Michigan Department of Transportation
VII Test Bed Inventory Report

Center for Automotive Research
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All statements, findings, and conclusions in this report are those of the authors and do not necessarily reflect those of the Michigan Department of Transportation.

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EXECUTIVE SUMMARY

Michigan is home to the largest extent of roadside deployment of vehicle infrastructure integration (VII, now called IntelliDrive^{SM} at the federal level) in the United States. This infrastructure includes equipment deployed by the U.S. Department of Transportation (USDOT) and equipment deployed by the Michigan Department of Transportation (MDOT). All told, this deployment is split into eight different deployment areas (or test beds), with one belonging to USDOT and the rest to MDOT and its partners. To help keep track of what has been deployed where, MDOT asked the Center for Automotive Research (CAR) to complete an inventory off all VII assets deployed in southeastern Michigan. MDOT further requested that the inventory include a list of existing VII assets (hardware, software, etc.), an assessment of the status of these assets, a recommended plan for ongoing maintenance and improvement of the current deployment, and an RFP that MDOT could release for a contractor to implement this plan.

To complete the requested inventory, CAR researchers met with people involved in the deployed sites (especially Glenn Davies of the Road Commission for Oakland County), reviewed available documents pertaining to each site, and visited each roadside location (except for the USDOT test bed locations). From the discussions with informants, CAR researchers learned about the history of each deployed area and its current status. These discussions required multiple follow ups to obtain all desired information, and in some cases desired information simply was not available. During the site visits, CAR staff recorded the precise location (latitude and longitude) of each roadside unit and photographed each unit.

CAR researchers found that MDOT possesses a variety of VII assets and that other organizations also possess VII roadside equipment. The MDOT-owned assets are concentrated near Rock Financial Showcase in Novi, with a smaller concentration near the Chrysler Tech Center and a few other units located in other areas (e.g., along Telegraph Road). The USDOT VII Proof-of-Concept test bed amounts to the largest single deployment (at 56 units), while the Connected Vehicle Proving Center has the smallest deployment, with three units distributed between one rest area (I-94 eastbound near Chelsea) and two intersections along Nine Mile Road in Southfield.

In total this roadside deployment relies on several different vehicle-to-infrastructure communication technologies, including DSRC at 5.9 GHz, MotoMesh at two different frequencies, and Wi-Fi. While this prevents interoperability across all sites (at least with current in-vehicle units), it does provide a variety of test environments to meet the needs of testers.

In completing the requested asset inventory study, CAR researchers determined that the work and its products would be improved by including a spatial data component that maps the locations of all the roadside VII assets in Michigan, along with attribute information for each location. This work was completed using a combination of tools, including a hand-held GPS unit, the ArcMap GIS package, and the data collected about each site. The resulting GIS layers and data are another deliverable that CAR is providing to MDOT as part of this study.

CAR researchers found that the roadside units have the potential for a 10-15 year lifespan if the units are well installed and maintained. CAR has developed portions of an RFP that MDOT can use to obtain a vendor to perform upgrades and maintenance.

INTRODUCTION

During summer 2008, the Michigan Department of Transportation (MDOT) recognized that it would benefit from possession of a detailed inventory of its current VII deployments. MDOT further requested that the inventory include a list of existing VII assets (hardware, software, etc.), an assessment of the status of these assets, and a recommended plan for ongoing maintenance and improvement of the current deployment. In addition, MDOT requested a draft of the technical portion (tasks and prescribed scope of work) of an RFP that it could release to retain a contractor to implement the maintenance plan. Because the Center for Automotive Research (CAR) has an existing contract with MDOT whose scope includes such a study, MDOT asked CAR to develop a proposal for completing this inventory within Phase B of the existing CAR contract. CAR began work on the project in August 2008, and this report describes the findings from this study. The draft RFP sections are provided in separate document. Furthermore, CAR produced both Excel- and ArcGIS-based databases, and these have been provided to MDOT on CD, along with the photographs of each roadside unit.

The main sections of this report are:

- Data Collection Process
- Inventory of MDOT VII Assets
- Assessment of Status of MDOT VII Assets
- Plan for Maintenance, Integration, and Improvement of MDOT VII Assets

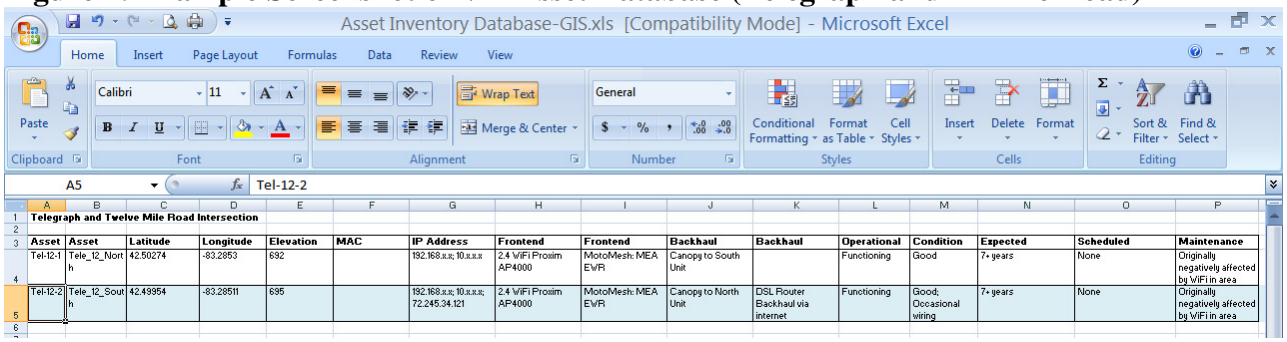
DATA COLLECTION PROCESS

The data collection process for completing the inventory consisted of three major components: meeting with people with a working knowledge of each deployment area, reviewing documents pertaining to the deployed sites, and visiting the location of each roadside unit. These visits did not include the USDOT DTE, because a web site containing detailed information about each roadside unit was available for this test area.

