CHAPTER 13: DATA MANAGEMENT

Proof of concept for many of the prototype vehicles' add-on technologies involved comparing, organizing, and otherwise working with data collected by systems on the vehicles. As described in Chapter 6, Rockwell's PlowMaster was critical to this process. Data outputs from vehicle sensors and other technologies were collected on the PlowMaster, which formatted the various data outputs in a common format and stored the data on PCMCIA cards for delivery to CTRE. Figure 13-1 demonstrates the data flow during Phase II.

As data outputs were delivered from the state DOTs via PCMCIA cards, CTRE staff invested significant effort in developing procedures for organizing, translating, and manipulating the data. In Phase II, these efforts were critical for determining if data being collected by the add-on technologies were reasonable and if the systems appeared to be working as expected; that is, the data were critical to proof of concept. In the future, these Phase II development efforts will provide the basis for statistical analyses and reporting to be conducted during the Phase III field evaluations, as well as a foundation for developing data formats that will make the data accessible to DOTs' management systems.

This chapter briefly discusses CTRE's process for managing data downloaded from the PCMCIA cards.

OBJECTIVE

Conduct proof of concept regarding formatting and organization of data collected by technologies on winter maintenance vehicles to support proof of concept of the various add-on technologies and to provide a foundation for future use of data collected by the vehicles in maintenance decision making and in DOT management systems.

MEASUREMENT

Raw data downloaded from PlowMaster PCMCIA cards are converted to more understandable terms: GPS latitude and longitude to mileposts, GPS time to Central Standard Time, GPS speed to distance traveled by the vehicle. After conversion, data are plotted in graphs using various parameters.

DISCUSSION

In Phase II, data collected by the prototype vehicles' onboard technologies were stored on PCMCIA cards and delivered to CTRE via one of three avenues, at the convenience of the individual states:

