Modeling Workgroup
Mobile Sources Technical Review Subcommittee
Detroit, Michigan
December 2, 2003

Introduction

John Koupal (USEPA) and Megan Beardsley (USEPA) called the meeting to order at approximately 10:00 a.m., and Workgroup participants introduced themselves. The purpose of this meeting was to update the Modeling Workgroup on the progress of the Motor Vehicle Emission Simulator (MOVES) model, and provide as much technical detail as possible about the model. The following presentations were given:

- MOVES Fleet & Activity Inputs 1999 Base Year, Megan Beardsley
- MOVES Update, John Koupal
- Data Acquisition and Management for MOVES, Carl Scarbro (USEPA)
- Emission Rate Development, John Koupal
- Review of MOVES Draft Design, Chris Lindhjem (ENVIRON)
- Discussion of CRC and NYDEC Comments, John Koupal
- MOVES Demonstration, Mitch Cumberworth (USEPA)

MOVES Update

John Koupal presented recent progress on the MOVES model. Acronyms have changed to reduce confusion, and the implementation schedule has been revised. 1999 will be the base year. The first version of the model, MOVES2004, addresses energy consumption and greenhouse gases (carbon dioxide (CO_2), methane (CH_4), and nitrogen oxide (N_2O)), and should be released in May 2004. MOVES2005 will add draft aircraft, marine, and locomotive emission estimates. MOVES2006 will finalize the 2005 additions, and will also include onroad vehicles. MOVES2006 will be a draft replacement for MOBILE6. The final onroad and draft nonroad emission estimates will be included in MOVES2007. The implications of this new schedule are that States will have to use MOBILE6 for their Particulate Matter State Implementation Plans (SIPs).

Jeremy Heiken (Air Improvement) is concerned that States will have to use MOBILE6 emission rates (which have not been updated for several years) in their fine PM SIP developments, where modeled emissions factors are only a function of calendar year (and do not address the key effects of temperature, in-use deterioration, I/M, fuel use and operating mode). Has there been any effort to develop a more robust PM emission rate methodology? Gene Tierney (USEPA) replied that he has undertaken a project to evaluate PM emissions in light-duty (LD) vehicles in Kansas City starting in 2004. Those results combined with the CRC E55 project, which will evaluate PM emissions in heavy-duty (HD) vehicles, will be used to update emission factors for MOBILE6. MOBILE Version 6.2 was designed to facilitate substitution of new emission factors. However, this new information will not be available in time for the SIP

planning process. Only those States that start late would be able to take advantage of the improved factors.

MOVES Fleet & Activity Inputs

Megan Beardsley has been spending recent months developing fleet and activity inputs for MOVES2004. Her presentation described the inputs necessary for the Core Model, including total activity, source bin distribution, and operating mode distribution. She discussed the concept of generators, which provide a link between the generic core model and specific implementations. Generators produce core model inputs from available data.

Source types are defined by activity while source bins are defined by emissions characteristics. Long-haul trucks are defined to be trucks that travel more than 500 miles in a typical trip. Some activity inputs were determined using vehicle in-use surveys (VIUS), and the NEMS-DOE Model was used to project future vehicle miles traveled (VMT).

John Byun (FHWA) asked if the VMT growth rate is an input variable, how should the external-external (E-E) travel be dealt with? E-E travel is a problem where a lot of vehicles travel through the modeling area, but these vehicles do not have an engine start in the modeling area. E-E travel would lower the ratio of starts to VMT and the future ratio of E-T travel to I-I (internal-internal) travel could be changed. Ms. Beardsley responded that the model does allow for off-network travel. Mr. Koupal added that this is a larger issue for mesoscale modeling than for the current macroscale implementation of MOVES.

Albie Hochhauser (Exxon/Mobil) stated that Slide 20, which showed a schematic of the model, suggests that source bin distribution and activity/operation modes are independently distributed. Is there an activity for each source bin distribution? He thought that they should be completely integrated. Ms. Beardsley replied that they are independently distributed, but they are from the same set of activity data. An attempt was made to split up source use type by activity, and then to assume within a type that the hours within the activity data do not differ. Source bins are divided by model year group and age (assuming that older vehicles are driven less than newer vehicles); however, it should not be assumed that Tier I vehicles are driven differently than Tier II vehicles.