The first step in gathering data was to meet with Glenn Davies, Electronic Communications Specialist for the Road Commission for Oakland County (RCOC). He provided the CAR team with background information on the sites, as well as documents that detail various pieces of equipment at each site. He also pointed us to Booz Allen Hamilton's maintenance web site, which includes all the pertinent information for the USDOT Development and Test Environment. CAR researchers also collected information from other sources, including Azulstar, the company that set up the VII assets at the Chrysler Headquarters campus, and Udi Naamani of the Connected Vehicle Proving Center (CVPC).

The information collected from these informants and documents were organized into two data bases to support creation of an asset inventory. First, data was entered in an Excel database organized by each site. Figure 1 presents a screenshot of the database for the Telegraph and 12 Mile Road site as an example. Second, these data were copied into ArcGIS attribute data files so that the data could be queried from a GIS interface and so that MDOT would have a GIS-based record of all test locations.

Figure 1: Example Screenshot of VII Asset Database (Telegraph and 12 Mile Road)



In addition to gathering information from those involved in deploying VII assets and reviewing available documents, the CAR team also visited 40 sites and took photographs of the equipment and geocoded the position of each roadside unit using a mobile global positioning service (GPS) device. This geospatial information was also included in the two databases. CAR staff did not photograph the DTE sites, because their latitudes and longitudes were already provided in a website (http://66.202.167.42/rse_monitor/index.html) maintained by Booz Allen Hmailton. The photographs were named according to the location of the equipment photographed, and the GPS data were uploaded into a digital map using ArcGIS software. The location data were then colored-coordinated by deployment area to enable easy differentiation between the eight areas. Finally, the CAR team synchronized the Excel database with the attribute tables in ArcGIS to aid in asset information dissemination.

INVENTORY OF MDOT VII ASSETS

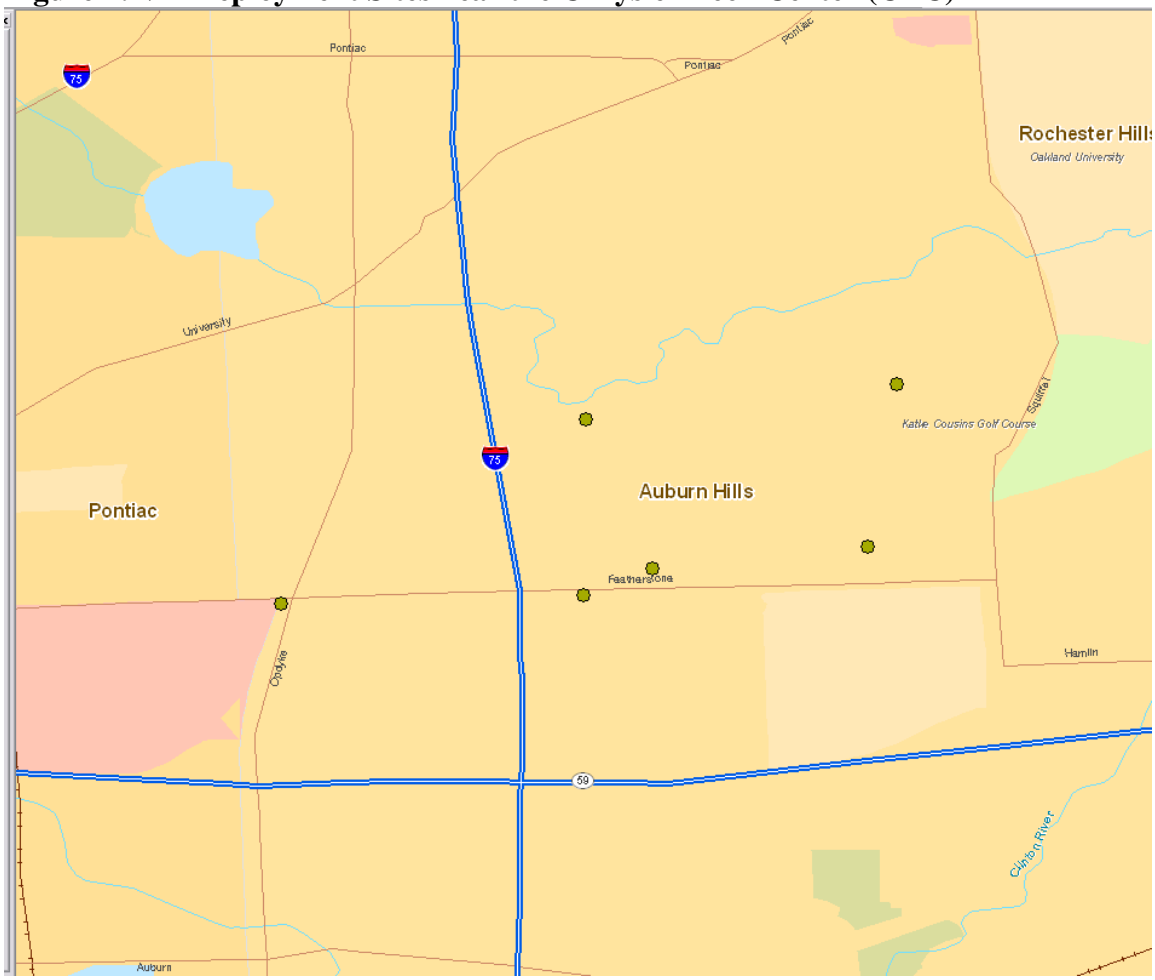
CAR researchers collected data for eight different VII deployment areas. The deployments in each of these areas are described below, focusing on the technologies deployed within each area, along with small-scale maps of the locations of roadside units (captured as screenshots from ArcGIS). In general, these eight areas each contain more than one roadside unit, and the GIS screenshots show these multiple locations. The eight test areas are:

- Chrysler Tech Center
- Telegraph and 12 Mile
- Telegraph and 15 Mile
- Farmington Hills (and parts of Novi)
- Rock Financial Showcase
- USDOT DTE (Novi and vicinity)
- CVPC Intersection (Southfield)
- CVPC Rest Area (Chelsea)

Chrysler Tech Center (Auburn Hills)

The Chrysler Tech Center (CTC) in Auburn Hills is home to six roadside VII locations (see Figure 2). Each of these sites contains 5 GHz and 2.4 GHz mesh radios that communicate with properly equipped vehicles (front-end communications), 2.4 GHz 12.5 dBi omni antennas, and 5 GHz 21dBi backhaul antennas. Three of these locations also have DSRC capability. These six sites were installed in June 2005 by Azulstar (with help from RCOC), use Proxim equipment, and are scheduled to be replaced soon. Thus, they will have had about a four-year operational life.

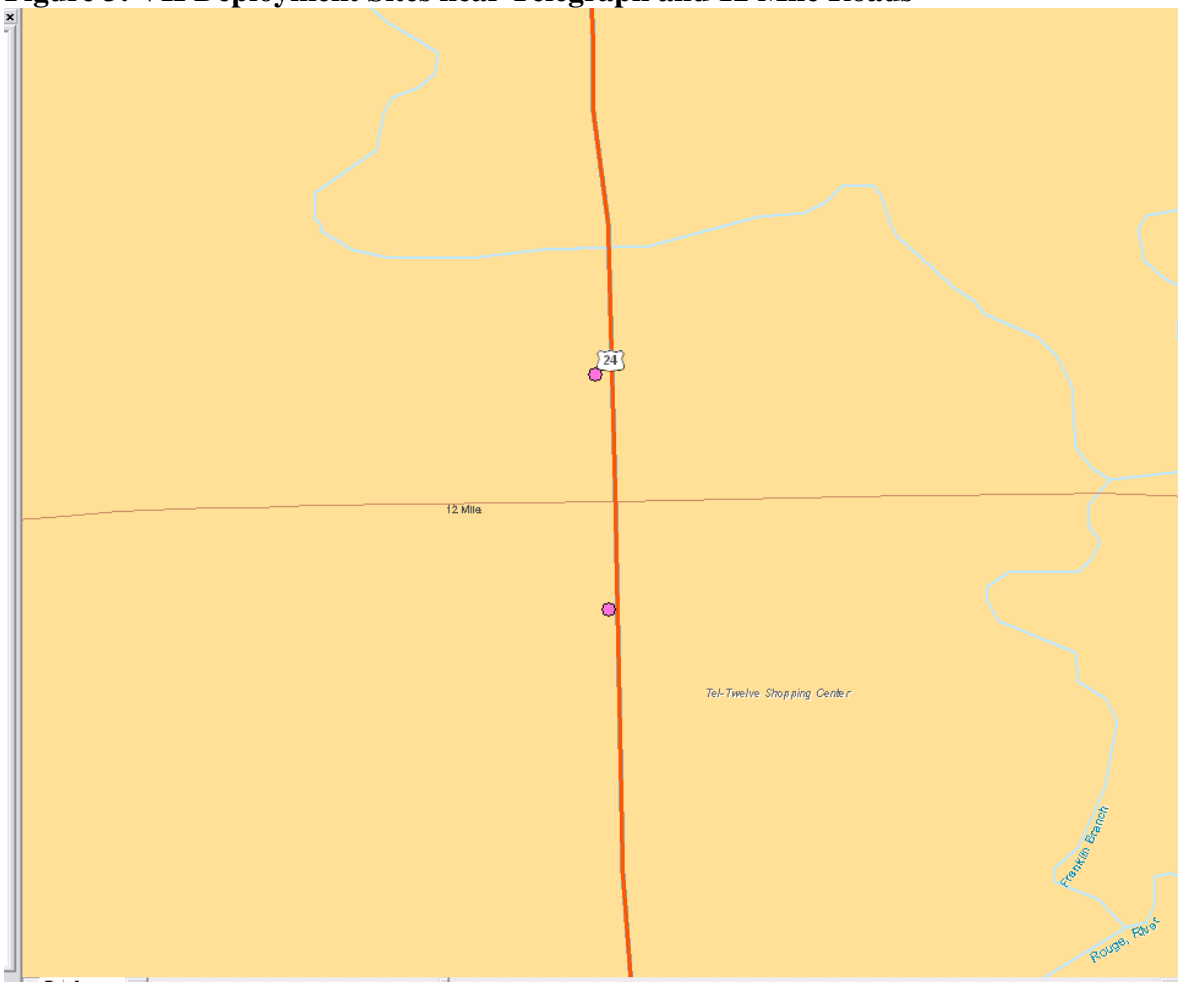
Figure 2: VII Deployment Sites near the Chrysler Tech Center (CTC)



Telegraph and 12 Mile Road (Southfield)

The intersection of Telegraph Road and 12 Mile Road has two VII roadside units in the vicinity, one north of the intersection along Telegraph and one south of the intersection on Telegraph (se Figure 3). This arrangement is best suited for the "Michigan left turns" at this intersection. Each of the two sites contains 2.4 GHz WiFi frontend radios (for communication with vehicles), as well as MotoMesh MEA EWR equipment. These units use Motorola and Proxim equipment, and both are currently functional. They were installed in December 2005, and Glenn Davies of RCOC estimates that they should remain in working order until 2015 or so. Neither site has an pending maintenance scheduled, though both sites experienced some interference from nearby Wi-Fi installations (e.g., in nearby businesses) that hindered their performance.