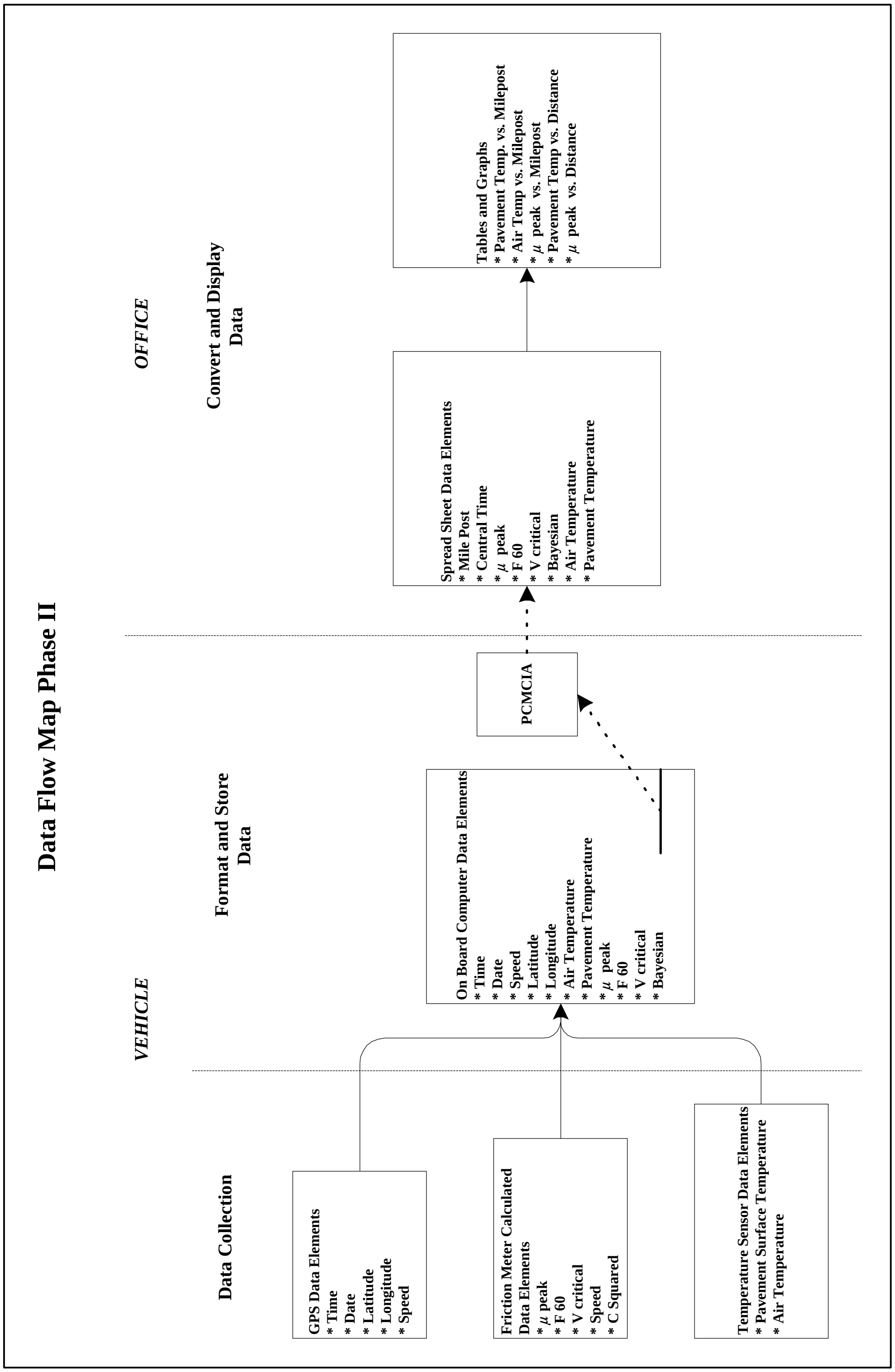

Figure 13-1 Phase II data flow chart

1. CTRE staff went to the vehicle location, collected the PCMCIA card, and returned with the card to CTRE where they downloaded the data, cleared the card, and mailed it back to the originating location.

2. Local maintenance personnel removed the PCMCIA card from the PlowMaster and transmitted the card via overnight mail to CTRE. CTRE downloaded the data, cleared the card, and mailed it back to the originating location.

3. Local maintenance personnel removed the PCMCIA card from the PlowMaster, downloaded the data, and transmitted the data via electronic mail to CTRE.

Data downloaded at CTRE from the PCMCIA cards were imported into Microsoft Excel 7.0 for translation and organization. All files were organized at CTRE by state, technology, and date and stored permanently on zip disks along with a detailed directory structure. They are available for distribution on request.

The raw data sets from the PCMCIA cards contained thousands of data points, which CTRE filtered down to sets containing only necessary data points collected by correctly operating equipment. Raw GPS time and location data downloaded from the PlowMasters were not referenced in terms that were meaningful to most DOT staff or the study team, and CTRE converted these data to commonly understood terms for easier analysis. Also, distance data were not provided on the PlowMaster data sets; CTRE therefore computed distances and added distance data points to the data sets.

A macro program was written in Visual Basic to simplify and accelerate the tedious process of converting location and time data, computing distance traveled by the vehicles in each data capture run, and plotting graphs in Microsoft Excel; the complete macro code is included in Appendix I. For each data set collected and filtered in the winter of 1997-1998, all parameters were plotted against each other and reviewed for discrepancies, trends, etc. The macro will greatly facilitate data management during Phase III evaluation.

Raw Data from PlowMaster

All three prototype vehicles recorded sensor outputs during the winter of 1997-1998 and transferred the results to CTRE, for a total of 35 data files. On data capture trips, the Rockwell onboard computers recorded sensor outputs every ¼ second. Data runs lasted from five minutes to two hours, generating data files containing thousands of data points, often more than 10,000.

Table 13-1 lists the names of the files in the file directory, using the following naming convention:

- The “A” indicates the file is from the onboard computer.
- The first two digits indicate the calendar date when the file was created.
- The next one or two digits indicate the digit(s) of the current month.
- The next digit indicates the last digit of the year.

- The last two digits indicate the number of this file, in relation to other ones recorded the same day.

