
NEVADA
DOT
SAFE AND CONNECTED

Nevada DOT

Dedicated Short Range Communications (DSRC) Radio for Rural ITS

Yreka, CA

Thursday, June 23, 2016

Acronyms

DSRC	Dedicated Short Range Communication
IMO	Integrated Mobile Observations
MDSS	Maintenance Decision Support System
MMS	Material Management System
mESS	Mobile Environmental Sensor Station
NCAR	National Center for Atmospheric Research
NDEX	Nevada Data Exchange
NIMO	Nevada Integrated Mobile Observation
OBU	On-Board Unit
RSU	Road Side Unit
TMDD	Traffic Management Data Dictionary
UNR	University of Nevada - Reno

Acronyms

C2C	Center to Center
WSDL	Web Services Description Language
XSD	XML Schema Definition
XML	Extensible Markup Language
TMS	Traffic Management System
NNG 511	Nevada Next Generation 511
EDACS	Enhanced Digital Access Communications System
JSON	JavaScript Object Notation

DSRC Radio for Rural ITS

Nevada DOT

Traffic Operations ITS, Signals, and Lighting

- Rod Schilling
- ITS Design Manager
- Work: 775-888-7863
- Email: Rschilling@dot.state.nv.us

Nevada DOT

Traffic Operations Technology Section

- Jim Whalen
- ITS Technology Manager
- Work: 775-888-7887
- Email: JWhalen@dot.state.nv.us

NEVADA DOT

University of Nevada, Reno

U.S. Department of Transportation
Federal Highway Administration

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Joint collaboration to leverage existing NIMO resources and expertise in the state and develop a pilot test corridor for Connected Vehicles using multimodal communication methods

DSRC Project Outline

1. Background Review
2. NIMO DSRC Hardware Implementation
3. DSRC Pilot Corridor RSU Site Plan
4. DSRC Installations
5. Application Development & Implementation
6. Sustainability Planning
7. Lessons Learned

DSRC Challenges in Nevada

1. Past experiences: road weather forecasts have historically not been of adequate quality for NDOT.
2. Microclimates: many local areas (especially in mountainous areas) make forecasting more challenging, especially without "enough data".
3. Data Telemetry: cellular telemetry is the standard (nationwide), but not currently workable in most of Nevada.

DSRC Challenges in Nevada

4. **Pilot Demonstration: need to show that a viable approach can be implemented in Nevada for MDSS, MMS and other services.**
5. **Previous NIMO Phases: focus was on developing general understanding of how to gather data. Use of that data was not adequately explored and evaluated.**

Applications

Nevada
Integrated
Mobile
Observations

Material
Management
System

Enhanced
Maintenance
Decision
Support
System

Additional Information for
- Freight Carriers
- Emergency Responders
- DMS, 511 Motorist Advisories
- Variable Speed Limits

NIMO System Framework

Cellular

In-Vehicle Equipment
- Weather sensors
- Vehicle sensors (OBU, CANBus)
- Equipment sensors (spreader)
- Location sensor (GPS)
- Radio(s)

DSRC

Multi-Mode Receiving Station
- Receives data from mobile vehicles
- Archives and forwards data
- Currently UNR moving to NDOT

U.S. Department of Transportation Federal Highway Administration

NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Applications
- Current conditions
- Weather data environment
- Forecasts
- Material usage tracking
- Road maintenance recommendations

NEVADA DOT

NIMO System Framework

Cellular

DSRC

In-Vehicle Equipment
- Weather sensors
- Vehicle sensors (OBU, CANBus)
- Equipment sensors (spreader)
- Location sensor (GPS)
- Radio(s)

Multi-Mode Receiving Station
- Receives data from mobile vehicles
- Archives and forwards data

U.S. Department of Transportation Federal Highway Administration

NCAR National Center for Atmospheric Research

Applications
- Current conditions
- Weather data environment
- Forecasts
- Material usage tracking
- Road maintenance recommendations

NIMO 3 Vehicles

- **9 Snow plows with instrumented spreader motors and 1 freeway service patrol vehicle**
  - **5 in Reno**
  - **3 in Carson City**
  - **2 in Lake Tahoe**

District II IMO Inventory				
UNIT #	YEAR	MAKE	MODEL	DESCRIPTION
2272	2007	PETERBILT	357	TANDEM AXLE DUMP TRUCK
1915	2007	PETERBILT	357	TANDEM AXLE DUMP TRUCK
0763	2009	PETERBILT	367	TANDEM AXLE CAB AND CHASIS
2275	2007	PETERBILT	357	TANDEM AXLE DUMP TRUCK
3200	2007	PETERBILT	357	TANDEM AXLE DUMP TRUCK
2274	2007	PETERBILT	357	TANDEM AXLE DUMP TRUCK
3319	2009	PETERBILT	367	TANDEM AXLE CAB AND CHASIS SWL
0323	2007	PETERBILT	367	TANDEM AXLE CAB AND CHASIS
0267	2001	INTERNATIONAL	5000	AWD
R1	2012	FORD	E240	FREEWAY SERVICE PATROL VAN/PU

NIMO 3 Vehicles

- **4 OBUs are gathering data**
- **1 installation approximately 3 days**
- **Lessons learned**
  - **Coordination efforts are essential**
  - **Different plow interiors having to redesign backplane**

On Board Units (OBU, ~$3,500 ea.)

Arada Locomate

$1,200

Comet T7511 Ethernet

Weather Sensor Head
- Barometric Pressure
- Air Temperature
- Humidity

$600

Technologic Systems
CPU (Main Computer)
$400

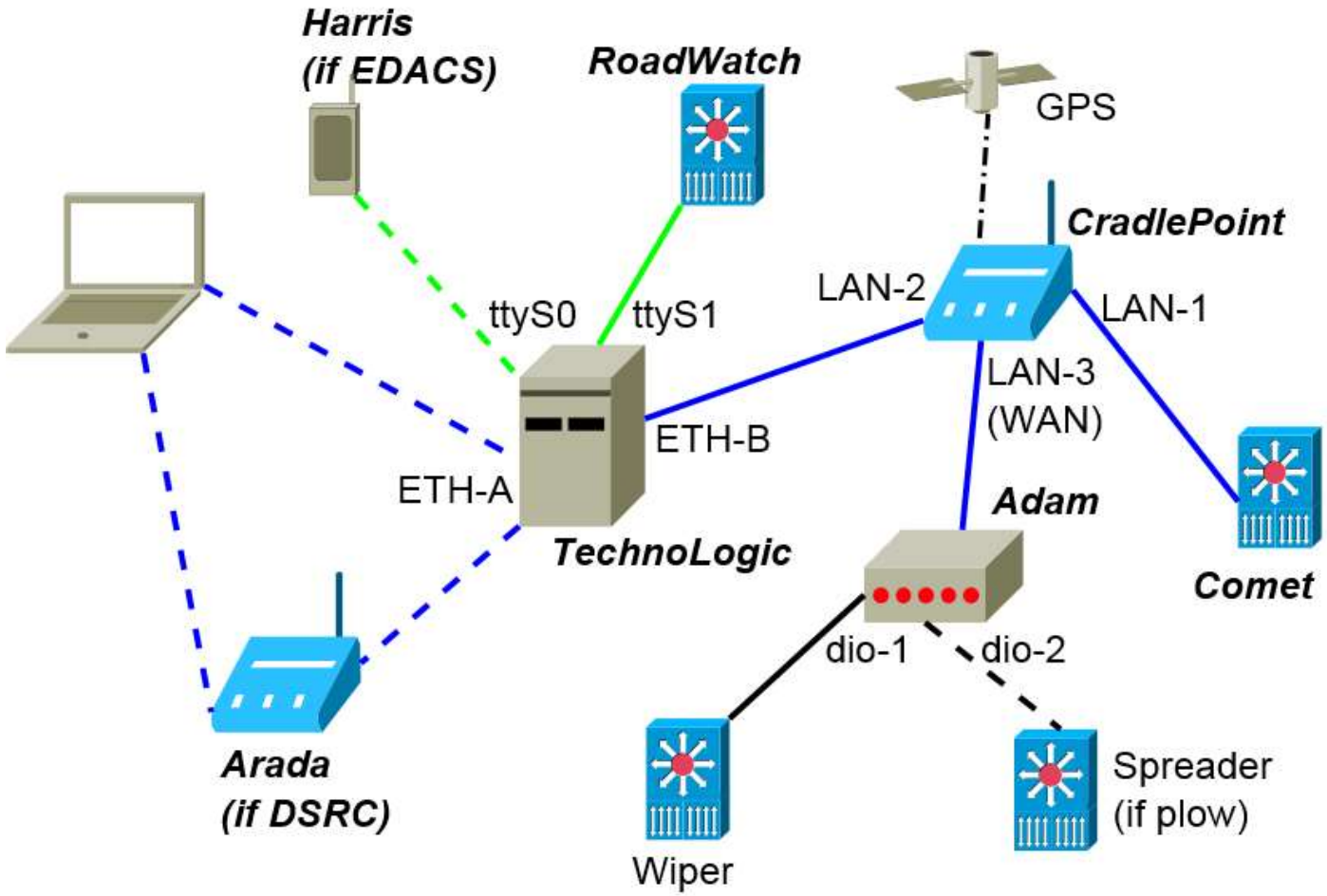
Roadwatch
(not included in costs)
- Air Temperature
- Surface Temperature

Cradlepoint IBR1100
Cellular Modem, GPS
$800

Custom Sensors
- Windshield Wiper Sensor
- Spreader Rate Sensor
- Spreader Material Sensor

Adam 6051
Ethernet DIO/counter
$200

Connectivity Diagram (OBU)