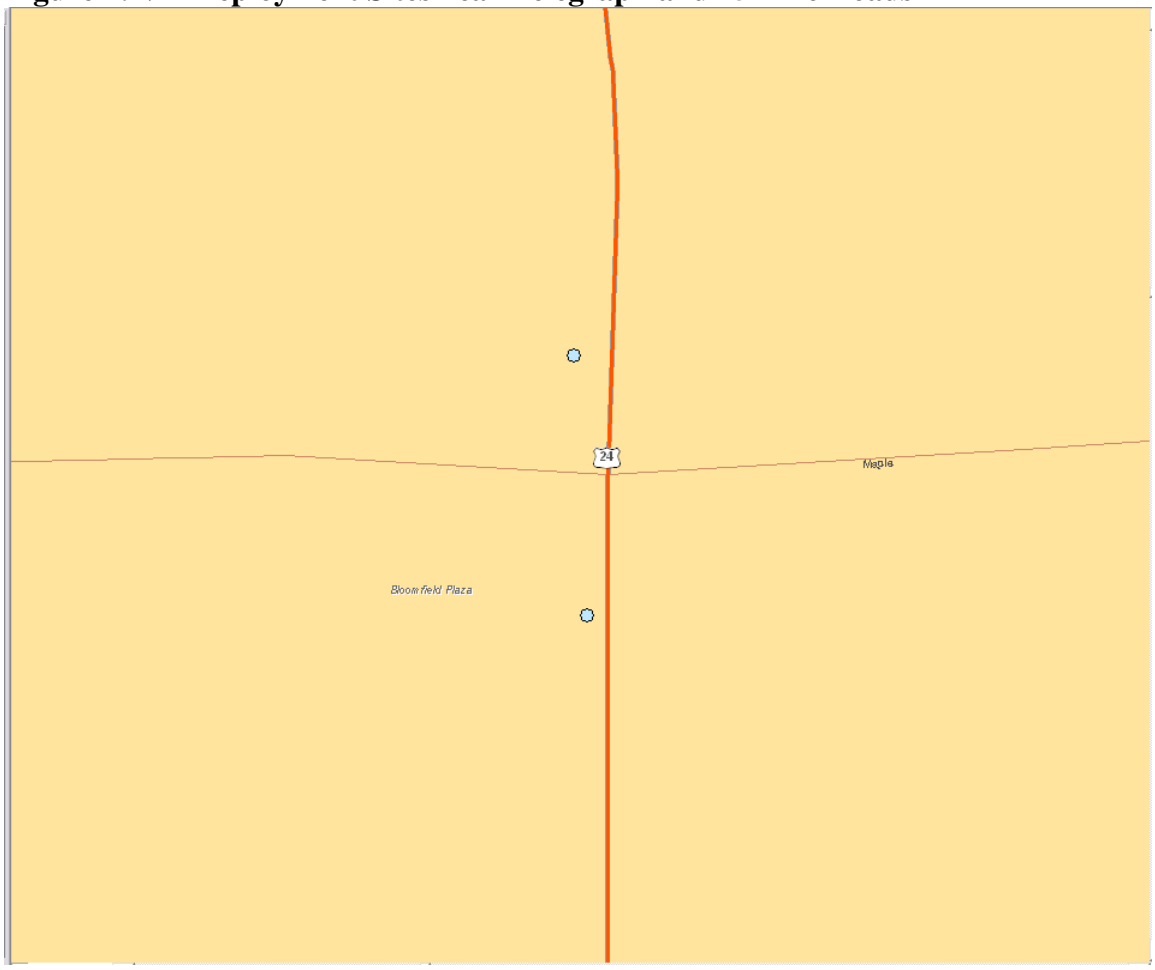
Figure 3: VII Deployment Sites near Telegraph and 12 Mile Roads



Telegraph and 15 Mile Road

Similar to the deployment at Telegraph and 12 Mile Roads, the intersection of Telegraph Road and 15 Mile Road has two roadside units, one north and one south of the intersection along Telegraph (see Figure 4). Again, this arrangement supports the Michigan left turns at this intersection. Each site contains 2.4 GHz Wi-Fi frontend hardware and 5.8 GHz backhaul hardware. These units were installed in June 2006, use Proxim equipment, and are currently functional. Glenn Davies estimates that they should remain operational until at least 2016, and they have no pending maintenance scheduled. The DSL router on the set-up south of the intersection has required two service calls since being installed (about one call every 15 months).

