. (LCD panel will do nothing.)
    - PROMPTLY remove the USB stick when finished.

Firmware Updates on ATC 2070LX

EconoliteATC login: Found factory upgrade script, executing...

dtb

uImage

rootfs

optfs

Done.

Actual Putty Console session result of correct Update 2 Firmware process.

Firmware Updates on ATC 2070LX

- What did I learn?
  - Read directions. (Doug's team did provide a note about this. I suggested it be emphasized higher.)
  - Perhaps the ATC 2070LX team in Caltrans HQ could standardize this procedure?
  - How to recover from a bricked controller (There is no factory reset button.) But I was able to get some tech support advice from Dan Brandesky at McCain and salvaged the unit. (Shared with Doug's team and Caltrans HQ team.)

ASWSC – Testing in D2 Lab

- Weather simulation in the lab

Weather simulation in the lab

- Weather is interpreted by the ASWSC through standard variables in the NTCIP 1204 version 2.

A Joint Standard of AASHTO, ITE, and NEMA

NTCIP 1204 version v02

National Transportation
Communications for ITS Protocol

Object Definitions for
Environmental Sensor Station v02

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published in May 2008

A major revision of NTCIP 1204 v01

Weather simulation in the lab

- There are several hundred definitions of variables for ESS within this document. The ASWSC is interested in the following two variables for Icy Warning sign activation;
  - essSurfaceTemperature(i)
  - essSurfaceStatus(i)
  - Note that the ‘(i)’ refers to the variable as an array and represents capability for multiple sensors.

Weather simulation in the lab

5.11.3.8 Surface Temperature

```
essSurfaceTemperature OBJECT-TYPE
SYNTAX      INTEGER (-1000..1001)
ACCESS      read-only
STATUS      mandatory
DESCRIPTION "<Definition>The current pavement surface temperature in tenths
of degrees Celsius.
<SetConstraint>read-only
<DescriptiveName>PavementSensor.surfaceTemperature:quantity
<Valid Value Rule>
The value 1001 shall indicate an error condition or missing value.
<Data Concept Type>Data Element
<Unit>tenths of degrees Celsius"
::= { essPavementSensorEntry 8 }
```

- essSurfaceTemperature(1) = 35 would interpret as 3.5 degrees Celsius on surface sensor #1

Weather simulation in the lab

5.11.3.7 Surface Status

```
essSurfaceStatus OBJECT-TYPE
SYNTAX      INTEGER {   other (1),
                        error (2),
                        dry (3),
                        traceMoisture (4),
                        wet (5),
                        chemicallyWet (6),
                        iceWarning (7),
                        iceWatch (8),
                        snowWarning (9),
                        snowWatch (10),
                        absorption (11),
                        dew (12),
                        frost (13),
                        absorptionAtDewpoint (14)}
ACCESS      read-only
STATUS      mandatory
DESCRIPTION "<Definition>A value indicating the pavement surface status.
```

- essSurfaceStatus(2) = 4 would indicate ‘traceMoisture’ on surface sensor #2

Weather simulation in the lab

- So how do you simulate all of the various surface status situations in the lab?
  - Expensive environmental chamber? (We do have a small Thermotron device that holds a wide range of temperatures well.)
  - What is the ‘recipe’ for Snow Warning or Ice Watch? (anyone here on the NTCIP standards committee?)

Weather simulation in the lab

- So how do you simulate all of the various surface status situations in the lab?
  - Spoiler: We do not need to simulate the weather conditions, the sensors take care of reading the conditions. This has already been worked out.
  - We simply need to provide the various NTCIP possibilities from our Campbell Scientific CR1000 datalogger to the ASWSC in the lab.

Weather simulation in the lab

- So how do you simulate all of the various surface status situations in the lab?
  - Created a simple weather simulation module for our lab ESS whenever surface status is needed.
  - All tower instruments report normally, but because of the modular design of our code I could easily replace just the Surface Sensor module with the simulation and compile it into the main program.