Geo-fencing: Cradlepoint vs. DSRC RSU

Multimodal Communications Testing

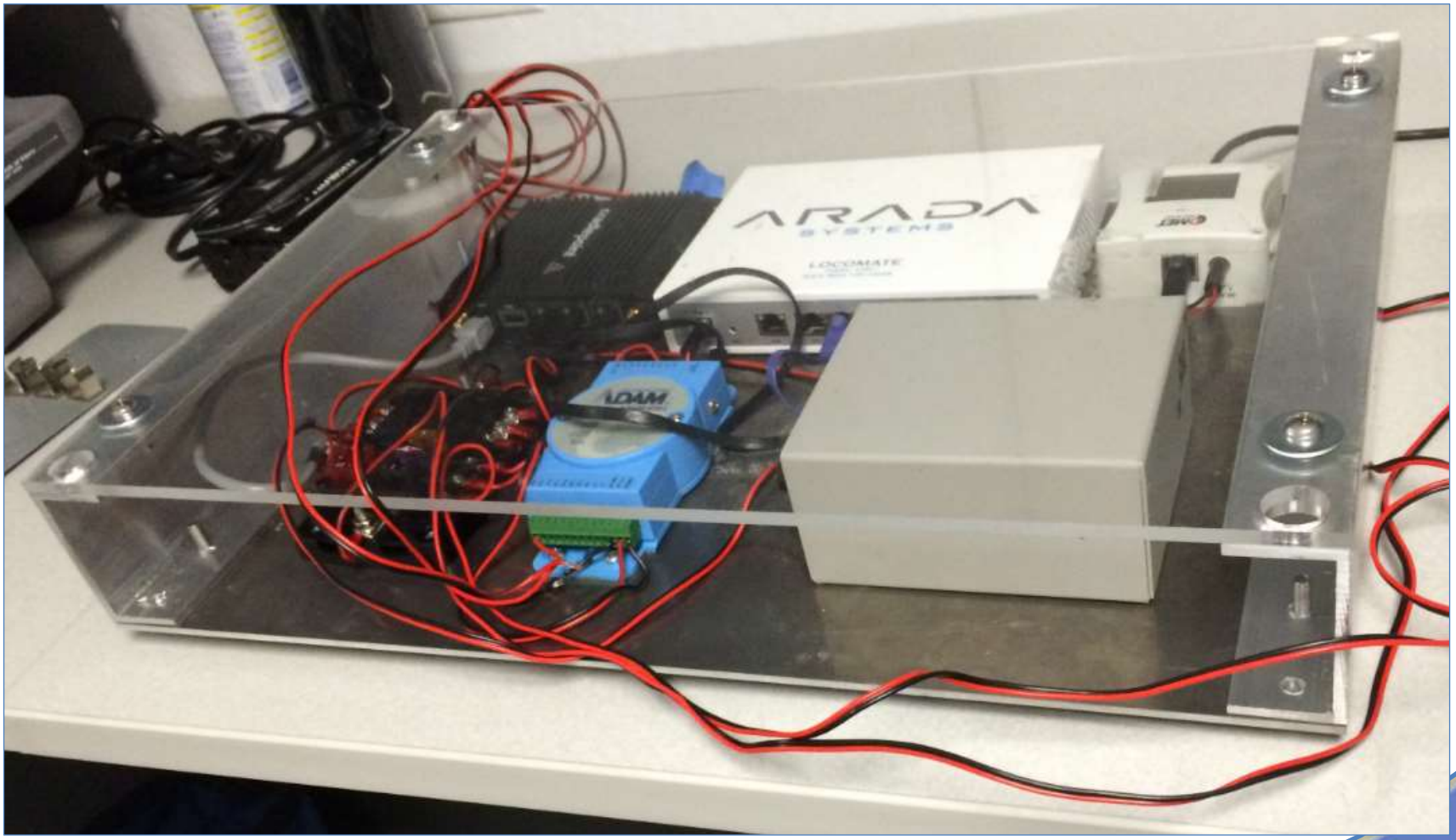
DSRC

Multi-Mode Receiving Station

- **Receives data from mobile vehicles**
- **Currently UNR (Moving to NDOT)**

Cellular

“IMO 3” Sensor Package



Example Snow Plow Installation

Use of COTS components. Only software is "custom" (no custom electronics)

- **Pilot will have 10 vehicles**
- **Retrofits of IMO phases 1 & 2 installs to follow**
- **Typical mount on back wall of passenger cabin behind seats**
- **Transmission frequencies vary with the telemetry mode, ranging from ~10 seconds to 5 minutes**
- **No driver interface/display**
- **No imagery/video**

GPS Antenna
DSRC Antenna
Road Temperature Sensor
Air Sensor
Spreader Sensor

Plow On-Board Hardware

FSP Van On-Board Hardware

Sensor Package

Dataset

- **Wave Short Message Protocol (WSMP)**
- **Same "payload" over DSRC and cellular**

- **Date**
- **Time**
- **Location (lat., long.)**
- **Speed**
- **Altitude**
- **Air Temp**
- **Barometric Pressure**
- **Humidity**
- **Dew Point**
- **Road Temp**
- **Wiper Status**
- **Spread Rate**

Status – NIMO 3 Vehicle Hardware

- All sensor components selected & tested
- Interface via on-board Ethernet LAN that can link to WAN (internet) via cellular modem
- 12V vehicle power bus designed and tested, individually fused per device, ~50 watts

Status – NIMO 3 Vehicle Hardware (cont.)

- Enclosure prototype designed & field tested
- All enclosures (cases) are 90% manufactured
- Ruggedized sensor/network/processing units (-20 to 60 degrees C) and vibration

Status – NIMO 3 Vehicle Hardware

- **Software to sample all sensors completed**
  - **Comet WX: air temperature, humidity, dew point**
  - **Roadwatch SS: air temperature, surface temperature**
  - **Adam DIO 32-bit Counter/frequency: spreader, windshield wiper**
  - **Cradlepoint COR Modem/Router: NMEA GPS, WAN access**

Status – NIMO 3 Vehicle Hardware

- **Modular architecture will allow same system to support vehicles not operating in the DSRC areas**
- **Main processing unit (Technologic TS-7250-V2) is separate from OBU (Arada Locomate)**

Status – NIMO 3 Vehicle Hardware

- **Multi-modal capability partially implemented – geo-fenced RSU database drives switch between cell and DSRC mode, but confirmations are under development. Handoffs need to be fine-tuned.**

- **Data snapshots taken every 10 seconds, synchronized to GPS time.**

Status – NIMO 3 Vehicle Hardware

- Cell and DSRC packets received by same development server, which detects transmission mode, and associates data with a plate ID

- Currently using same compressed CSV format for both cell and DSRC modes as with phase 2 NIMO, will have also the ability to have transmission over low-bandwidth trunked radio if/where necessary

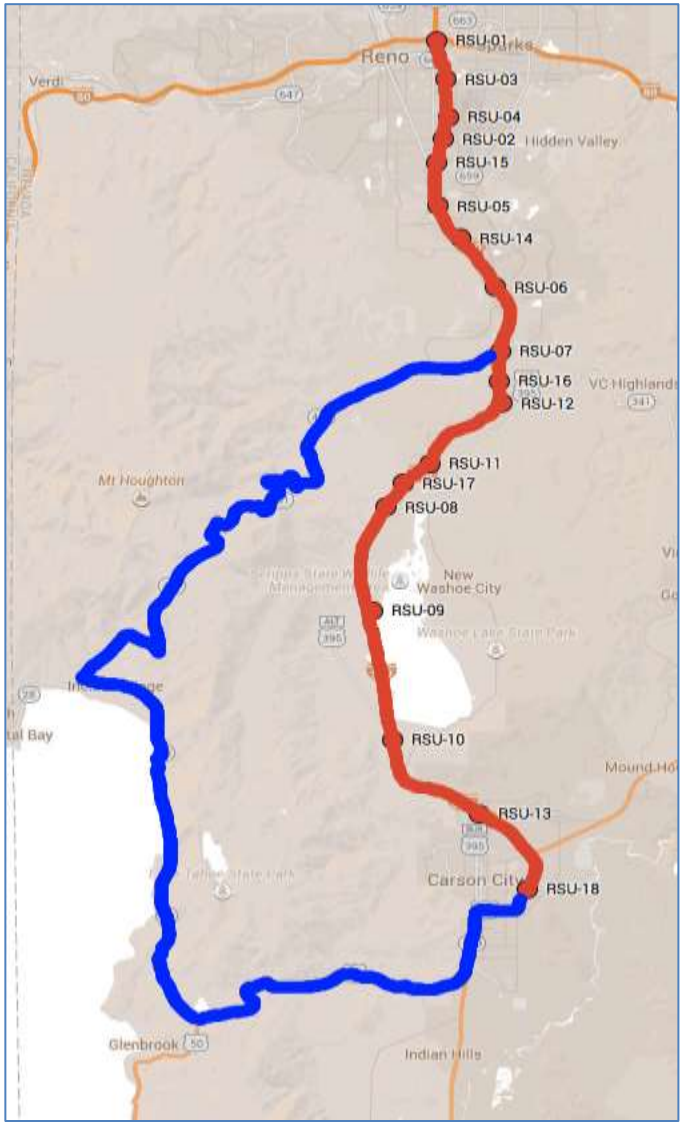
Status – NIMO 3 Vehicle Hardware

- Application on the server will interface with the Nevada Data Exchange (NDEX)
- Current focus is implementation of NTCIP compliance (through the NDEX), and ACK confirmations from RSU's (or TCP/IP over DSRC) to support DSRC retransmission/error-checking, and to fine-tune hand-offs with other modes