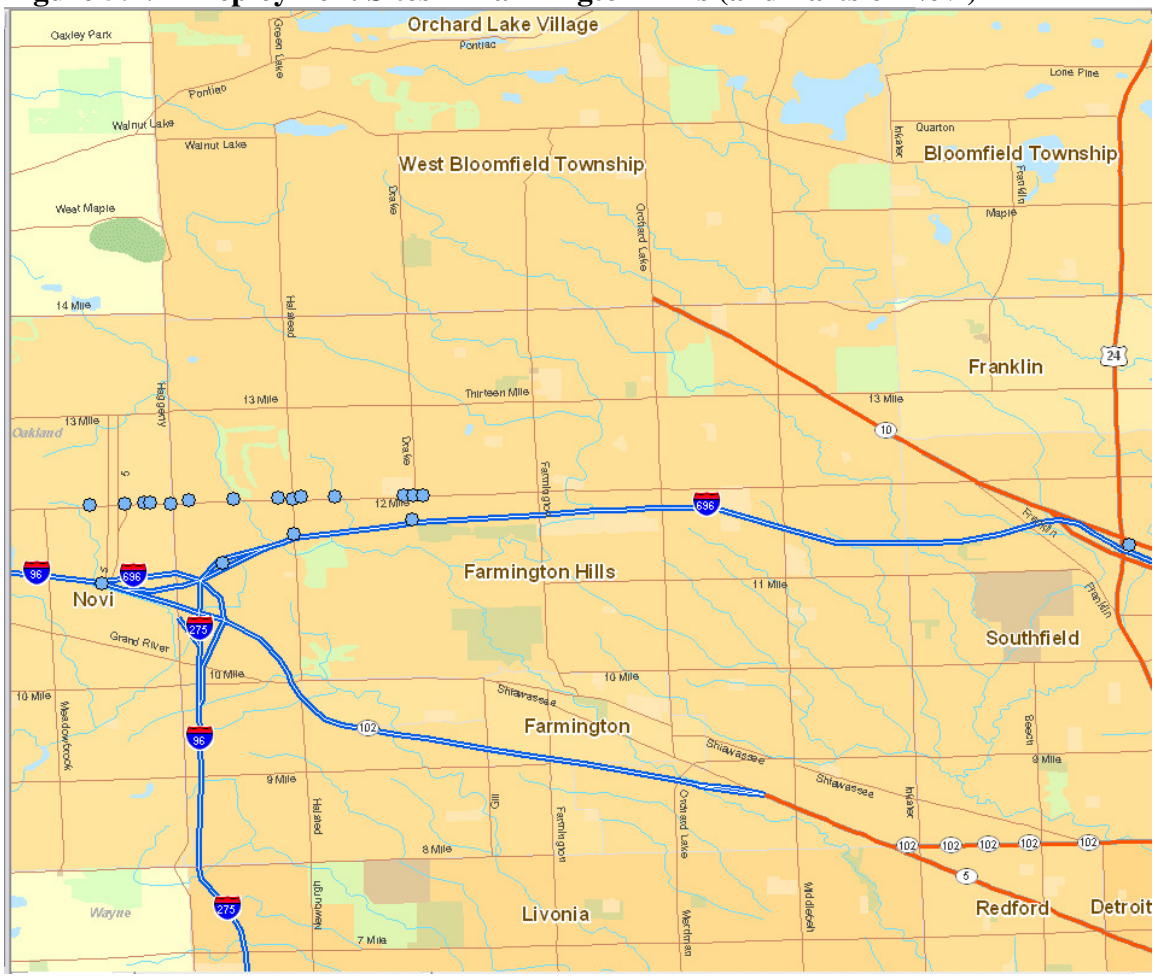
Figure 4: VII Deployment Sites near Telegraph and 15 Mile Roads



Farmington Hills

The VII roadside deployment area in Farmington Hills (and parts of Novi), largely along 12 Mile Road, is more complex than the previously mentioned areas due to both the number of units deployed and the types of technologies deployed. These locations primarily use Rauhorn and Motorola equipment, and the deployment area includes two large radio towers and 17 roadside equipment locations (see Figure 5). Of the roadside equipment locations, ten provide canopy service using either 5.7 GHz or 5.2 GHz frequencies. The remaining seven locations have 2.4 GHz WiFi and Mesh, 4.9 GHz Wi-Fi, and Mesh IAP6300 equipment. As of January 2009, this deployment area, which dates from March 2007, was not operational, because the two radio towers, which are critical components of the overall deployment, where not operational and slated for replacement. According to Glenn Davies, however, the roadside units proper are in working order and should be operational (assuming working towers are again in place) until 2023 or so. The roadside units have no scheduled maintenance pending.

Figure 5: VII Deployment Sites in Farmington Hills (and Parts of Novi)



Rock Financial Showcase (Novi)