Weather simulation in the lab

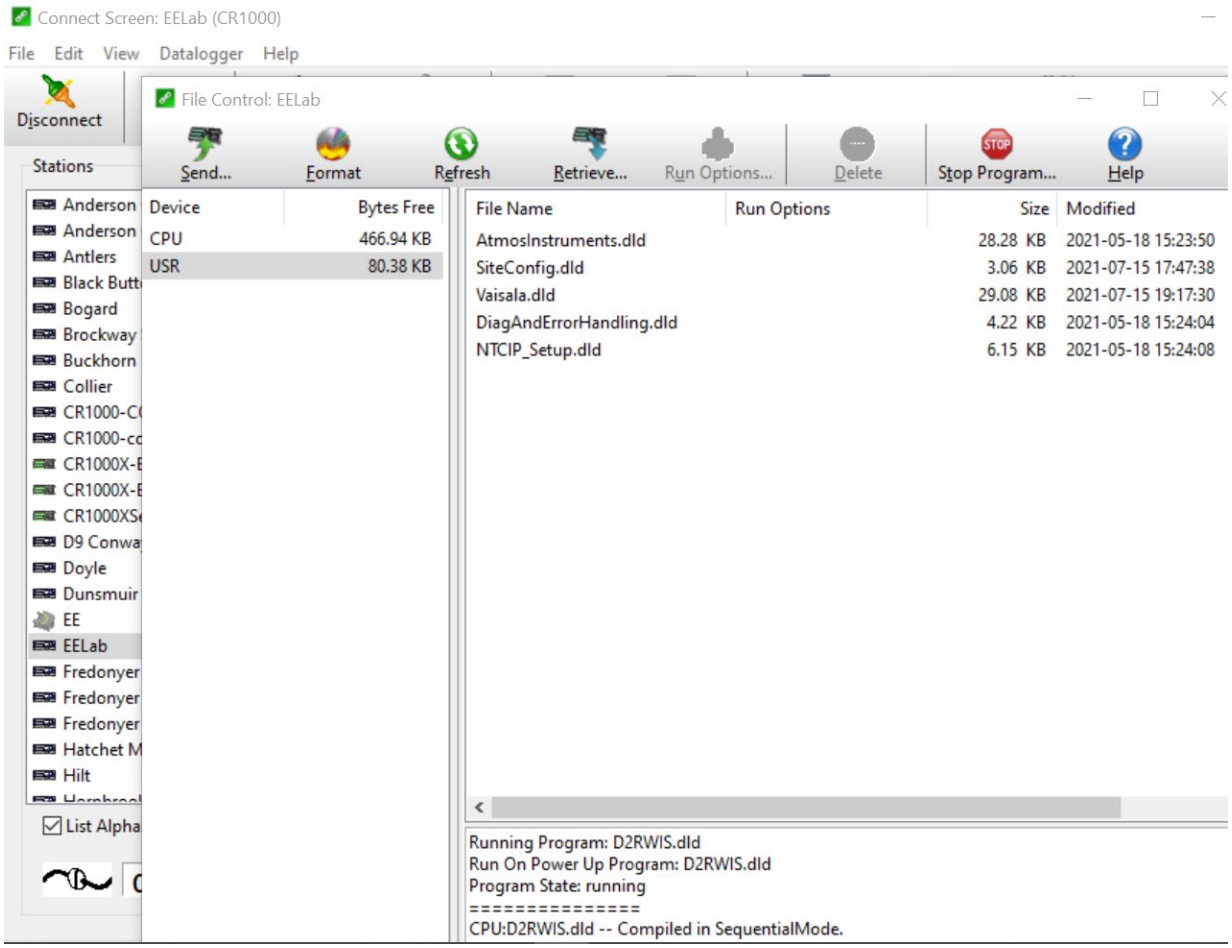

Figure: Screenshot of Loggernet Session with Lab ESS

Weather simulation in the lab

Zooming in on the USR directory of the datalogger, note the five modules of source code. The ‘Vaisala.dld’ module contains the simulated code for surface sensors. All others behave normally and report real instrument data, perform error checking, diagnostics, etc…

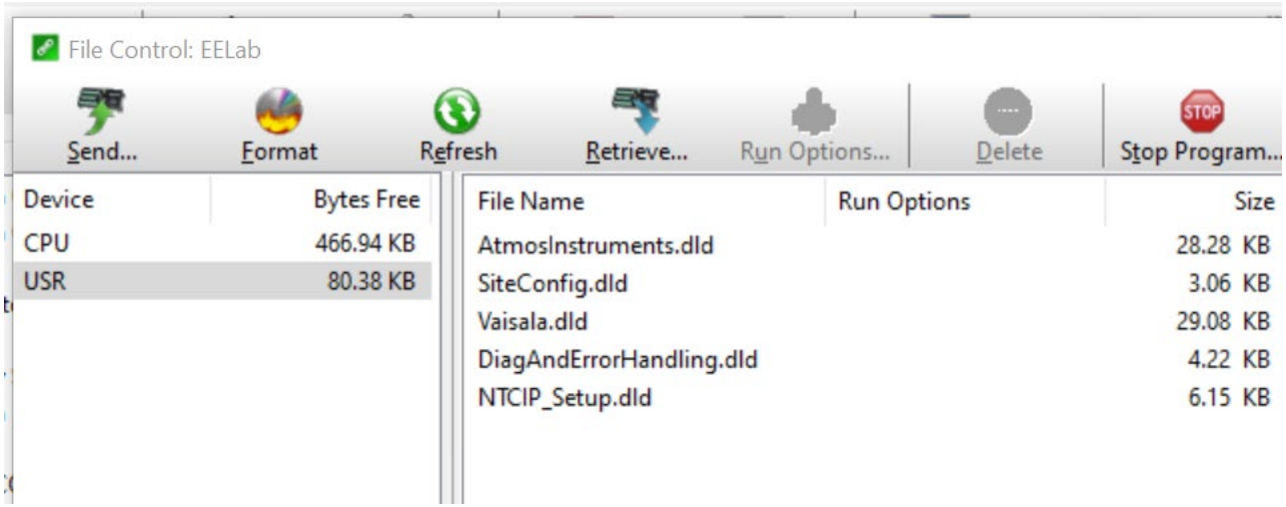

Figure: Screenshot of Loggernet Session with Lab ESS-Directory USR.

Weather simulation in the lab

Zooming in on the CPU directory of the datalogger, this is the main program that is compiled with all modules together and the continuous running program at site.