One caller asked whether heavy use vehicles such as taxis would be classified differently. Ms. Beardsley replied that MOVES currently does not have a taxi source type, but that is something that could be added in the future if it is needed.

Mr. Heiken stated that when examining the local HPMS data for Detroit, it appears that one in five light duty vehicles (LD) are trucks, while MOBILE estimates two in five are trucks based on national sales data. It appears from these data that HPMS systematically undercounts LD trucks and Mr. Heiken asked whether EPA was planning to address this apparent bias in the HPMS data. Ms. Beardsley replied that she has seen studies that have shown problems estimating LD truck VMT. EPA is planning to study fuel-consumption estimates to compare the data.

Mr. Heiken acknowledged that the collection of MOVES activity inputs is geared to be similar to MOBILE inputs. He asked whether grade and topography effects, which have yet to be addressed with MOBILE, would also be finally addressed in MOVES. Ms. Beardsley replied that EPA would like to add grade/topography; however, EPA does not have any details yet. Mr. Koupal added that for macroscale, MOVES still assumes that the world is flat; grade will come into play on the mesoscale. Grade could be added at the macroscale level, but EPA would not be confident about its accuracy. Mr. Byun added that grade could be dealt with for wreckers and other towing vehicles by adding additional weight. Also, the Department of Transportation (DOT) has elevation data and grade. Ms. Beardsley stated that getting data by county could be problematic. Sue Kimbrough (USEPA) stated that grade data can be problematic. Some State DOT's have grade information while others do not. When developing mesoscale models, it is important to remember that when roadways are built, the actual roadway constructed may be different than what was described in the plan. Therefore, to have accurate data, the roadways in question would need to actually be surveyed. This is especially true with interstate highways where a lot of cut and fill may occur. In one study, the EPA used a geographic positioning system (GPS) and drove major freeways; however, this method was problematic. The issue also may become more complex when utilizing geographic information systems (GIS).

Ted Younglove (UC-Riverside) said that on the macroscale, model year groups were not defined well enough. The variability increases with LD vehicles, especially for NH_3 where emissions from mid-90's models would be greater than emissions from late 90's models. This variability would also exist between the super ultra low emitting vehicles (SULEVs) and ultra low emitting vehicles (ULEVs). He asked whether additional bins could be created. Ms. Beardsley responded that she saw no problem with adding additional bins where needed. These bins could also be associated with different emissions technologies as well as model year. Mr. Younglove emphasized that it would be especially important since big emissions differences can occur with annual model year groups.

Data Acquisition and Management for MOVES

Mr. Scarbro presented information on data acquisition and management for MOVES. The goal of his program was to provide quality assured vehicle and second-by-second (SBS) emissions data to MOVES. He discussed how the Eastern Research Group (ERG), who was the contractor for this project, obtained the emissions data and QA/QC'd the data, and how the EPA reviewed the data as well as their findings.

One of the callers stated that SBS data are very useful; however, they are concerned whether the identification on recruitment stored in the database was random, targeted, or generalized. Mr. Scarbro replied that the New York IPA discussed how vehicles were recruited as well as regulatory information, but such discussion was not the case for all of the test programs.

Mr. Lindhjem asked about the timeline for the data and added that not all modal measurements are created equally. Mr. Scarbro stated that the alignment was done for the data

provided to the MOVES team and did not change the stored data. Also, the Vehicle Specific Power (VSP) data did correlate well with CO_2 and other gases. Whatever offset gave the best correlation was the offset that was used. Some labs had better correlation than others.

A participant asked about quality control data. The bag data was within 10 percent, but what about when bag data was not available? Mr. Scarbro replied that the data was aggregated from SBS data and also from the data collected by West Virginia University (WVU). The participant also asked about test fuels and low sulfur gasoline as well as ultra-low sulfur diesel. Mr. Scarbro stated that the database stores detailed information about fuel. In certain situations, though, information may be generalized. For example, gross estimates are used to calculate fuel specifications on a particular day. Mr. Koupal added that sometimes either assumptions must be made about the data, or all the data gets thrown out. It would be nice for future testing to be able to get fuel samples, but that is not always possible. The modeling of microscale situations will have to use many default assumptions, which is a source of error that needs to be quantified.