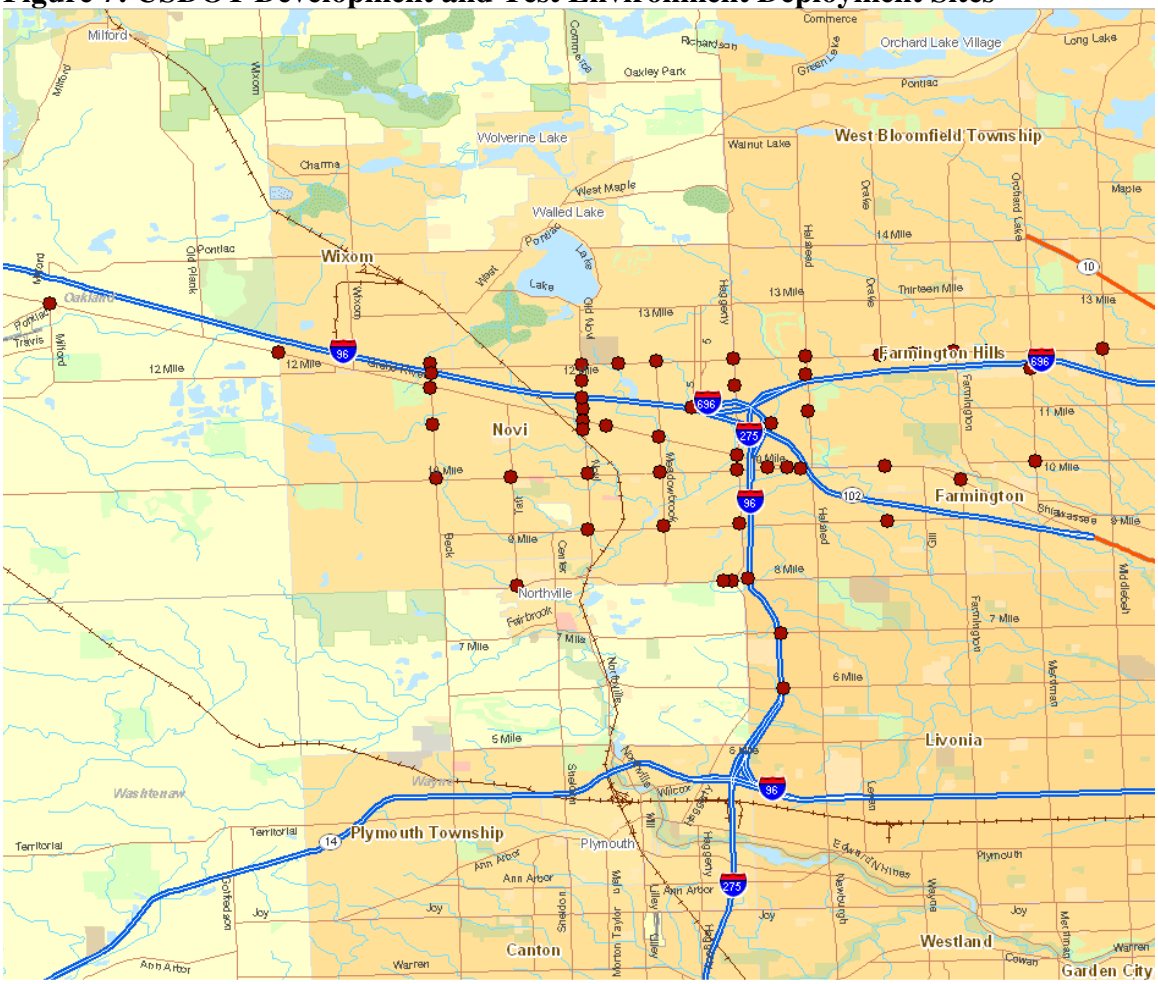
MDOT has deployed roadside VII units at nine locations in the vicinity of the Rock Financial Showcase (see Figure 6), and these use Motorola equipment. These locations were originally deployed in 2007, but the sites were completely rebuilt in 2008. These assets are not currently in use, but they have been tested and are in good condition. Aside from the one site that served as a Virtual Traffic Management Center (VTMC) at 12 Mile and Beck, the remaining eight sites use 2.4 GHz Wi-Fi and Mesh, 4.9 GHz Wi-Fi, and either Mesh IAP6300 or Mesh MWR6300 for frontend hardware. Three of these sites also have backhaul hardware of 5.8 GHz radios. The VTMC was removed after the ITS Michigan conference in May of 2008. Again, Glenn Davies estimates that the roadside units should be operational until 2023 or so, and they have no scheduled maintenance scheduled.

Figure 6: VII Deployment Sites near Rock Financial Showcase (Novi)

USDOT Development and Test Environment

With 58 roadside units, the VII Development and Test Environment (DTE) deployed by the USDOT in the Novi area is by far the largest single deployment of VII assets in Michigan (see Figure 7). The DTE roadside units were produced by Technocom (now part of Kapsch), installed by the RCOC, and managed and operated by Booz Allen Hamilton (BAH). The frontend hardware consists of 5.9 GHz DSRC, while the backhaul varies between 3G, WiMAX, and T1. BAH built and maintains a detailed website that posts and updates the status of each of the units. The website address is http://66.202.167.42/rse_monitor/index.html. These roadside locations have suffered from numerous failures due to environmental factors (e.g., water penetrating the cases and frying the electronics). With improved casing and protection from the elements in place, these units are checked frequently and have an unknown remaining life span, according to Glenn Davies.