DSRC Site Locations

18 Locations

Vehicle Routes



Cellular

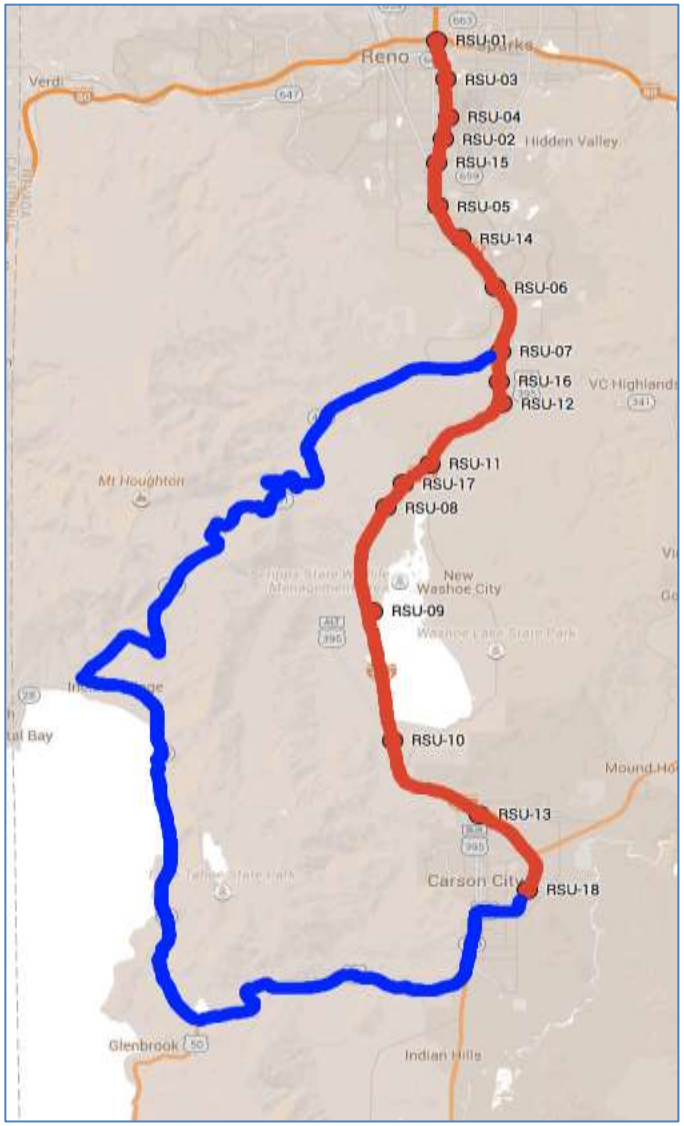
DSRC

18 DSRC Locations

32 Miles DSRC

54 Miles Cellular

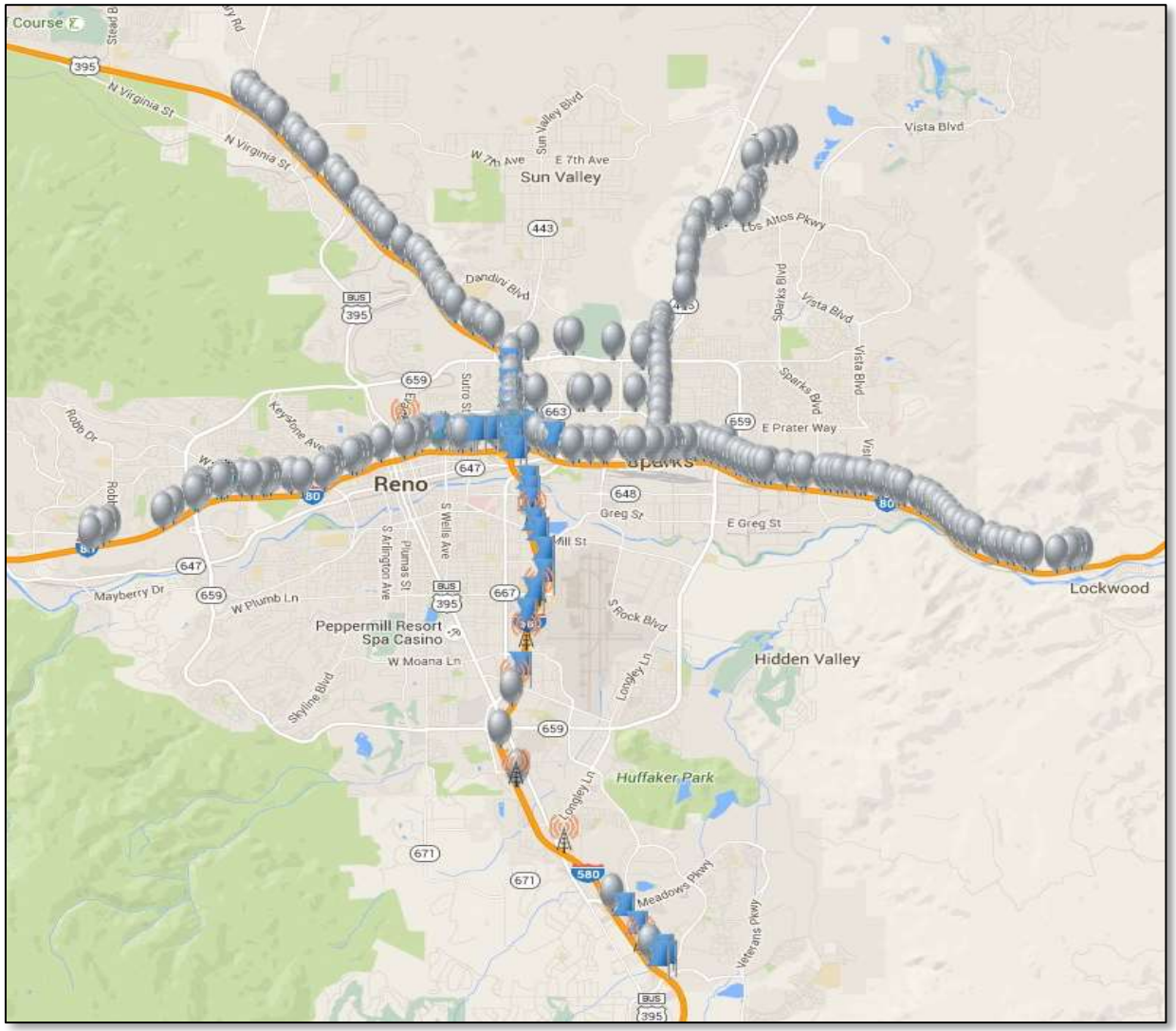
DSRC Multimodal Data Tests



Preliminary Tests:

- **Multimodal functionality is good**
- **Message transmissions confirmed**
- **Geo-fencing behavior needs decreased latency for sharper transitions**