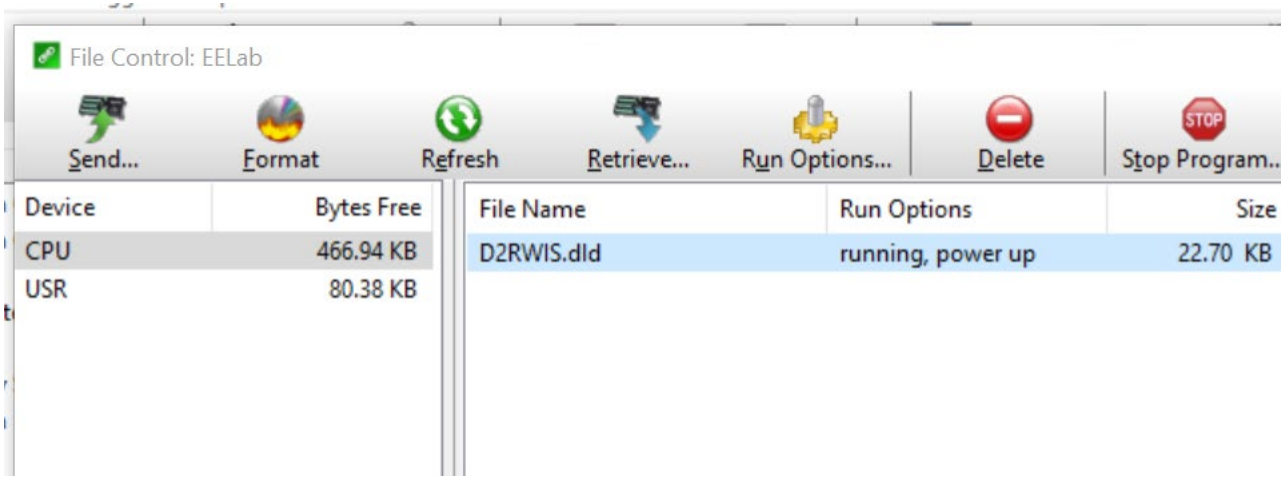

Figure: Screenshot of Loggernet Session with Lab ESS-Directory CPU.

Weather simulation in the lab

Including a few snippets of code on the following pages. Things to note;

- Our datalogger code design reads the tower instruments every 30 seconds, and the pavement sensors every two minutes.
- I created a test routine with a count up to 500, at which it will reset itself and start over. So 500 counts would represent 1000 minutes for a complete cycle of all test parameters I have set up. Not quite 17 hours.
- Easy to make adjustments to the test cycle, but this is a manageable amount of time to review in the ASWSC log history to watch for activations.

Weather simulation in the lab

```
'*************************************************************************
' Exerciser is on the same 2 minute cycle to 'read' the sensors. Of course,
' these values are fake.

Sub SetupSurface

If TestCount = 1
   essSurfaceStatus(1) = 3    ' Dry
   essSurfaceStatus(2) = 3    ' Dry
   essSurfaceTemperature(1) = 50    ' 5 degrees C.
   essSurfaceTemperature(2) = 50
EndIf

If TestCount = 10
   essSurfaceStatus(1) = 5    ' Wet
   essSurfaceTemperature(2) = 1 '   ' .1 degrees C.
EndIf

If TestCount = 16
   essSurfaceStatus(2) = 4    ' Moist
EndIf
```

Figure: Screenshot of CR Basic Icy Warning Simulation Exerciser code.

Weather simulation in the lab

```
If TestCount = 24
   essSurfaceStatus(1) = 13   ' Frost
EndIf

If TestCount = 30
   essSurfaceStatus(1) = 3    ' Dry
   essSurfaceStatus(2) = 3    ' Dry
EndIf

If TestCount = 42
   essSurfaceStatus(2) = 7    ' Ice Warning
EndIf

If TestCount = 48
   essSurfaceStatus(1) = 10   ' Snow Watch
   essSurfaceStatus(2) = 10   ' Snow Watch
EndIf

If TestCount = 52
   essSurfaceStatus(2) = 8    ' Ice Watch
EndIf
```

Figure: Screenshot of CR Basic Icy Warning Simulation Exerciser code.

Weather simulation in the lab

```
If TestCount = 76
   essSurfaceStatus(1) = 2    ' Error
EndIf

If TestCount = 77
   essSurfaceStatus(2) = 2    ' Error
EndIf

If TestCount = 80
   essSurfaceStatus(1) = 5    ' Wet
   essSurfaceStatus(2) = 5    ' Wet
   essSurfaceTemperature(1) = -11   ' -1.1 C
   essSurfaceTemperature(2) = -12
EndIf

If TestCount = 100
   essSurfaceStatus(1) = 8    ' Ice Watch
EndIf

If TestCount = 101
   essSurfaceStatus(1) = 3    ' Dry
   essSurfaceStatus(2) = 3    ' Dry
EndIf

If TestCount = 110
   essSurfaceTemperature(1) = 1001   'Surface Temperature error
EndIf
```

Figure: Screenshot of CR Basic Icy Warning Simulation Exerciser code.