Mike Vaillancourt (Ford) asked if any work has been done to relate the NYIPA system to the VMAS system to standardize laboratory equipment. Mr. Scarbro replied that this effort has been recorded in a report, but instead of relating the NYIPA system to the VMAS system, it was related to bag data. He offered to provide a contact name for more information.

One of the callers asked if a consistency check for similar vehicles would show similar results. Mr. Koupal answered that the bin and cycle SBS analysis focused on fuel energy consumption. A consistency check has not yet occurred, but EPA is planning to do one. The caller commented that if the drive cycle on the same vehicle is changed, then different emissions would occur. The same drive cycle within different data sets and groupings should yield the same results. It is important to look for bias within the dataset, and suggested using SBS data to check for consistency. James Warila (EPA) replied that the EPA has done some examination on the data, which included graphic plotting with an emphasis on distinguishing different tests. First, EPA divided the data into source bins and then into operational bins. They then looked at individual tests to examine variability within and between tests. This process was not performed specifically on the basis of test program, fuel, or other characteristics, but such an examination would be possible. He has seen differences that are probably due to cycle. It would be possible to expand on what has already been completed. Mr. Koupal added that there are differences for different test programs. These differences will be added into the uncertainty analysis. If differences are still present after filtering vehicles to temperature and fuel range, then they would assume vehicle-to-vehicle variability.

Mr. Heiken stated that for each adjustment factor to be developed for MOVES, the underlying data will be based on local ambient and fuel conditions. For I/M-based data for example, the outside temperature could be a significant variable affecting the estimated emission levels. So when MOVES is developed, will the underlying test data be adjusted to a predetermined set of standard conditions before the model applies any correction factors? Mr. Scarbro replied that the data delivered were identified with temperature. MOVES has filters in its binning program to standardize the data by looking at the temperature. Also, there is a way to exclude data if necessary. Mr. Heiken then asked about what is known regarding the presence

of start-up emissions in the underlying data which can be highly variable in I/M programs. Mr. Scarbro said the vehicles met the preconditioning data specified in the I/M regulations. Also, these vehicles had multiple tests. The NYIPA is more standardized. The carbon monoxide (CO) program and other State programs are not as standardized. The concerns about other I/M programs are noted. Mr. Koupal added that these issues will have to be dealt with as well as variations in other I/M programs, preconditioning, and criteria pollutants.

Tom Darlington (AIR, Inc.) was confused about what was said regarding I/M data not being used in the program, especially since the NYIPA data, which is SBS I/M data, is 90 percent of the data used. Mr. Koupal explained that the NYIPA data is distinguished from the data collected in British Columbia. Mr. Tierney added that the NYIPA is not I/M lane data. Instead, it is laboratory data and thus more reliable. Mr. Darlington responded that the data are not exactly laboratory data since variable temperatures, open doors, and other factors existed. Mr. Koupal replied that preconditioning is what pushed the data to be recognized as laboratory quality. Additional controls were used. Mr. Darlington then asked what measurement systems were used for the I/M 240 full test cycle data (e.g., VMAS, traditional IM240). Mr. Scarbro replied that the traditional measurement system was used. Mr. Tierney added that the test program collected both, but it was two separate systems. VMAS demonstrated efficacy.

Emission Rate Development

Mr. Koupal gave a presentation on emission rate development. He discussed the MOVES2004 emission rate sources, running total energy rates, and rates for other processes and pollutants such as CH_4, N_2O, starts, extended idle, and well-to-pump. Total energy consumption is considered to be a "pollutant" because a better term could not be found. Starts in MOVES are characterized like starts in MOBILE6. Also, the binning approach can be run on multiple scales. The VSP metric accounts for load per mass, speed, acceleration, grade, and road load (friction losses). This results in more flexibility in MOVES than in MOBILE6. EPA discovered that VSP was biased at low and high speeds, so they did further analysis and improved the binning approach. Instantaneous speed was added as Bin-Option 5 (BO5), and is used to supplement VSP. BO5 predictions are within 10 percent of predictions using VSP for all trips, but with high and low speeds, it improved dramatically. On a one-to-one comparison, EPA is confident that the observed and predicted trip results had some scattering but were overall very good for both LD and HD. The comparison for CO and hydrocarbons (HC) was not as good, and EPA needs to determine if the scatter is because of the binning approach or the data used.