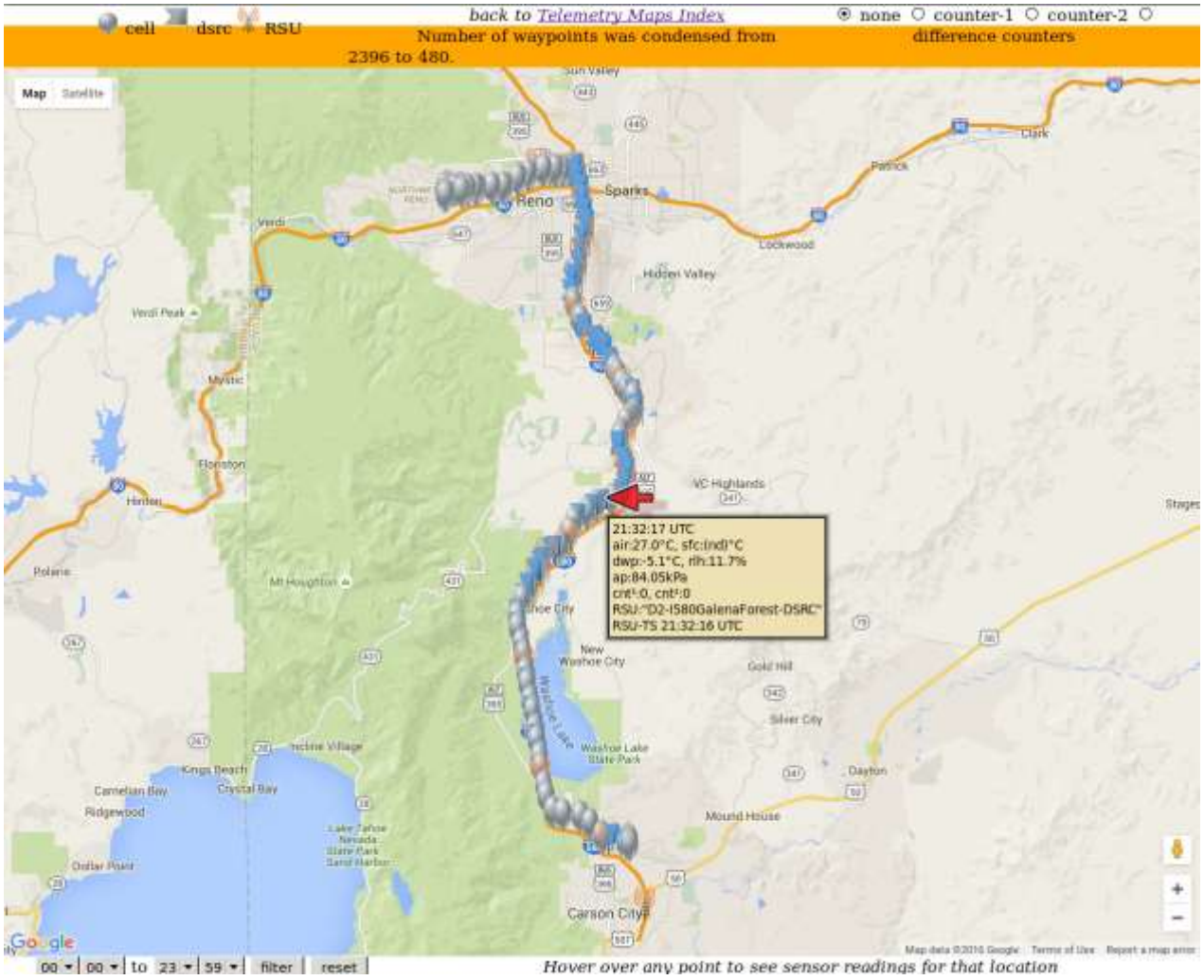
FSP Van, 2/8/16 Data



Prior to full DSRC Radio Install

- Cellular
- DSRC

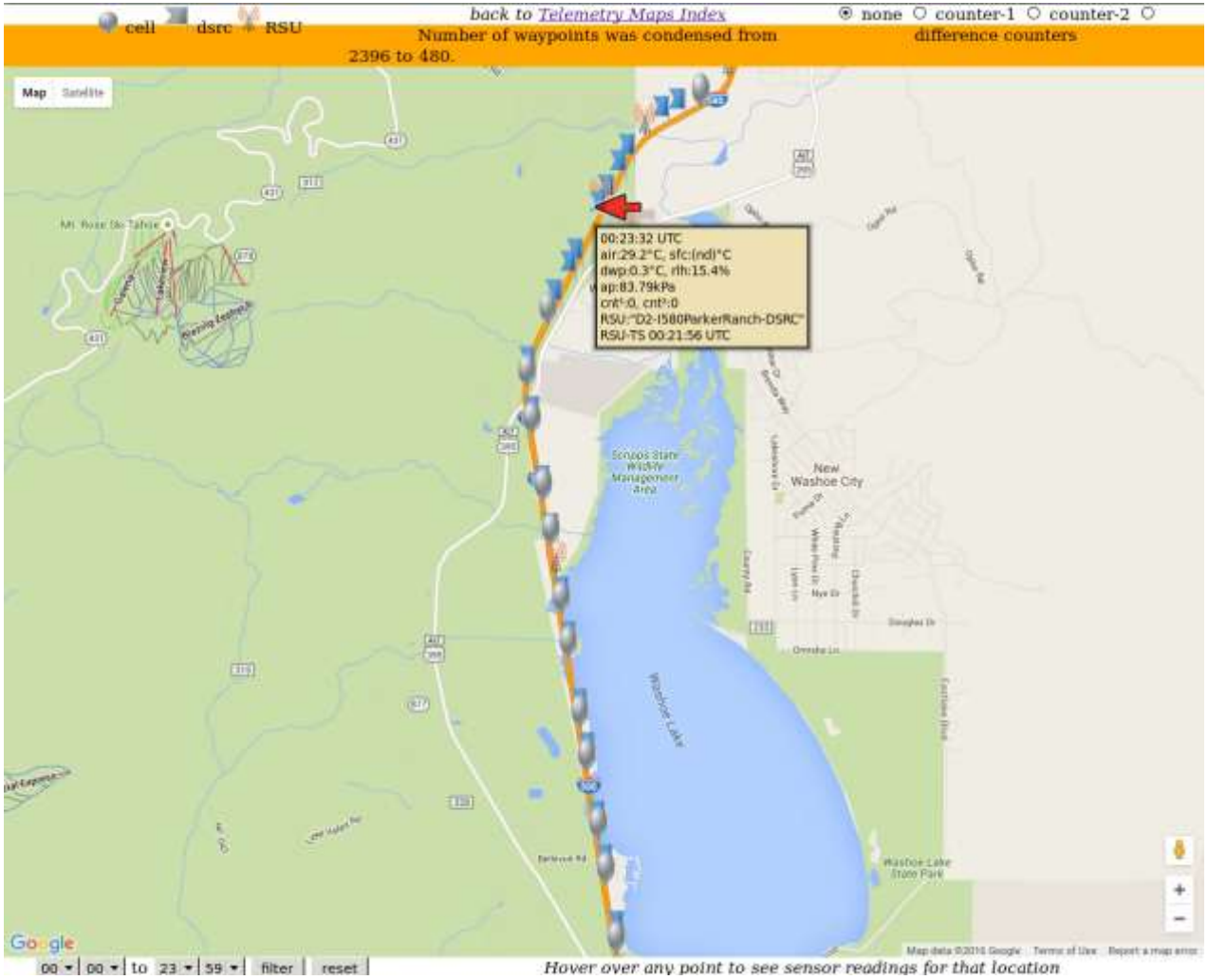
I580/US395 Test Corridor with SR341/US50 UNR test vehicle, 6/20/16 Data

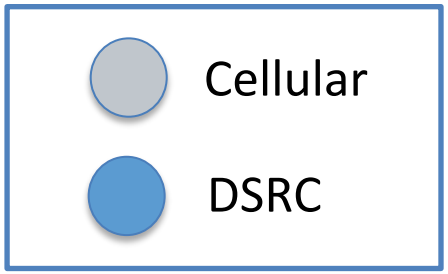


Cellular

DSRC

I580/US395 Test Corridor with SR341/US50
UNR test vehicle, 6/20/16 Data





I580/US395 Test Corridor with SR341/US50 UNR test vehicle, 6/20/16 Data

Cellular

DSRC

DSRC Installations

18 sites completed

- **First two done under single quote contract**
  - **Completed November 2015**
- **Remaining 16 done under three quote contract**
  - **Completed February 2016**

UNR IMO Portal

https://134.197.27.248:8001/

Nevada Data Exchange (NDEX)
Integrated Mobile Observations (IMO)
Integration
mobile ESS (MESS)

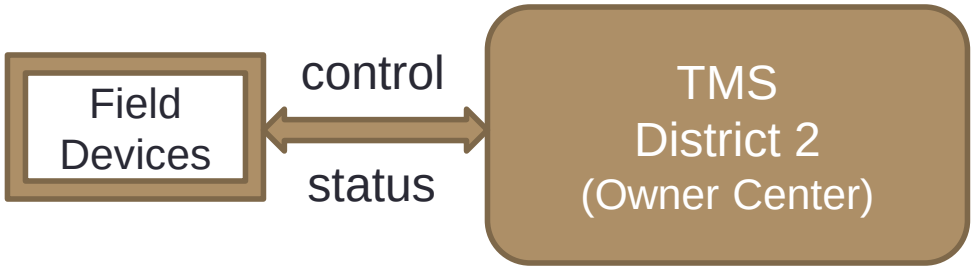
Nevada TMDD Data Exchange (NDEX)

- Nevada DOT's C2C
  - Central Data Exchange
  - Data Warehouse
- Web Services Implementation: WSDL, XSD and XML
- Traffic Management Data Dictionary Standard (TMDD)
- Restricts access based on authentication
- Three-Tier Security Implementation
- NDOT's Needs Requirements Traceability Matrix (NRTM)

User Needs

1. Need to authenticate access
2. Need to support request-response
3. Need to support error handling
4. Need to share IMO vehicle inventory
5. Need to share IMO sensor inventory from any vendor-specific sensor
6. Need to share IMO observations