For example, using the file A141801.xls from Minnesota:

- The “A” means this file is from the onboard computer.
- The first two digits, 14, indicates the calendar date of the day when the file was created (the 14^{th}).
- The next digit, 1, indicates the month is January.
- The next digit, 8, indicates the last digit of the year, 1998.
- The last two digits, 01, indicates this file was the first to be recorded for this date.

The naming convention was the same for data files from all three prototype vehicles.

Tables 13-2 , 13-3, and 13-4 are excerpts of data sets (onboard sensor outputs) received on the PCMCIA cards by CTRE, one data set from each of the prototype vehicles.

- The first five columns (UTC Time, Lat, Lon, Heading, and GPS Speed) are GPS outputs (i.e., the GPS stamp).
- The next two columns (air temp and road temp) are temperature sensor outputs.
- The Mu Peak values are outputs from the friction meter sensors. (Readings of –1 indicate the sensor was not reporting when these data were recorded.)

Table 13-1 File directory, winter 1997-1998

State	Date	File Name
Iowa	01/04/98	A041801.xls
	01/05/98	A041802.xls
	01/12/98	A121801.xls
	01/14/98	A141802.xls
	01/21/98	A201801.xls
		A211801.xls
	01/22/98	A221801.xls
	03/02/98	A023801.xls
	03/07/98	A073801.xls
	03/08/98	A083801.xls
		A083802.xls
		A083803.xls
		A083804.xls
	03/09/98	A093801.xls
Michigan	01/08/98	Nm.xls
	01/14/98	A141801.xls
	02/24/98	A242801.xls
	03/04/98	A043801.xls
	03/06/98	A063801.xls
		A063802.xls
	03/09/98	A0681026.xls
		A0681058.xls
		A093801.xls
		A093802.xls
Minnesota	11/13/97	A13b701.xls
	11/14/97	A13b702.xls
		A14b701.xls
	11/15/97	A15b701.xls
		A15b702.xls
		A15b703.xls
	12/30/97	A30c701.xls
	12/31/97	A31c701.xls
	02/05/98	A052801.xls
	03/23/98	A233801.xls
	04/01/98	A014801.xls
		A014802.xls

Table 13-2 Sample data from onboard computer data file A041801.xls, Iowa vehicle, January 4, 1998

UTC Time	Lat	Lon	Heading	GPS Speed	Air Temp	Road Temp	μ Peak (as x 1,000)
65668	41.6646108	-93.5764253	347.499	37.536	33.75	24.00	731
65669	41.667580	-93.5764689	347.499	37.446	33.75	24.00	731
65670	41.6649047	-93.5765130	347.270	37.491	33.75	23.88	540
65671	41.665014	-93.5765560	347.671	37.312	33.75	24.63	540
65672	41.6651975	-93.5765978	347.957	37.178	33.75	23.25	540
65673	41.6653425	-93.5766385	348.129	36.842	33.63	23.88	540

Table 13-3 Sample data from onboard computer data file A141801.xls Michigan vehicle, January 14, 1998*

UTC Time	Lat	Lon	Heading	GPS Speed	Air Temp	Road Temp	μ Peak (as x 1,000)
219765	44.0059180	-85.5030835	192.170	10.133	31.25	23.88	-1
219766	44.0058916	-85.5030910	192.055	5.816	31.25	23.75	-1
219767	44.0058796	-85.5030944	192.285	2.684	31.25	24.00	-1
221816	44.1674611	-85.4381147	317.416	6.331	31.13	24.63	-1
221817	44.1674731	-85.4381342	314.325	3.982	31.00	25.13	-1
221818	44.1674777	-85.4381457	302.293	1.767	31.00	25.38	-1

*Friction sensors were not reporting and did not record μ_{peak} values.