Mr. Byun stated that he was confused regarding the definition of start emissions. He also stated that the start emissions defined in MOBILE6 is different than the definition used for the previous MOBILE models. Mr. Koupal replied that the definition of a start is the same as in MOBILE6, so the activity of a start is not changing. The Bag 3 method may produce some uncertainty, but it does not change the way that the activity of a start is treated. Both Total energy and CH_4/N_2O could be calculated in the same way, but it does not make a big difference in emission rates. Mr. Byun added that start emissions make up a big portion of emissions, so the definition should not be changed. Mr. Koupal stated that the definition of start emissions does not change.

Mr. Hochhauser asked how certain Mr. Koupal was that a good average is represented, especially since lots of data exists within the passenger car bin due to a broad range of low and high emitters within one bin. Mr. Koupal replied that the source bin idea captures large areas of variation. For energy consumption, low and high emitters do not matter. However, source bins will need to be created for dealing with high emitters for criteria pollutants. Mr. Hochhauser added that the same thing would occur for temperature. Mr. Koupal replied that some adjustments will have to be applied during the process. If the data demands a temperature adjustment for hydrocarbons, then an adjustment can be added. EPA is currently in the process of statistically determining how certain they are that the bins are representative of the fleet. A minimum of three vehicles is the criteria as well as a standard deviation of no more than 40 percent of the mean. If these criteria are not met, then the bin is not representative and will need to be supplemented. One caller asked if this criteria was only for fuel consumption. Mr. Koupal replied that it will be for everything but there are additional criteria as well.

A phone participant asked whether for speed bins of only three vehicles, each vehicle had to spend a specific amount of time in the bin. Mr. Koupal replied that no specific criterion for a specific test exists, but it could be added as a refinement.

Another participant asked about the impact of engine technology, engine parameters, etc. Mr. Koupal replied that a bin is defined by applying fuel type, engine technology, weight, model year group, engine size, and vehicle weight. Seventeen VSP combinations exist for each source bin. Each VSP in each source bin is a statistical cell.

Mr. Hochhauser said that users should be able to decide how much data are needed to populate a bin and develop an algorithm to get a good prediction of what is in the bin. There should be a basis to use to decide how many vehicles are enough, as three may not be enough for each bin. Also, if three vehicles are found to be similar, it does not necessarily mean that the right vehicles are in the right bins, especially with criteria pollutants. Mr. Warila replied that the number of tests per cell is not the only criterion. Cells are also evaluated on the estimated coefficient of variation for the cell mean (CV). If the CV for a cell exceeds a pre-specified maximum, the bin will not be populated. Secondly, knowledge of numbers of tests within cells and associated estimates of variability will be useful in planning for future data collections.

Doug Lawson (NREL) stated that 131 bins are needed to cover 98 percent of the fleet. If the model is trying to capture 100 percent of the emissions, 100 percent of the fleet may not have

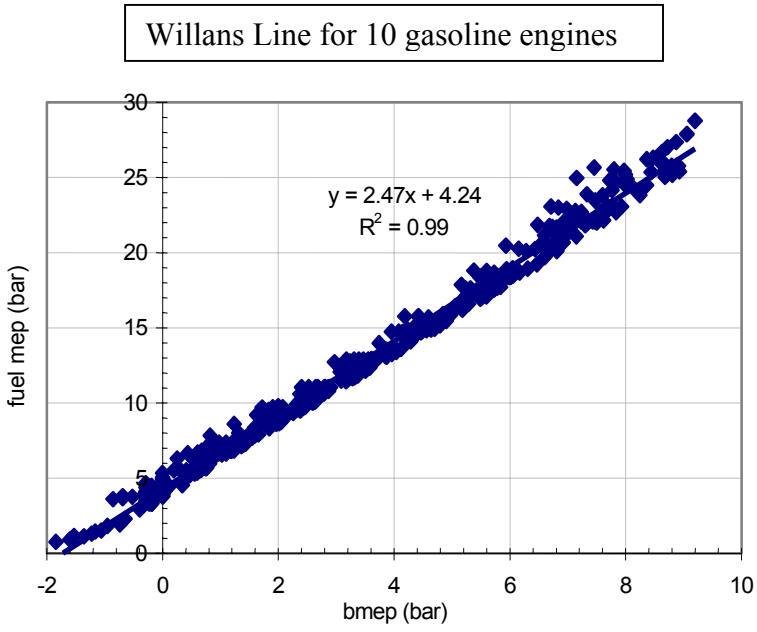
to be captured; the clean bins may not need to be populated as much, and the absolute number of high emitters and their absolute g/mi emissions need to be fully understood. Mr. Koupal replied that bin population would be discussed in the presentation regarding CRC and New York Department of Environmental Conservation (NYDEC) comments.