Weather simulation in the lab

```
' Decrement this way each cycle
If TestCount > 400
   essSurfaceTemperature(1) = essSurfaceTemperature(1) - 1
EndIf

' Increment this way each cycle
If TestCount > 420
   essSurfaceTemperature(2) = essSurfaceTemperature(1) + 5
EndIf

If TestCount = 475
   essSurfaceStatus(1) = 4   ' Moist
   essSurfaceStatus(2) = 4   ' Moist
EndIf

   TestCount = TestCount + 1

   If TestCount > 500
      TestCount = 0
   EndIf
EndSub
```

Figure: Screenshot of CR Basic Icy Warning Simulation Exerciser code.

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ASWSC – D2 Deployment- Spring Garden, CA

Jeff Worthington – ITS Engineer

October 5th, 2021

ASWSC – Deployment At Site

- This would not be a good day to install a new system!

Previous Images Elevation 3813' Preset Information

Susanville Area
Spring Garden

Data Date/Time
February 15, 2019 7:22:57 am PST

Visibility

Distance
No Visibility Sensor

Air

Temp	Humidity	Dew Point
29.5 F	100 %	29.7 F

Wind

Direction	Speed	Gust
North 0°	0 mph	0 mph

Precipitation

Precip	Intensity	Accum in 24hrs	Rate
Yes	Slight	1.15 in	0.04 iph

Close

ASWSC – Deployment At Site

- Installed September 29, 2020
- Typical first winter storm in early November. Earliest recorded was Oct 20th.
- This year first activation was November 6th, 2020.

ASWSC – Deployment At Site

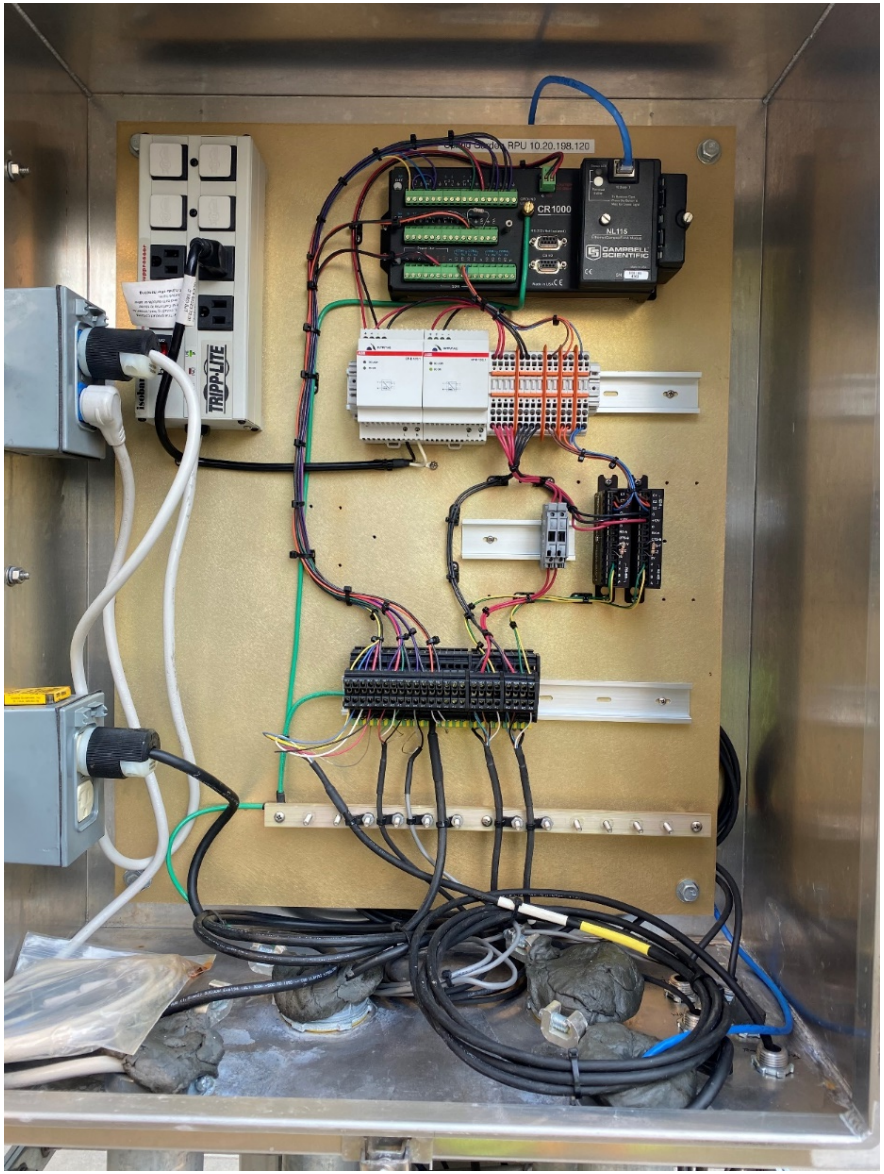
View of RWIS station in background.

ASWSC – Deployment At Site

Redundant pavement sensors on RWIS tower.

ASWSC – Deployment At Site

Performed a firmware upgrade and latest D2 RWIS code onto local CR1000 RPU.



ASWSC – Deployment At Site

Performed a sign test prior to leaving site.