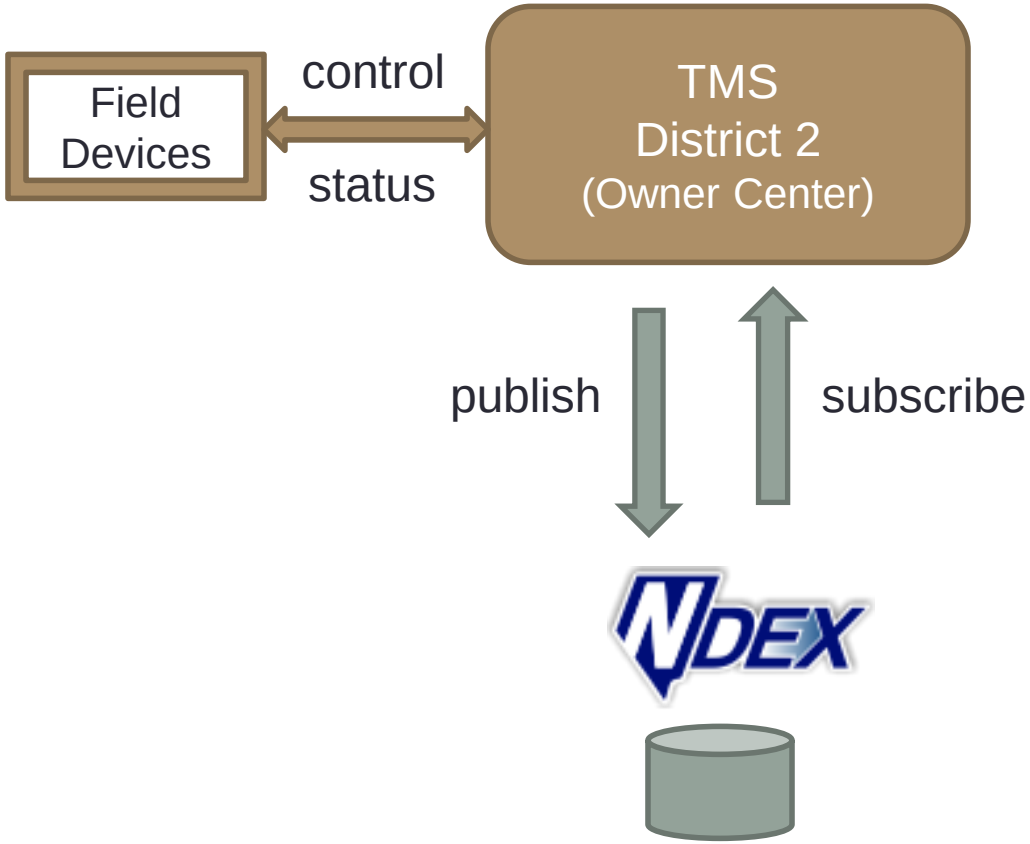
NDEX Architecture



Only the owning center may control field devices

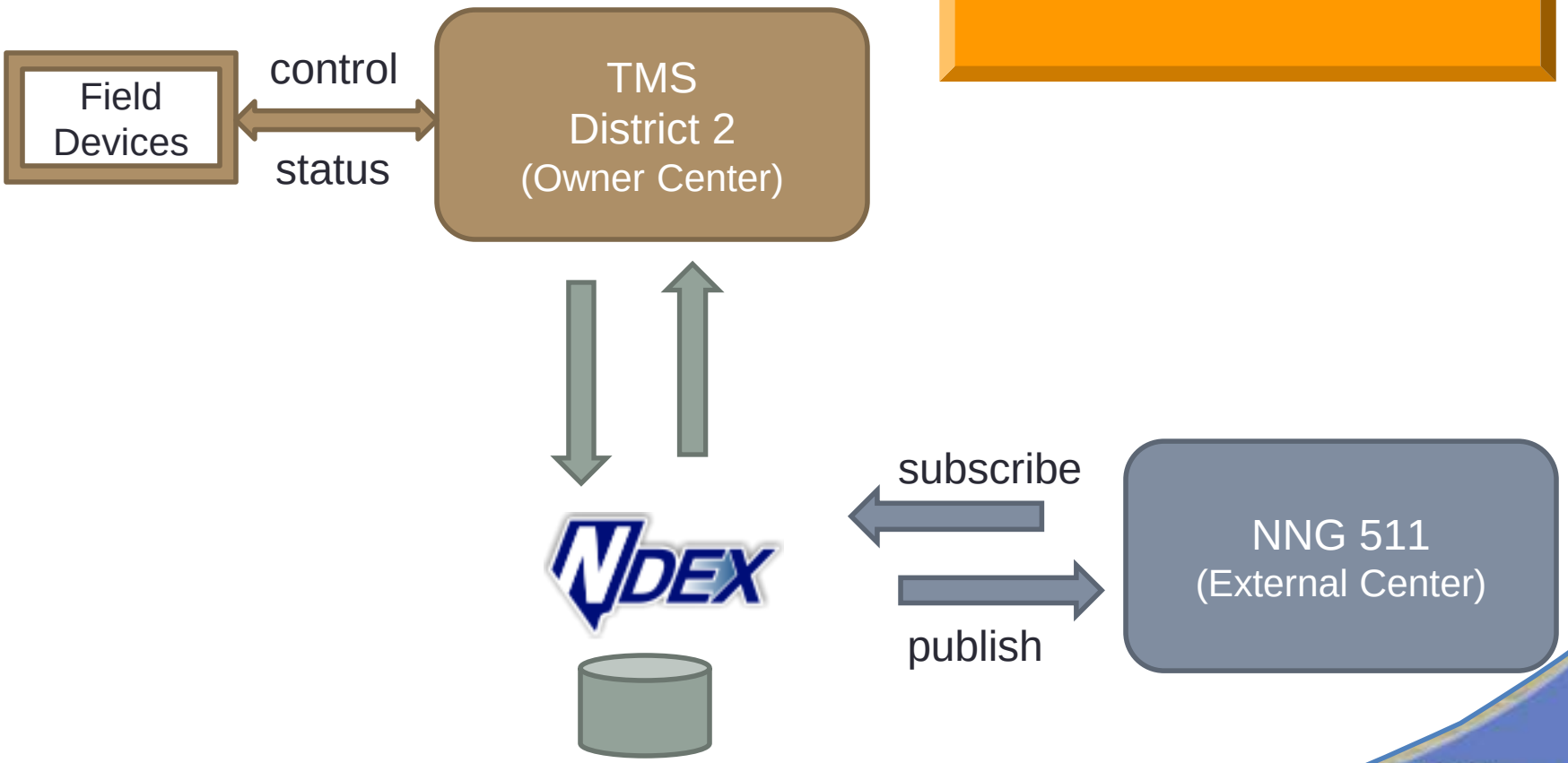
NDEX Architecture

NDEX receives data from the owning center



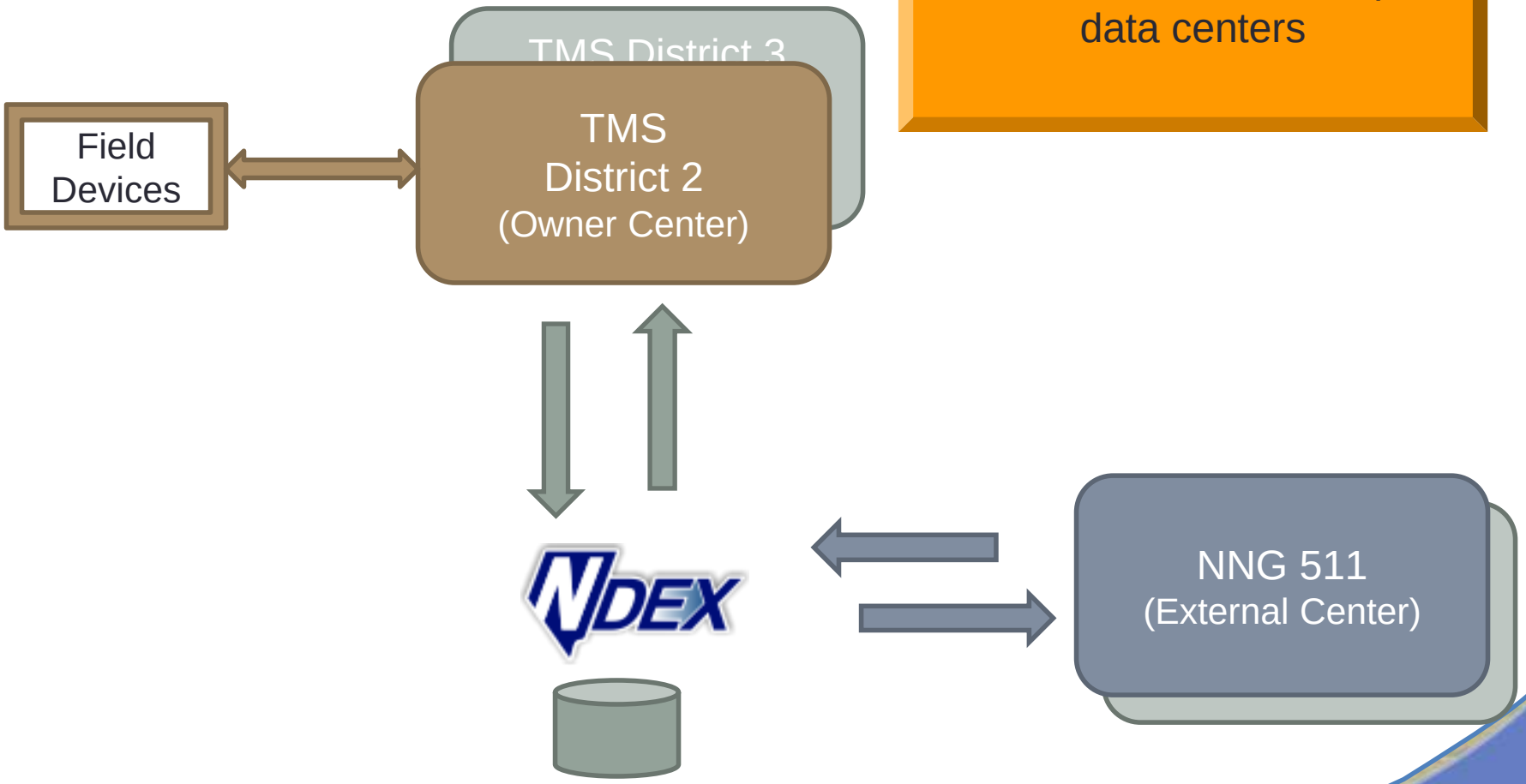
NDEX Architecture

NDEX shares data with external centers



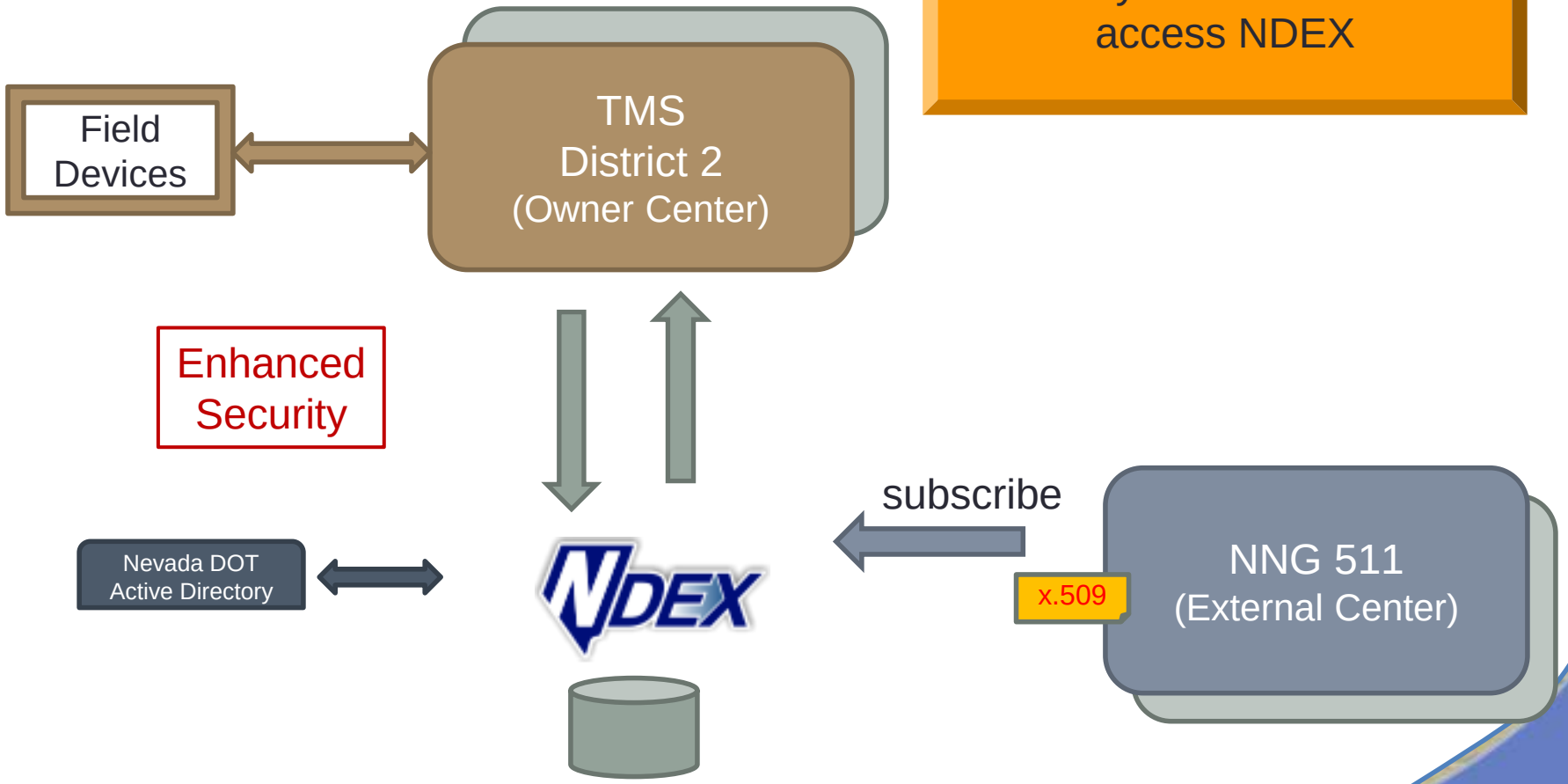
NDEX Architecture

NDEX works with multiple data centers



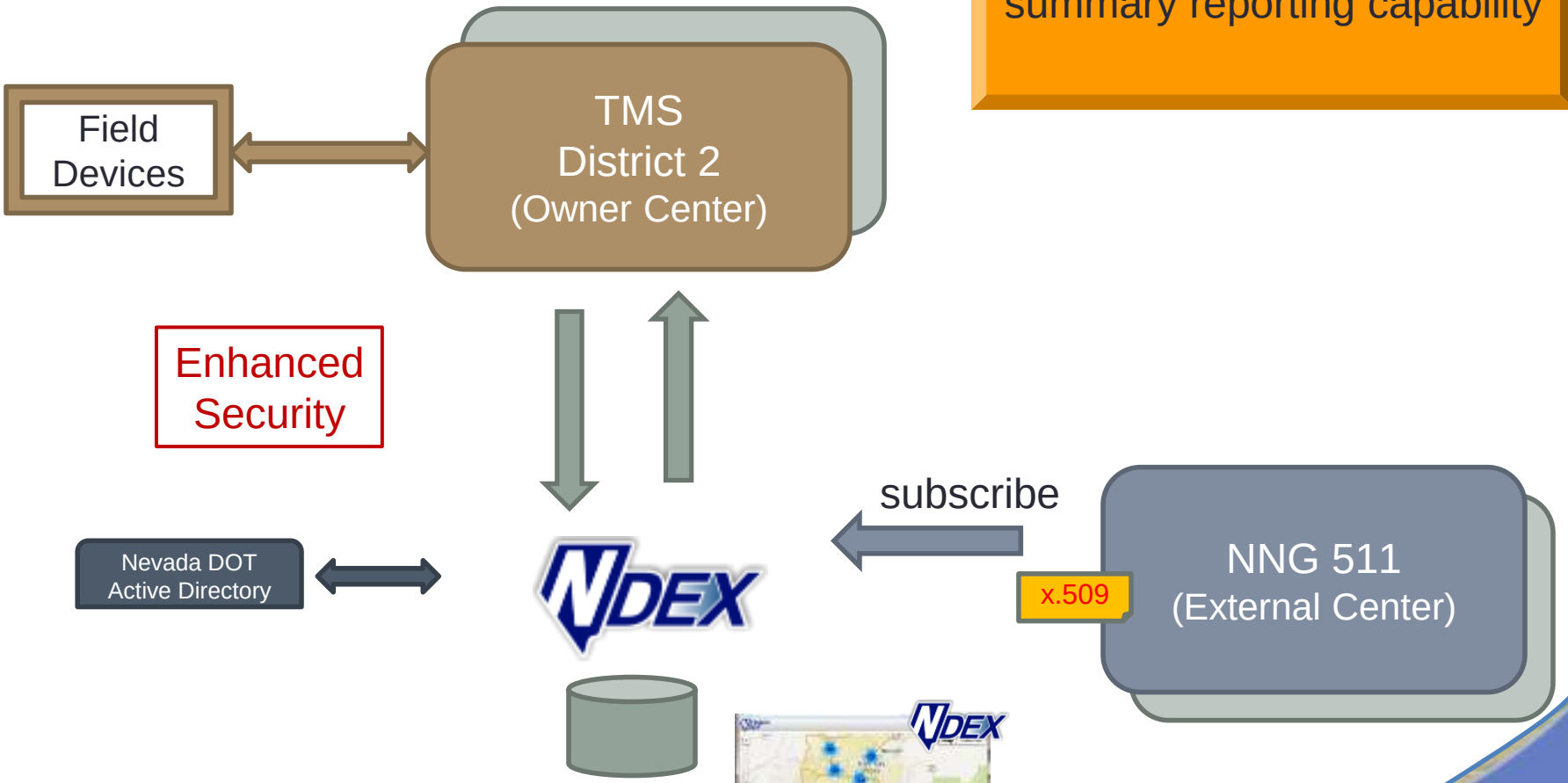
NDEX Architecture

External centers require security authentication to access NDEX

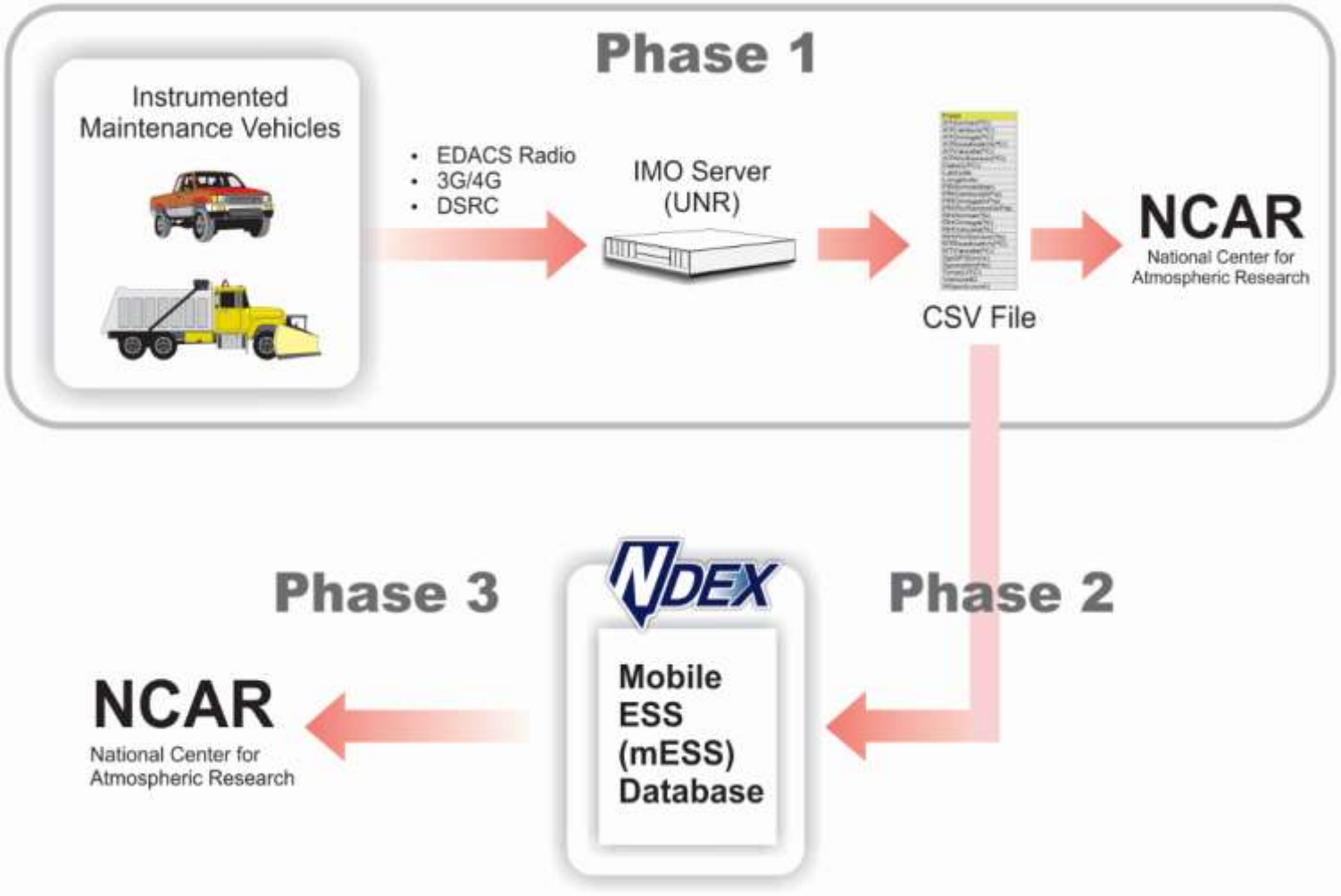


NDEX Architecture

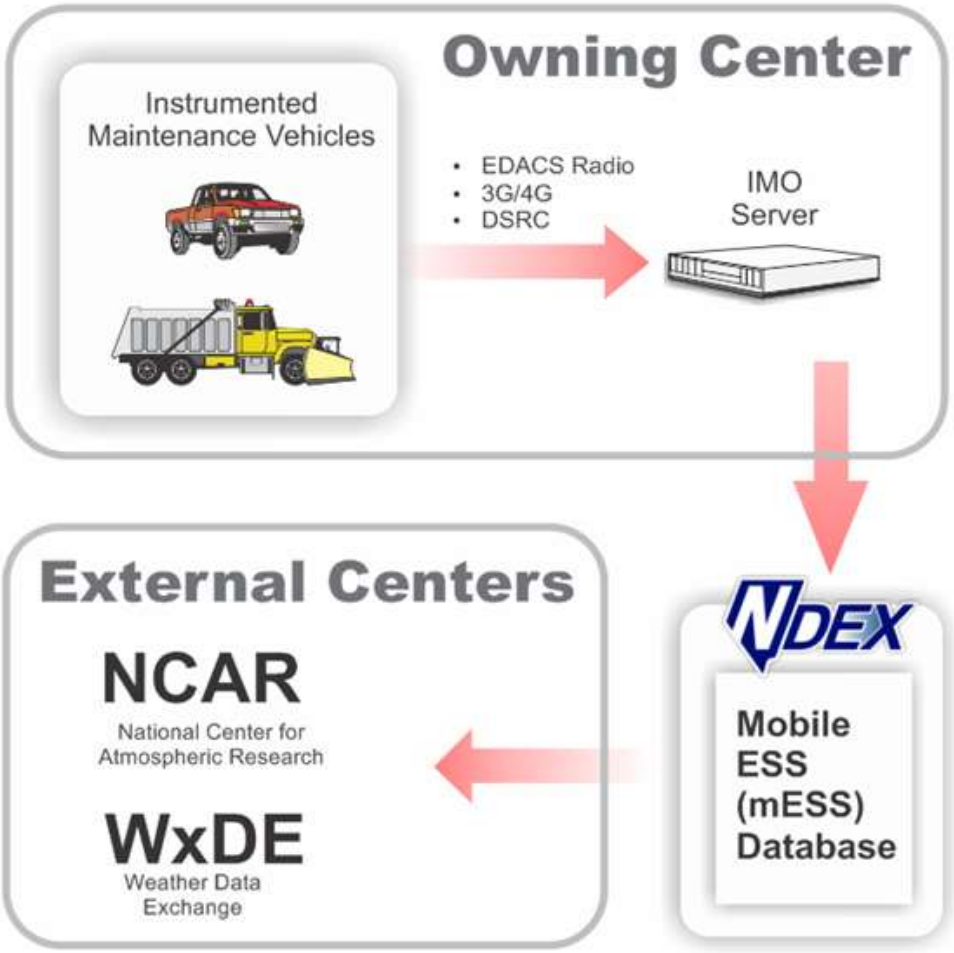
NDEX provides data summary reporting capability



Concept of Operations



Concept of Operations



NDEX Organizations and Centers

Organization Id	Organization Name	Center Id	Center Name
its.nv.gov	NVDOT ITS	D1	District 1