Advanced Technology Vehicle Modeling in MOVES using PERE

Ed Nam (U.S. EPA) presented information on advanced technology vehicle modeling in MOVES using the Physical Emission (& Energy) Rate Estimator (PERE). This analysis was used to fill source bins. This model is a backwards looking model where driving cycle is the input and energy and emissions are the outputs. It examines SBS loads and effects on energy consumption and emissions. The components were modeled on an aggregate scale. The model provides pump-to wheel (PTW) results. PERE will help feed the emissions rate database in MOVES.

Mr. Heiken stated that PERE seems to work only for describing fuel economy. What about criteria pollutants? Mr. Nam replied that the model starts with fuel economy and CO_2. Previous work was proof-of-concept and included criteria pollutants. That model was based on the Comprehensive Mobile Emission Model (CMEM) from the Bourns College of Engineering-Center for Environmental Research and Technology (CE-CERT), which went from fuel consumption to engine-out to tailpipe. PERE is the same way.

Mr. Hochhauser asked how PERE handles changes in base engine efficiency like compression ratio or valve train efficiency for gas engines. This does not include just friction but also the basic efficiency of the engine as well. The slope on the graph in Slide 10 will change with lean fuel burning. Will other types of data be needed to fill those points? Mr. Nam replied that estimates can be made using rules of thumb (or information from the literature). When a lean-running engine has more efficiency, friction is not that different. When this drastically changes, a new line is needed.



Michael Reale (Daimler-Chrysler) asked how going from fuel efficiency to NO_X varies. Is there an index, or does it vary by design? Mr. Nam replied that criteria pollutants were not discussed at all in the presentation. The NO_X index would be calibrated to data such as SBS dynamometer engine-out data. To some extent, it would be engine-specific, but many engines have the same NO_X index. Some engines

will differ, but for a given engine, the line is usually very tight for engine-out data.

One participant asked when the final emission criteria model will be used. Mr. Koupal replied that the draft emission criteria model will be released in January 2006. The criteria aspects in PERE will be developed on that time frame. EPA has not completed a detailed schedule regarding the criteria pollutant model. This schedule might be completed in 2004 or early 2005.

David Lax (API) asked about the 1999 base-year and 2030 projection. The previous presentation stated from 1990 to 2020. Mr. Nam replied that EPA could revise the projection to 2020. Mr. Koupal added that near-term rates will apply to GREET well-to-pump emissions from 1990 to 2020 and that no information beyond 2020 is available.

Questions on all presentations and other discussions

Rob Ireson (consultant), who called in by phone, asked a question regarding the Bin Option 5 (BO5) scatter plots in the Emission Rate presentation. He asked if similar plots had been generated for data that had been used in generating the model relationship as well as those data reserved for evaluation. Was there less scatter/unexplained variability? Mr. Koupal replied that he did not know since he did not conduct that particular analysis. North Carolina State University (NCSU) did a similar validation to determine whether disaggregated and reaggregated data got the same results. The results show whether the variability is due to limitations in the binning approach or in the model's ability to capture what occurs in individual trips. If the same kind of scatter results, then the uncertainty can be ascribed to the binning approach (i.e., model formulation) as opposed to limitations of the dataset.

Mr. Darlington asked whether the same binning approach has been tried with LEVs in the SBS dataset and with other vehicle classes. Mr. Koupal replied that this had not been tried. When validation started, the comments focused on high emitters and validation for older LD and HD vehicles, so the approach shifted accordingly.