ASWSC – Deployment At Site

Took a photo of LCD panel. Hard to see, but says “Controller OK, Start time: Sep 29, 2020 14:16”

ASWSC Deployment

- Also re-installed an ATC 2070LX back in the EElab with same ASWSC version as in the field. Same Date.
- Routine Monitoring Begins.

ASWSC Deployment

Continuous Monitoring of System all Winter

- Monitor Weather Forecasts (daily)
- Weathershare Tool (as needed)
- CCTV Images (as needed)
- Talk to local maintenance personnel (as needed)
- Talk to local Highway Patrol (as needed)
- HTML display of sign activation (from ASWSC)
- Logs from ASWSC (daily)
- Data from weather station, and ASWSC (real-time during a storm)

ASWSC – Deployment

Kudos to the ITS crew playing various roles in visiting the site during winter conditions. (see credits at end of presentation).

- Verifying calibration of pavement sensors
- CMS Sign Debug/repair
- Preventative Maintenance
- Checking Status through HTML interface

ASWSC Deployment

- Had 4 ½ months of solid performance.
- Multiple sign activations.
- Analysis with weather conditions seemed spot on.

ASWSC Deployment

- Had 4 ½ months of solid performance.
- Multiple sign activations.
- Analysis with weather conditions seemed spot on.
- *System Crash* on Wednesday, February 17th, 2021.

ASWSC Deployment

ASWSC System Crash (February 17th)

- Electrical Maintenance was performing routine Preventative Maintenance (PM) procedure.
- During PM procedure the power in cabinets is shut off. (…and powered back on.)
- The ASWSC ‘froze up’ and was unresponsive.
- I was on vacation.
- Multiple winter storms were on the way.

ASWSC Deployment

ASWSC System Crash (February 17th)

- Redundant system in lab was also powered off/on, same result. Unresponsive.
- Options were explored to manually activate the signs through the legacy SOCCS application.
- Arrangements were made with local maintenance to apply the backup procedure of manual signage should weather arrive.
- An ITS team was assembled to go to the site the next day for a fresh install.
- The team could not make it because of a snow storm.
- Ultimately it was a few days before the ASWSC could be restored.

ASWSC Deployment

ASWSC System Crash (February 17th) – What did we learn?

- Root cause of failure still undetermined.
- Difficult to simulate in lab due to length of time ASWSC needs to run prior to failure.
- Redundant system in lab proved helpful.

ASWSC Deployment

ASWSC System Crash (February 17th) – What did we learn?

- Consideration should be made to PM procedures at Ice Warning System locations.
- Communicate with ITS Group
- Plan accordingly with weather forecasts
- Plan accordingly with support personnel (vacation schedule, etc.)
- I have developed an ‘ASWSC quick deployment kit’, an SD card with a pre-install configuration. SD card can be swapped easily.

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ASWSC – Concluding Remarks

Jeff Worthington – ITS Engineer

October 5th, 2021

CALIFORNIA DEPARTMENT OF TRANSPORTATION

ASWSC – One More Thing!

Jeff Worthington – ITS Engineer

October 5th, 2021

One More Thing!

Do Icy Roads only happen in the winter?

One More Thing!

Do Icy Roads only happen in the winter?

- How about thunderstorms with hail?

One More Thing!

Do Icy Roads only happen in the winter?

- How about thunderstorms with hail?
- But could an Ice Warning System react quick enough to summer weather condition changes and accurately detect the situation in real-time?

One More Thing!

A Recent Case Study at Spring Garden

One More Thing!

A Recent Case Study at Spring Garden

- While reviewing the log files on the ASWSC, just a couple days prior to my final submission of this presentation in early September, 2021…
    - *I noticed what looked like a sign activation on August 12th, 2021.*

One More Thing!

A Recent Case Study at Spring Garden

- August 12th, 2021 at 4:36 pm the signs came on.
- Interesting to note that the “Dixie Fire” was active all around the Spring Garden location since July 13th, 2021.
- Large wild fires, such as the Dixie Fire, are known to exhibit “Extreme Fire Behavior” and can create their own weather systems, out of Pyrocumulonimbus cloud formations.

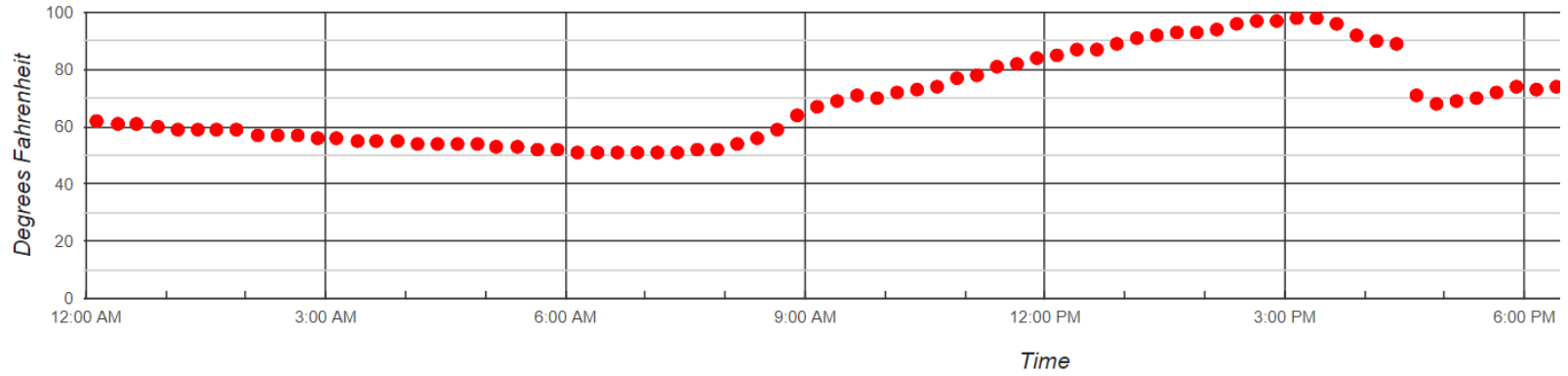
One More Thing!