its.nv.gov	NVDOT ITS	D2	District 2
its.nv.gov	NVDOT ITS	D3	District 3
its.nv.gov	NVDOT ITS	FAST	Las Vegas FAST
its.nv.gov	NNG511	511	NNG511
nhp.nv.gov	NHP	NHP	Nevada Highway Patrol

NDEX integrates data from various centers using Organization and Center Ids

mESS Organizations and Centers

Organization Id	Organization Name	Center Id	Center Name
imo.unr.edu	IMO Server University of Nevada, Reno	IMO	IMO UNR
ncar.ucar.edu	National Center for Atmospheric Research	NCAR	NCAR
wxde.fhwa.dot.gov	Weather Data Environment	WXDE	WxDE

NDEX Messages

NDEX messages include inventory and device status

Device Types:

- Detector Station
- CCTV
- Dynamic Message Sign (DMS)
- Environmental Sensors (ESS)
- Mobile Environmental Sensors (mESS)
- Highway Advisory Radio (HAR)
- Incidents/Events
- Ramp Meter
- Node, Link, Traffic Network

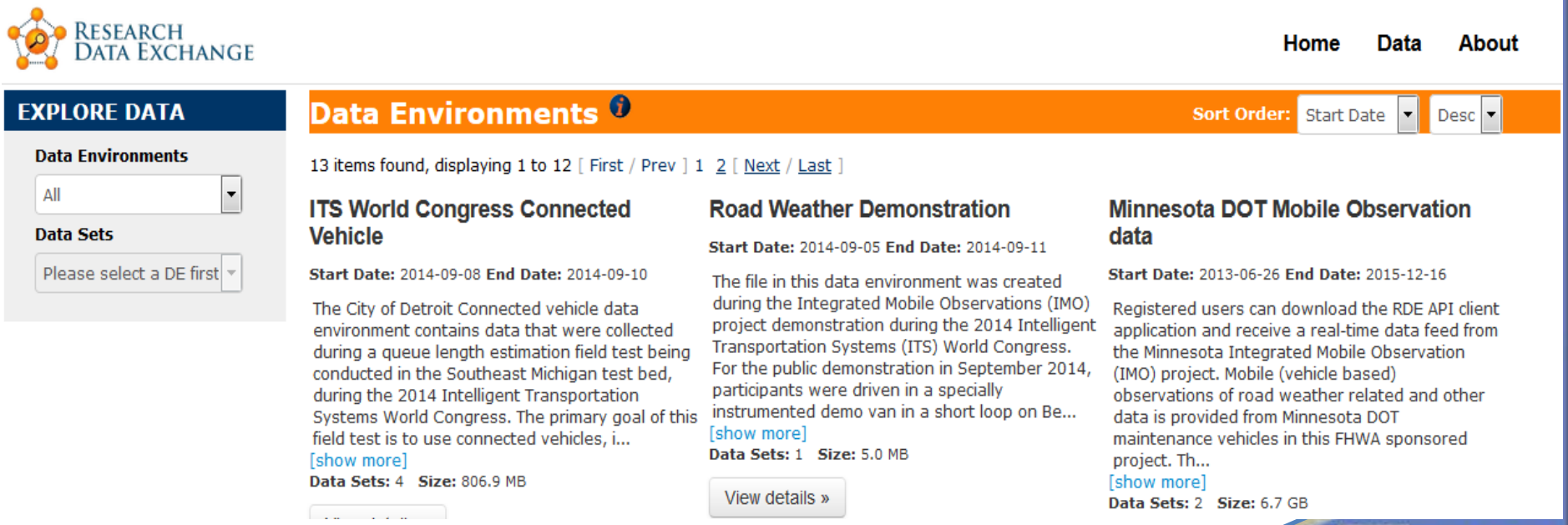
TMDD Web Service Endpoint

- http://coloNDEXsrv.its.nv.gov/tmddws/TmddWS.svc
- Web Services Implementation: WSDL, XSD and XML

- https://coloNDEXsrv.its.nv.gov/imows/
- REST API Endpoint Implementation: JSON
- Requires JSON plugin

IMO References

- DSRC SAE J2735 DSRC Message Set Dictionary
- NTCIP 1204 ESS Interface Protocol
- https://wxde.fhwa.dot.gov/
- https://www.its-rde.net/home



Sensor Package Inventory

SensorId	Manufacturer	Source Unit of Measure	Target Observation Type
ATAirmar	Airmar	Temperature Celsius	NTCIP 1204 ESS Air Temperature
RTRoadwatch	Roadwatch	Temperature Celsius	NTCIP 1204 ESS Surface Temperature
PRAirmar	Airmar	Atmospheric Pressure Bar	NTCIP 1204 ESS Atmospheric Pressure
PROmega	Omega	Atmospheric Pressure kPa (kilopascal)	NTCIP 1204 ESS Atmospheric Pressure
GPGGA	Cradle Point	NMEA 0183 Sentence GPGGA	NMEA 0183 Sentence GPGGA