Table 13-4 Sample data from onboard computer data file A13b701.xls Minnesota vehicle, February 5, 1998

UTC Time	Lat	Lon	Heading	GPS Speed	Air Temp	Road Temp	μ Peak (as x 1,000)
417826	44.6563648	-93.6771439	242.934	42.233	26.38	19.00	680
417827	44.6562875	-93.6773564	242.877	42.345	26.25	17.88	680
417828	44.6562101	-93.6775690	242.934	42.256	26.25	18.63	680
417829	44.6561339	-93.6777827	243.335	42.300	26.38	17.00	680
417831	44.6559821	-93.6782102	243.564	42.233	26.38	17.38	680
417832	44.6559065	-93.6784244	243.564	42.412	26.38	17.75	680

Data Filtering

Data delivered to CTRE on PCMCIA cards included several data points related to friction that were superfluous to the project's data management goals or simply incorrect. For example, F60 friction values are the equivalent of μ_{peak} (mu-peak) when vehicles travel at 60 km/hr on dry pavement. Because data required for proof of concept of the ROAR friction meter included only those collected under winter conditions (wet, snow, and ice), the F60 values are not needed for purposes of this project.

Generally, μ_{peak} is a measure of friction with a range of zero to one; the reading for μ_{peak} should therefore never be negative or more than one. PlowMaster multiplies the recorded μ_{peak} by 1,000 (to avoid fractions), creating an acceptable range for μ_{peak} up to 1,000. Some μ_{peak} values, however, were recorded above 1,000, indicating that the ROAR friction meter was not operating correctly.

Finally, some data sets included friction data points with values of zero or –1. According to Rockwell, zero indicated that the ROAR friction meter was turned on but not able to record friction because the ROAR device was not touching the roadway surface. The –1 indicated that the ROAR friction meter was not turned on or not working.

To provide realistic and manageable data sets for graphing and other data reduction purposes, CTRE created data sets that filtered out the following information:

- Friction values of 0 or -1

- μ_{peak} readings outside the range of 0-1,000

All original data sets containing all data points are stored at CTRE.

Conversion to Central Standard Time

The Rockwell onboard computer recorded time in Uniform Time Conversion (UTC) time, which is the number of seconds past midnight Sunday at the International Dateline. UTC time therefore needed to be converted to days, hours, minutes, and seconds in Central Standard Time. This was a fairly straightforward conversion using Equations 2 through 5.

$$Day = \frac{UTC\ \mathrm{sec}}{86{,}400\ \mathrm{sec}/\,day} \quad [2]$$

$$Hour = \left(\frac{UTC\ \mathrm{sec}}{86{,}400\ \mathrm{sec}/day} - Day\right) \times \left(24\ hrs/day\right) - 6\ hr \quad [3]$$

$$Minute = \left(\frac{UTC\ \mathrm{sec}}{60\ \mathrm{sec}/\mathrm{min}}\right) - \left(Hour \times 60\ \mathrm{min}/hr\right) - \left(Day \times 1440\ \mathrm{min}/day\right) - \left(6\ hr \times 60\ \mathrm{min}/hr\right) \quad [4]$$

$$Second = UTC\ \mathrm{sec} - \left(Day \times 86{,}400\ \mathrm{sec}/day\right) - \left(Hour \times 3600\ \mathrm{sec}/hr\right) - \left(6\ hr \times 3600\ \mathrm{sec}/hr\right) \quad [5]$$

where
UTC = Uniform Time Conversion
6 hr = Time difference between International Dateline Time and Central Standard Time
86,400 = Number of seconds per day
3,600 = Number of seconds per hour

Computing Distance Traveled

A data point desired by CTRE but not recorded by any of the on-board technologies to the PlowMaster was distance traveled by the prototype vehicle. CTRE therefore calculated the distance, using GPS speed and UTC time elapsed, as shown in Equation 6:

$$\mathrm{Dist, ft} = \frac{\mathrm{Speed\ mi/hr} \times \mathrm{Time, sec} \times 5{,}280\ \mathrm{ft/mi}}{3{,}600\ \mathrm{sec/hr}} \quad [6]$$

where
Speed = Speed of the Vehicle in miles per hour
Distance = Distance Vehicle Traveled in feet
Time = Time Elapsed between Readings in seconds

Conversion to Milepost

The GPS vehicle location is recorded in latitude and longitude coordinates, and there is no commonly used reference point for these coordinates. DOT maintenance personnel wanted to know where their vehicles were in relation to mileposts on their routes, so a conversion from GPS distance to milepost was completed along the vehicle routes.