A Recent Case Study at Spring Garden

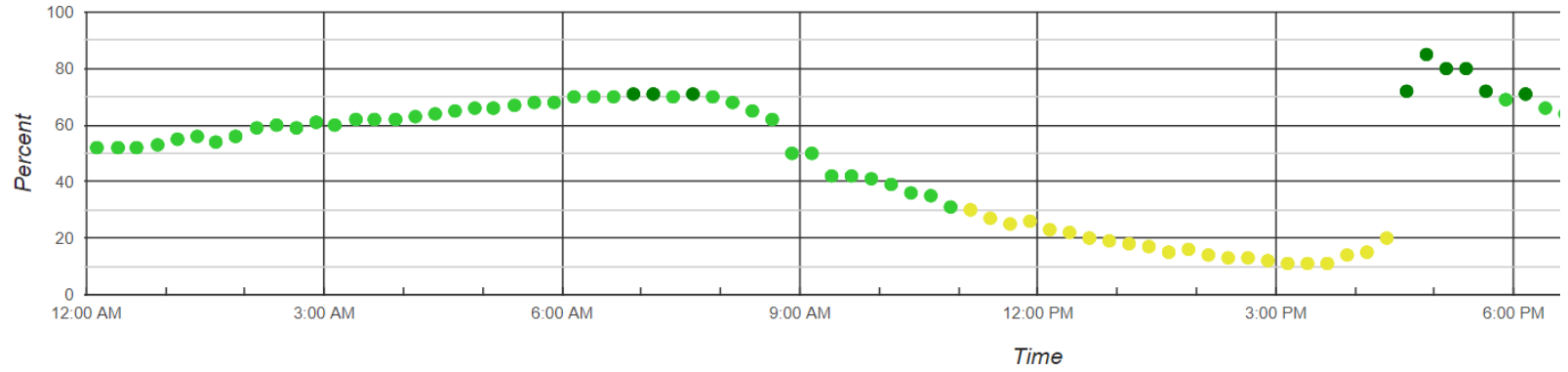
- August 12th, 2021 at 4:36 pm the signs came on.
- All weather instruments indicated a severe weather change in a very short amount of time.
- Air Temperature drop from 89F to 72F in 15 minutes.
- Humidity rise from 20% to 72% in 15 minutes.
- Surface Temp 1 drop from 92F to 7F in 15 minutes!
- Surface Temp 2 drop from 94F to 24F in 15 minutes!
- See the following graphs courtesy of Weathershare.org