UNR CSV Field Descriptions

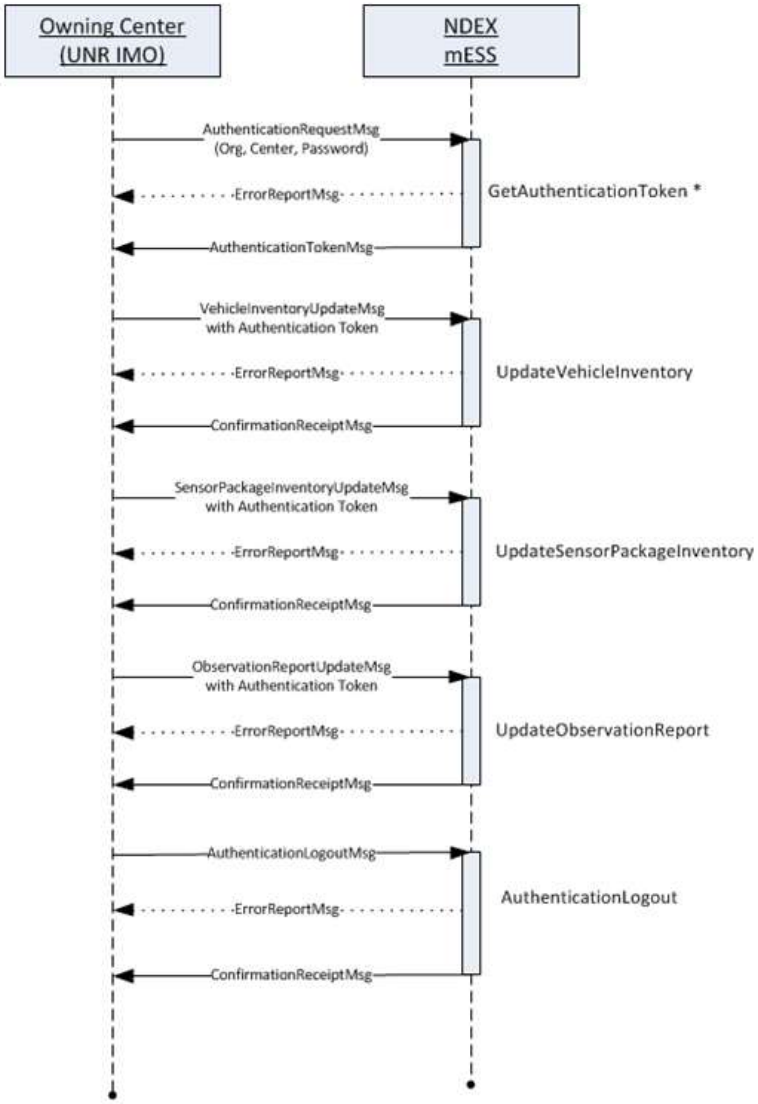
Field	Description
ATAirmar(ºC)	*Air Temperature*
ATCanbus(ºC)	
ATOmega(ºC)	
ATRoadwatch(ºC)	
ATVaisala(ºC)	
ATWxSensor(ºC)	*Air Temperature: UNR Custom Weather (Wx) Sensor*
Date(UTC)	
Latitude	*Decimal Degrees: [-][D]DD.DDDD*
Longitude	
PRAirmar(bar)	*Atmospheric PRessure*
PRCanbus(kPa)	
PROmega(kPa)	
PRWxSensor(kPa)	*Atmospheric PRessure: UNR Custom Weather Sensor*
RHAirmar(%)	*Relative Humidity*
RHOmega(%)	
RHVaisala(%)	
RHWxSensor(%)	*Relative Humidity: UNR Custom Weather Sensor*
RTRoadwatch(ºC)	*Road Temperature*
RTVaisala(ºC)	
SpGPS(m/s)	*GPS Speed*
Spreader(Hz)	*Spreader Rate (plows): Custom Sensor*
Time(UTC)	
VehicleID	*Plate Number*
Wiper(count)	*Wiper Cycle Count: Custom Sensor*

Need to preserve vendor-specific sensor measures

Use Available Standard Measures

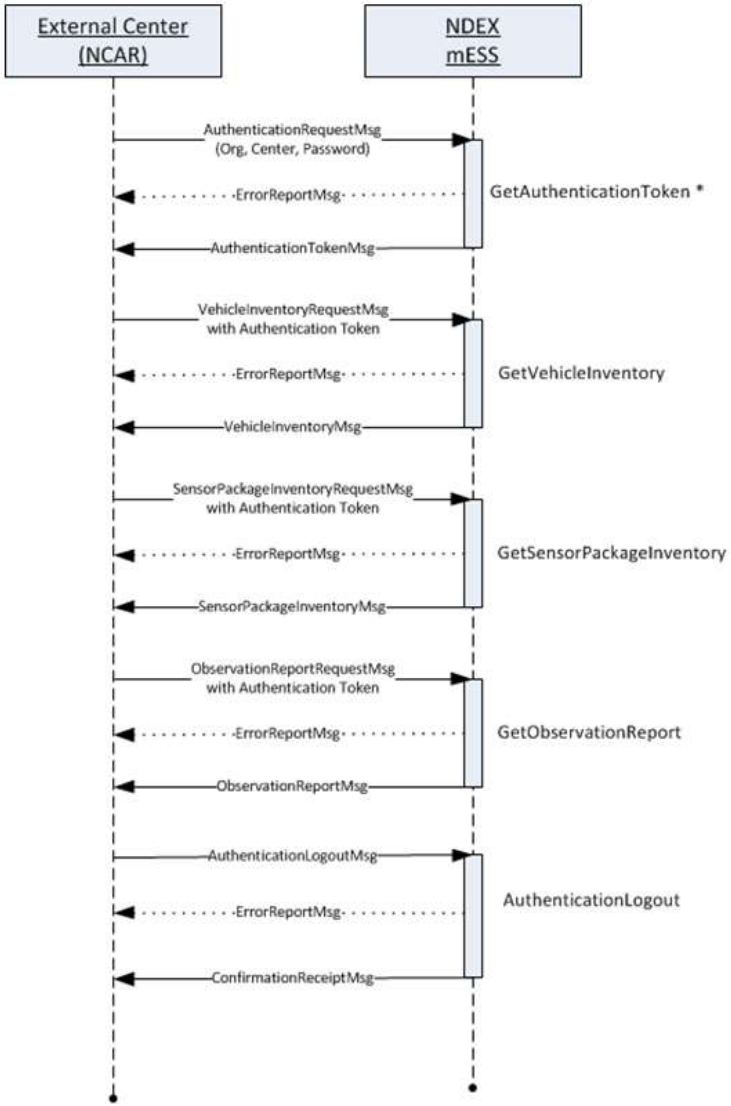
5.1.4	Target Observation Type (See Table 7 - Source and Target Units of Measure)	M	Requires at least one of following.
5.1.4.1	NTCIP1204_essAirTemperature	M	NTCIP 1204
5.1.4.2	NTCIP1204_essAtmosphericPressure	M	NTCIP 1204
5.1.4.3	NTCIP1204_essDewpointTemp	M	NTCIP 1204
5.1.4.4	NTCIP1204_essRelativeHumidity	M	NTCIP 1204
5.1.4.5	NTCIP1204_essSurfaceTemperature	M	NTCIP 1204
5.1.4.6	SAEJ2735_DE_WiperRate	M	SAE J2735
5.1.4.7	SAEJ2735_DE_WiperStatusFront	M	SAE J2735
5.1.4.8	SAEJ2735_DE_TractionControlState	M	SAE J2735
5.1.4.9	SAEJ2735_DE_StabilityControlStatus	M	SAE J2735
5.1.4.10	NTCIP1204_essPaveTreatProductType	M	NTCIP 1204
5.1.4.11	NTCIP1204_essPaveTreatProductForm	M	NTCIP 1204
5.1.4.12	NTCIP1204_essPaveTreatmentAmount	M	NTCIP 1204
5.1.4.13	NMEA0183_SentenceGPGGA	M	NMEA 0183
5.1.4.14	NMEA0183_SentenceGPRMC	M	NMEA 0183
5.1.4.15	mESS_SpreaderCyclesPerSecondHz	M	
5.1.4.16	mESS_WiperCount	M	

Owning Center Dialog Messages



* Authentication Token will be recycled after 20 minutes of inactivity

External Center Dialog Messages



* Authentication Token will be recycled after 20 minutes of inactivity

IMO Vehicle Inventory

4	Need to share IMO vehicle inventory			M	
		4.1	Contents of the vehicle inventory (See Table 5 – Fundamental Data Element Definitions)	M	
		4.1.1	Vehicle identifier	M	
		4.1.2	Organization identifier	M	
		4.1.3	Center identifier	M	
		4.1.4	Vehicle description	O	
		4.1.5	Vehicle primary purpose	O	
		4.1.6	Vehicle year	O	
		4.1.7	Vehicle make	O	
		4.1.8	Vehicle model	O	
		4.1.9	SAEJ2735_DE_VehicleType	M	SAE J2735

Sample Observation Report Message


```
{
        "ObservationReportMsg":{

    "RequestId":"123",
    "OrganizationId":"imo.unr.edu",
    "CenterId":"IMO",

    "ObservationReports":[

  {"VehicleId":"D2-0423","DateTime":"2015-09-17T00:00:19Z","Latitude":39527500,"Longitude":-
119792500
        ,"Bearing":46,"Elevation":333,"Speed":46,"Observations":[

        {"SensorId":"ATRoadwatch","SourceValue":"17.1"},
        {"SensorId":"ATWxSensor","SourceValue":"18.3"},
        {"SensorId":"RHWxSensor","SourceValue":"24.6"},
        {"SensorId":"PRWxSensor","SourceValue":"86.1"},
        {"SensorId":"RTRoadwatch","SourceValue":"22.8"},
        {"SensorId":"SpGPS","SourceValue":"12.7986"},
        {"SensorId":"Spreader","SourceValue":"0"},
        {"SensorId":"WiperCount","SourceValue":"0"}
          ]
  }
  ,
  {"VehicleId":"0423","DateTime":"2015-09-17T00:10:19Z","Latitude":39527500,"Longitude":-
119792500
        ,"Bearing":46,"Elevation":333,"Speed":46,"Observations":[


        {"SensorId":"ATRoadwatch","SourceValue":"17.1"},
        {"SensorId":"ATWxSensor","SourceValue":"18.3"},
        {"SensorId":"RHWxSensor","SourceValue":"24.6"},
        {"SensorId":"PRWxSensor","SourceValue":"86.1"},
        {"SensorId":"RTRoadwatch","SourceValue":"22.8"},
        {"SensorId":"SpGPS","SourceValue":"12.7986"},
        {"SensorId":"Spreader","SourceValue":"0"},
        {"SensorId":"WiperCount","SourceValue":"0"}
          ]
  }
    ]

  }

}
```

NEVADA DOT

SAFE AND CONNECTED

www.nevadadot.com