With the GPS transponder collecting location (latitude/longitude) data, the prototype vehicles were driven their assigned routes and stopped for approximately five seconds at each milepost. CTRE graphed these data runs and documented locations where vehicle speed was zero. CTRE recorded the latitude and longitude values where the vehicle speeds were zero and established the correlation for milepost locations. (Minnesota did not complete this exercise but instead provided CTRE with milepost latitude and longitude values.) Figure 13-2 shows sample data, using the Iowa vehicle, of the speed run for establishing this correlation.

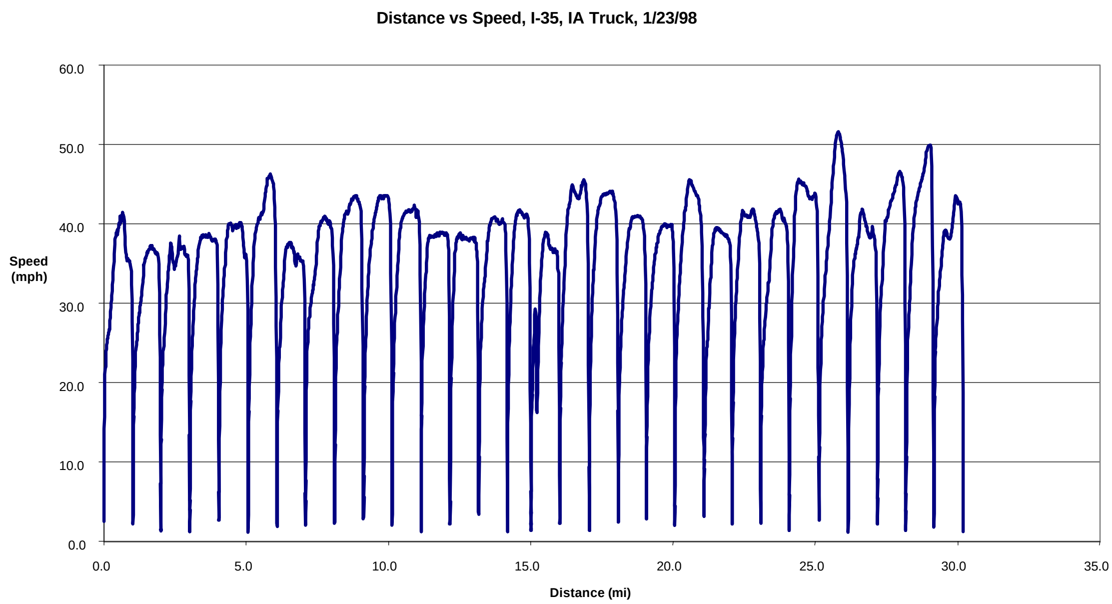

Figure 13-2 GPS speed versus distance, Iowa truck, January 23, 1998

Equation 7 was then used for the conversion from latitude and longitude to milepost along the Iowa vehicle's route:

$$\text{milepost} = 88.0 + (x - 41.66480) / (41.86635 - 41.66480)\ (102 - 88) \qquad [7]$$

where "x" is the latitude in degrees

Equation 7 applies to mileposts 87.5 to 104 along I-35 in Iowa. A similar equation was developed for Minnesota and for Michigan to convert GPS latitude and longitude to milepost.

After converting GPS location data, users could look at sensor output reports and relate them to known milepost locations, allowing CTRE and the DOTs to observe trends in sensor outputs, erroneous data points, or equipment malfunctions and relate them to milepost locations. CTRE then plotted various sensor outputs from the Rockwell onboard computers, using milepost as the y-axis.

Figures 13-3 through 13-6 demonstrate some of the ways in which parameters were plotted. These figures represent sample data collected for proof of concept; data anomalies were not closely examined during Phase II.