Spring Garden Weather 08/12/2021

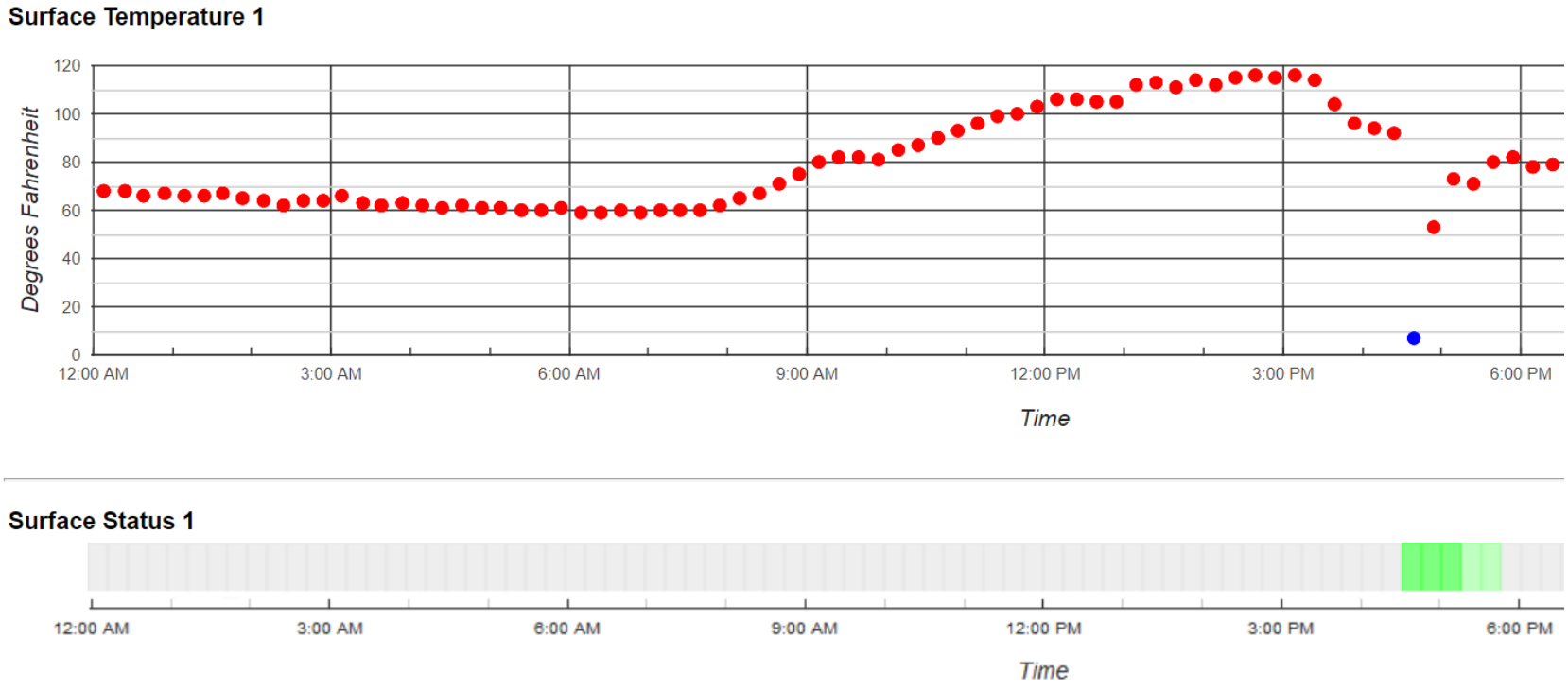
Air Temperature



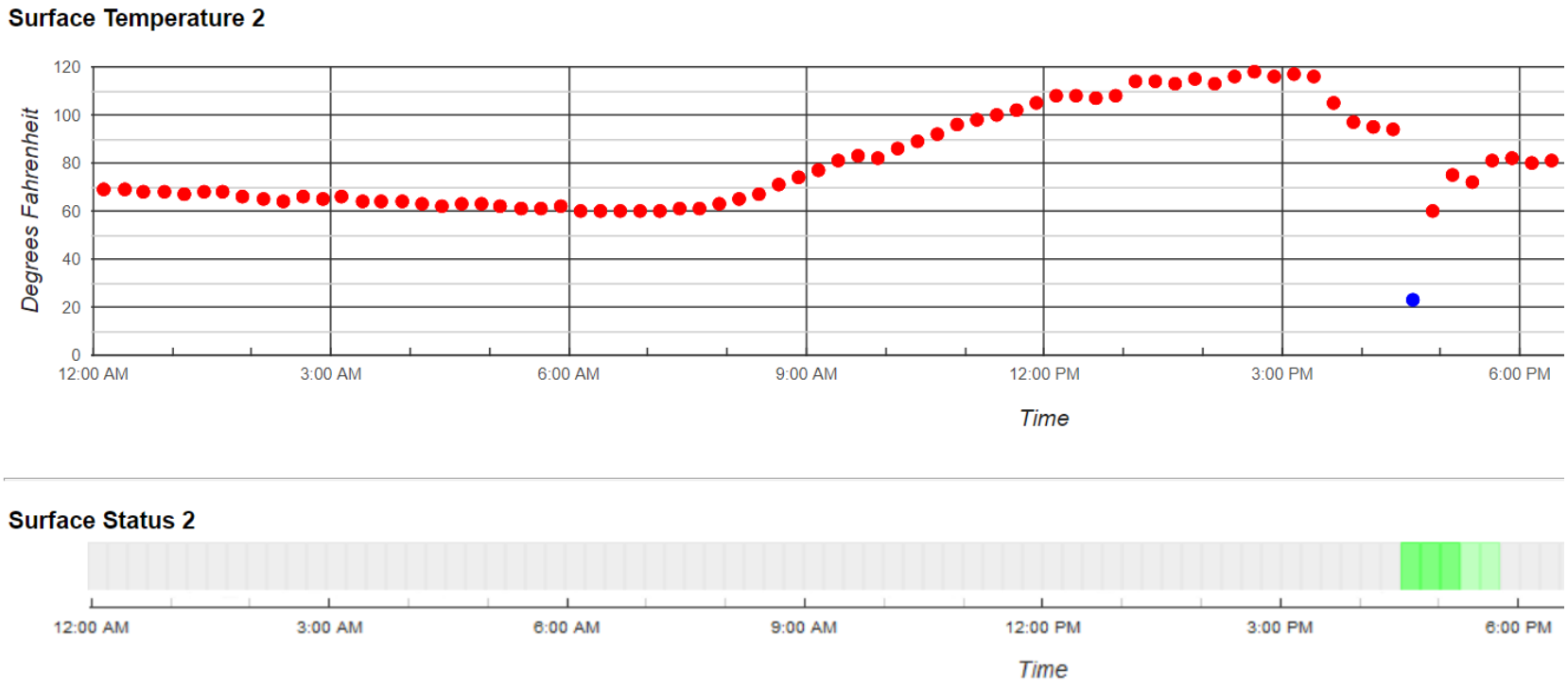
Humidity



Spring Garden Weather 08/12/2021



Spring Garden Weather 08/12/2021



One More Thing!