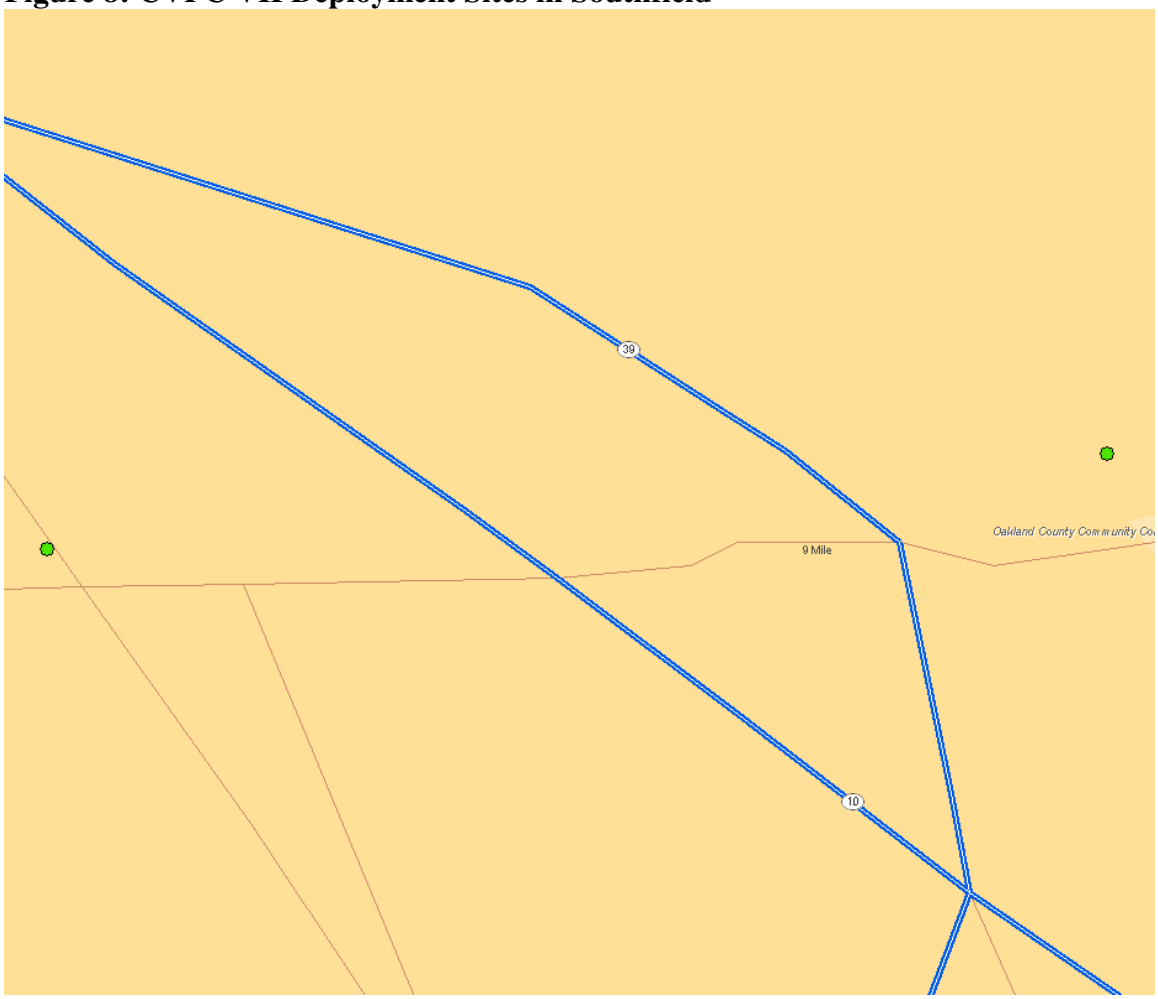
Figure 7: USDOT Development and Test Environment Deployment Sites



CVPC Intersection (Southfield)

The Connected Vehicle Proving Center sites in Southfield include two units, one at 9 Mile Road and Southfield Road, and the other at 9 Mile Road and Northwestern (see Figure 8). They have frontend hardware of WiFi and DSRC antennas, and a Motorola/Canopy Ethernet antenna for backhaul. These units were set up with assistance from Econolite and use Motorola technology, and are in current use and in good condition.

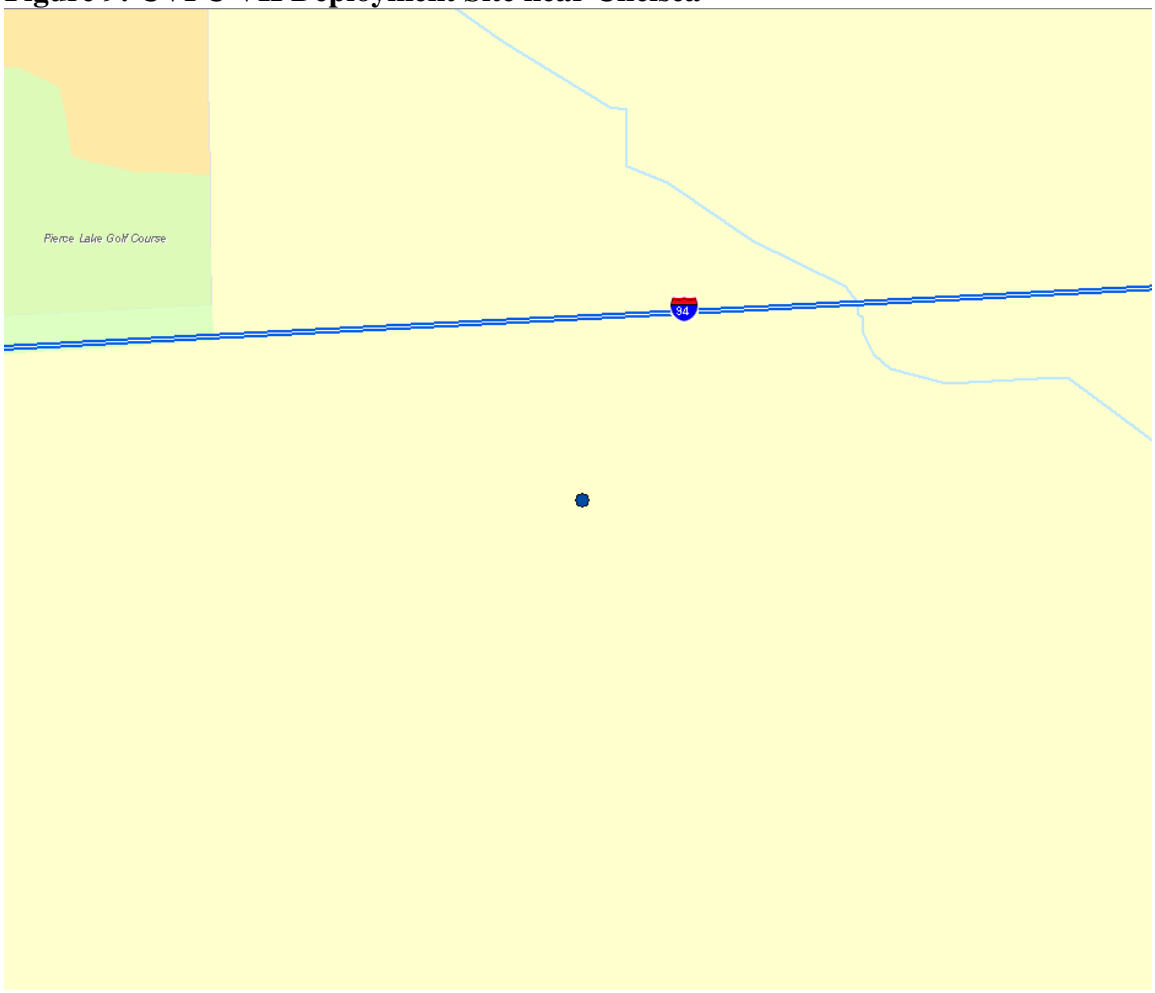
Figure 8: CVPC VII Deployment Sites in Southfield