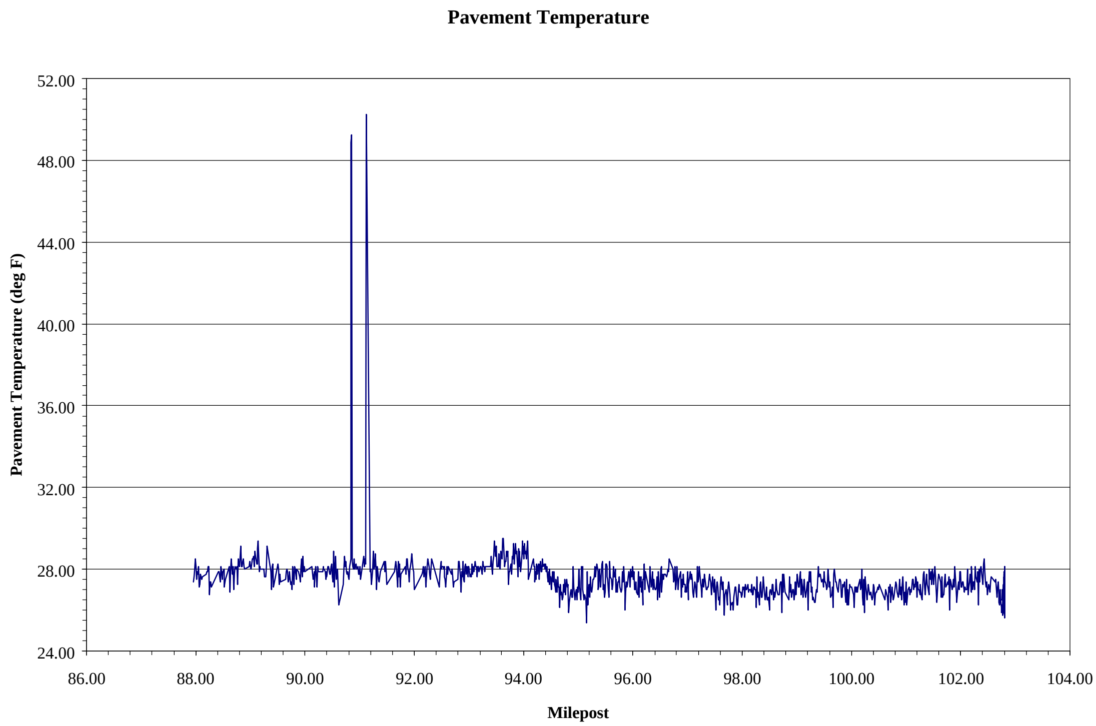

Figure 13-3 Pavement temperature versus milepost, Iowa vehicle, January 4, 1998

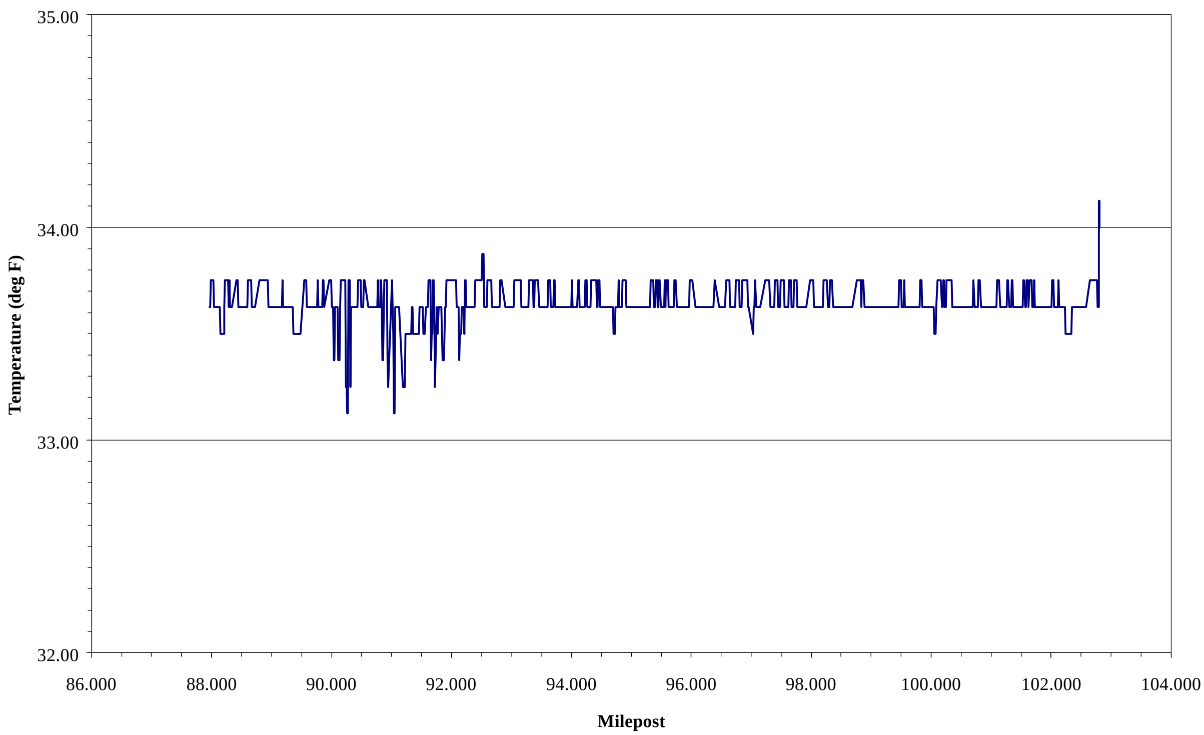

Figure 13-4 Air temperature versus milepost, Iowa vehicle, January 4, 1998

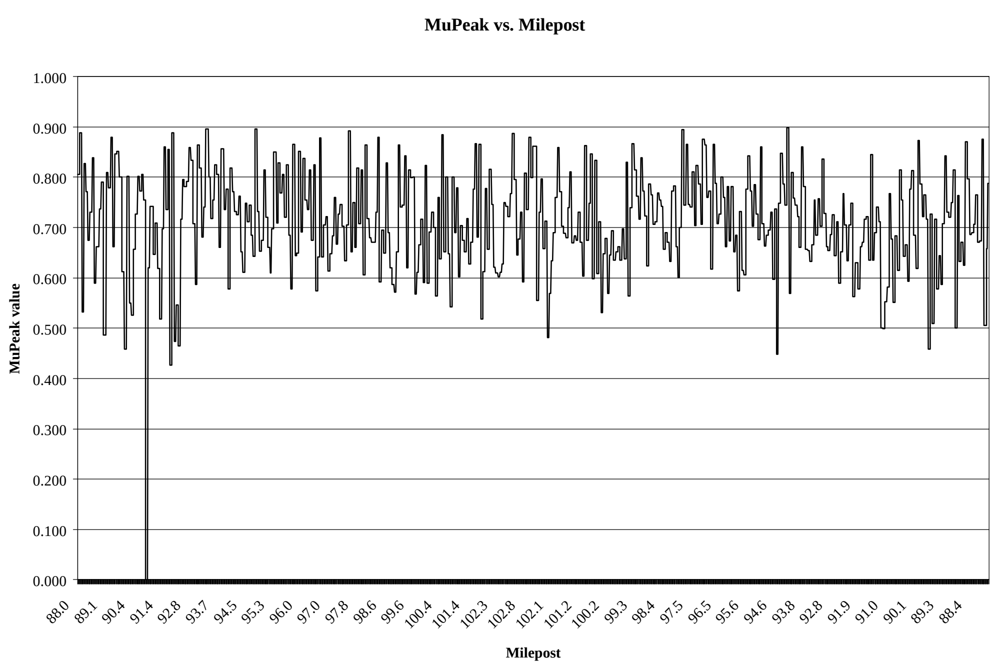

Figure 13-5 μ_{peak} versus milepost, Iowa vehicle, January 4, 1998

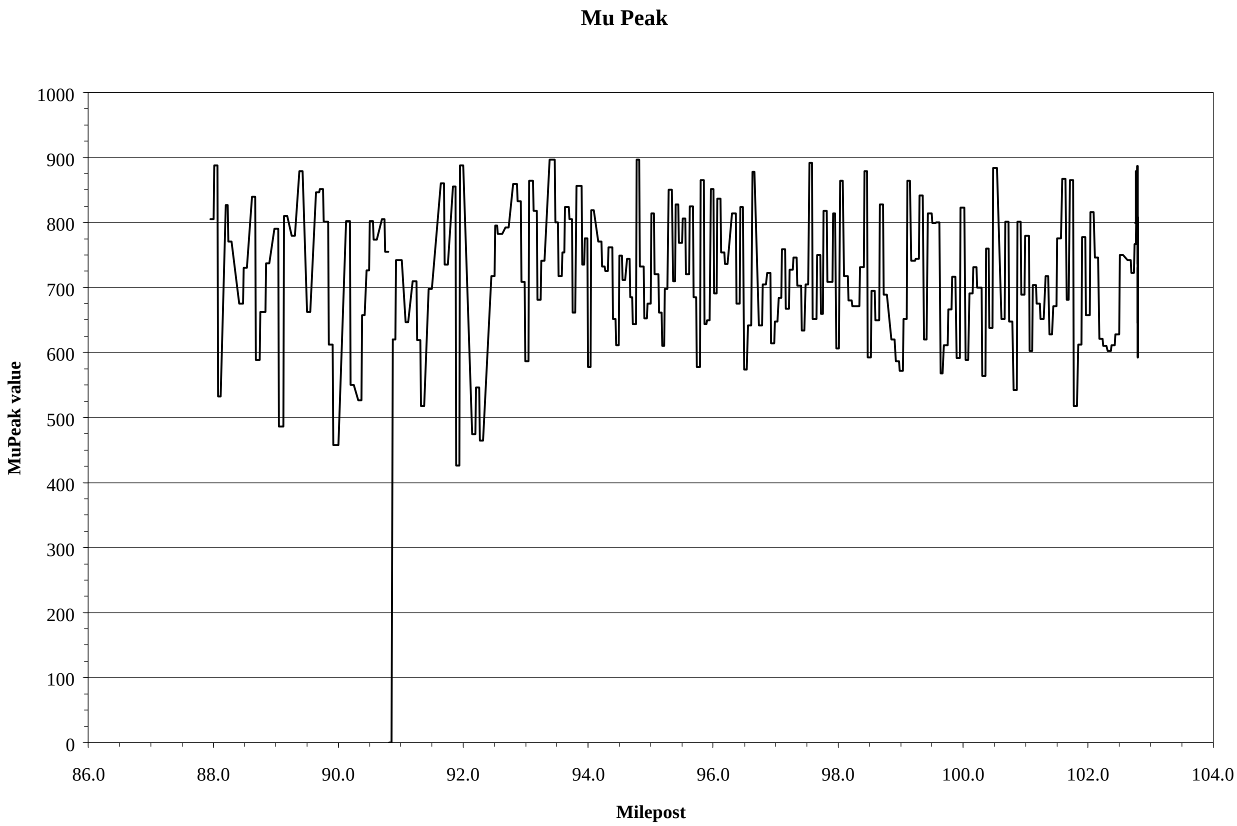

Figure 13-6 μ_{peak} versus distance Minnesota vehicle, February 5, 1998

OBSERVATIONS

Proof of concept regarding formatting and organizing data collected by technologies on the prototype vehicles was successful. Data were successfully downloaded from PCMCIA cards, filtered as necessary, translated into user-friendly terms, and plotted to find trends, erroneous data, and system malfunctions. Data files were stored in DOT format for use with decision-making tools like management systems.

Phase II data management activities demonstrated that data collected on winter maintenance vehicles can be translated into meaningful and useable data. The activities also helped identify problems with data collected by the onboard technologies so that adjustments could be made and proof of concept successfully accomplished for the technologies. The development activities for data management accomplished during Phase II will greatly facilitate data management processes in future phases.