A Recent Case Study at Spring Garden

- Weather event verified by all instruments.
- Signs reacted real-time to recorded event.
  - Consider the surface sensor scan rate of two minutes.
  - Consider the ability of the Vaisala Surface Sensors to react very quickly to *what is on the surface of the roadway*.

One More Thing!

A Recent Case Study at Spring Garden

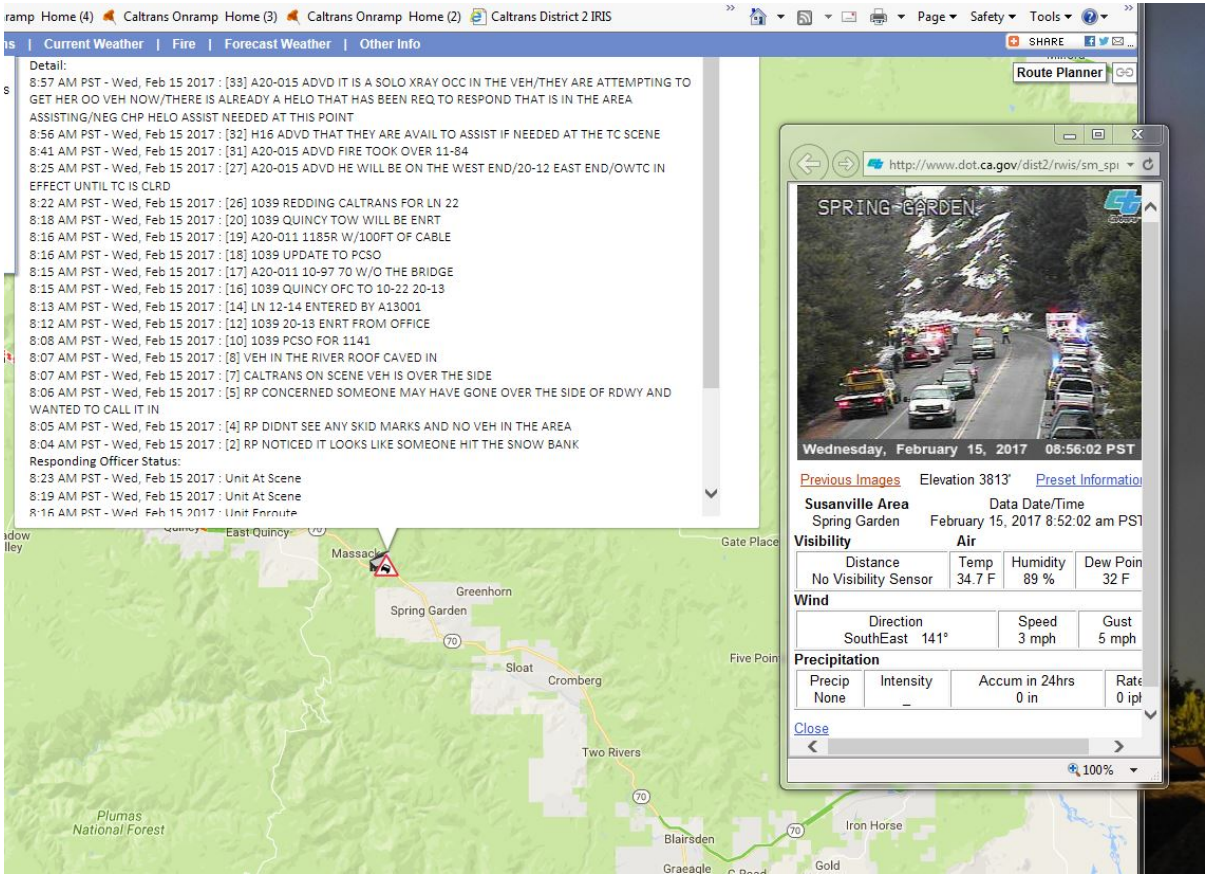
- Weather event verified by all instruments.
- Signs reacted real-time to recorded event.
  - Consider the surface sensor scan rate of two minutes.
  - Consider the ability of the Vaisala Surface Sensors to react very quickly to *what is on the surface of the roadway*.
- It worked as designed.

Acknowledgements

- The ITS crew
  - Mike Beyer
  - Keith Koeppen
  - Jeff Cullins
  - Chaylen Scrivner
  - Troy Moravec
  - Charles Price
  - Kenneth Shipley
  - Lonnie Hobbs
- CHP-Quincy
- Caltrans - Quincy Maintenance Group
- Sean Campbell (2070E CMS Solution Assist!)
- My two co-presenters

ASWSC

- It feels like this is making a difference in safety and meeting the primary goals to operate autonomously.
- Great to be a part of this project. Thanks!
- Can see future enhancements to make it even better. (I have a list Doug!)



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ASWSC Phase III – D2 Testing and Deployment

Any Questions?

Jeff Worthington – ITS Engineer for Caltrans, District 2

Presented at Western States Technology Forum, Yreka, CA

October 5th, 2021