CVPC Rest Area (Chelsea)

The CVPC also has created a VII deployment at the Chelsea rest stop off of I-94 (see Figure 9). It contains frontend hardware of WiFi and a Cisco 1811 managed router, and an Air-link BB router as backhaul. This unit was set up with assistance from Cisco, Nomadix, and ZOOM Information Systems and is currently in functioning and in good condition.

Figure 9: CVPC VII Deployment Site near Chelsea



ASSESSMENT OF STATUS OF MDOT VII ASSETS

Based on data related to the condition of the VII assets in Michigan collected as part of this inventory study, CAR researchers have determined that roadside VII units theoretically have a significant lifespan—perhaps has long as 10-15 years—if the units are properly installed to withstand harsh weather and other environmental factors. Of the Michigan deployments studied, CAR discovered that the largest failure occurred with the USDOT DTE sites, of which roughly half the roadside DSRC units failed within one year due to inadequate protection from water intrusion. These units have all been replaced and should now operate for an extended period of time, should USDOT choose to leave them in place.

The deployment near the CTC probably stands as the second most notable instance of failure of the units. These units were installed in 2006 and are scheduled for replacement in the near term. Thus, these units will not survive for the 10+-year lifespan estimate mentioned above, but this was the first deployment site in the State, and deployment here provided many valuable lessons that led to better installations elsewhere. Similarly, the deployment at Telegraph and 12 Mile Roads provided lessons on deploying Wi-Fi-based roadside units in a busy commercial strip home to much radio frequency interference.

Of the two more recent deployments undertaken by MDOT—those near Rock Financial and in Farmington Hills—the roadside units, based on Wi-Fi and Mesh technologies, were deployed in 2007-2008 and are predicted to be useful for roughly 15 more years, according to Glenn Davies of the RCOC. These deployments show the potential for roadside units to have a significant lifespan, with periodic maintenance.

PLAN FOR MAINTENANCE OF VII ASSETS

MDOT has tentative plans to release an RFP for a contractor to provide regular maintenance and upgrades for its roadside VII deployments. CAR is developing the technical sections of this RFP and will deliver them in a separate document. Nonetheless, some general concepts related to the maintenance plan are presented briefly below.

First, if the roadside VII units are properly installed to protect against weather and other climatological effects, then maintenance can be fairly simple, consisting of a yearly test and inspection of the units. This is made simpler if the units are being used on a regular basis for vehicle-to-infrastructure communication in that regular use will reveal any problems as they emerge.

Second, as standards are further developed by SAE, IEEE, and others involved in the IntelliDrive standards process, the MDOT infrastructure likely will need to be upgraded to stay current with the emerging standards. This could require complete replacement of roadside units (radios) or only software updates, depending on the extent of the changes and the desire to remain compliant with all developed standards.

CONCLUSIONS AND RECOMMENDATIONS

CAR's investigation of VII roadside deployment sites in Michigan shows that the State has a wealth of test sites available, but these sites are not all interoperable given current in-vehicle

technology and some sites require upgrading. This could present an important expense for MDOT going forward.

CAR's investigation also found that the various parties (contractors, etc.) involved in creating the Michigan VII sites have not provided MDOT with a consistent set of information about each site. Thus, CAR's most important recommendation is to ensure that consistent and complete records are maintained for MDOT VII assets from now on. This will ensure data are comparable between sites, and that the database has complete information. The information that should be documented for each distinct asset location includes, at a minimum:

- Asset identification number
- Descriptive name of the asset (suggests rough location)
- Latitude
- Longitude
- Elevation (ft)
- MAC address (for hardware that has one)
- IP address (for hardware that has one)
- Frontend (vehicle-to-infrastructure) communication hardware (e.g., Kapsch DSRC box)
- Frontend communication protocols (e.g., DSRC at 5.9 GHz)
- Backhaul Hardware (1,2,3…as many as necessary)
- Operational status of each location
- Expected remaining life
- Scheduled maintenance
- Maintenance history

Including the above information will make database entries more thorough and consistent across sites.