Dennis Kahlbaum (AIR, Inc.) asked if vehicle age was a bin. Mr. Koupal replied that in terms of emissions, age shows up as model year group. Emissions will not vary within the model year group; the bins will account for age, odometer, and emitter class. Energy consumption increases with age, but it is not as important as weight and engine size. Some deterioration is possible, but it is not significant.

A caller asked whether EPA has plans for examining every variable in the bin. Mr. Koupal replied that EPA plans to look at variability within a bin as a way of confirming the model. EPA also has criteria for bin cutoff sizes. Coefficients of variation are single point measures and assume that output within the cell are normally distributed. Mr. Warila added that EPA is representing the uncertainty in the mean estimate rather than total variability in the data itself. Coefficients of variation of the mean will be fed into the uncertainty analysis, assuming that the distribution of the mean will be normal regardless of the distribution of the data itself. This assumption relies on the central limit theorem, and EPA is working to evaluate this

assumption based on the amount of data in different cells. The final results will be presented at a later date, but the preliminary results suggest that this assumption is reasonable.

Mr. Younglove voiced concerns regarding the hidden assumption that sampling distribution will run toward normality, but smaller sample sizes may have a skewed distribution. Mr. Warila replied that the EPA is still grappling with that issue to see if the normality assumption is applicable to small samples. It is hard to tell if a sample is biased if only a few vehicles are within it. EPA is assuming that the data are representative, so if there are underlying questions regarding representativeness, they cannot be addressed through statistical approaches. Lingering questions would need to be addressed by other external means. Mr. Younglove then asked whether various test programs could be biased. Mr. Koupal replied that checks are done against other databases. Mr. Warila added that it is difficult to compare databases because the meteorological data and other types of data could be variable.

Review of MOVES Draft Design

Mr. Lindhjem presented information on ENVIRON's review of the MOVES draft design. They recommend that some of the bin definitions may need to be refined. EPA should identify the fleet fraction of high emitters from in-use measurements and target testing and investigate how new vehicles and technologies behave and age. In terms of emissions modeling, the modeling of regulated pollutants and high emitters will require additional LD vehicle activity terms. Additional activity terms are helpful for modeling LD normal emitters and fuel consumption. Diesel CO and PM emissions deserve more investigation. EPA should reconsider binning vehicle activity in favor of regressions. The level of interest in activity data collection should be raised. Analyses should consider the number of vehicle bins in terms of data population.

Doug Lawson (NREL) asked how the model would handle ambient temperatures, especially cold temperatures, when cold starts occur. Mr. Lindhjem replied that both starts and hot-running engines would have to be adjusted for temperature.

Doug Lawson stated that the availability of information is low for high emitters. A high-emitter study was completed in 1995 in Orange County, California. It found that 9 percent of the fleet had an average IM240 HC emissions of 7 grams/mile (g/mi). In the real world, 2 g/mi is on the low end. Mr. Lindhjem said the high emitter breakpoint in his presentation was for illustration purposes and should be adjusted upwards, perhaps from 2 to about 9 g/mi. He suggested that the selection bias should be removed using remote sensing and that available data should be used even if it is underweighted for high emitters.

NYDEC Comments

Mr. Koupal presented a summary of the CRC review (completed by ENVIRON) and the NYDEC comments. Highlights of the NYDEC comments included the following:

- National defaults are not adequate for local areas, but data requirements for local areas appear burdensome.
- High emitters require stratified sampling.
- Remote sensing effectiveness is uncertain.
- More clarification on the application of uncertainty is needed.

Highlights of the ENVIRON/CRC comments were as follows:

- Vehicle classification leads to a large number of bins.
- The high emitter definition needs to be resolved.
- Remote-sensing data can be used to quantify high emitter distribution.
- Data requirements appear burdensome.
- VSP can be improved upon.
- EPA should consider a regression approach instead of bins.

Responses to these comments were provided in the presentation and summarized by Mr. Koupal.

Mr. Lindhjem realizes the need to have vehicle source bins. However, the activity and emissions as a function of activity should not be binned. Any point (single value) estimate within a bin reflects an assumed activity distribution within that bin. For instance, data collected on the IM240 cycle (or any cycle) will not match actual activity distributions within an activity bin. This potential bias can be corrected using regressions rather than bins for any correlation of emissions to vehicle activity. Mr. Koupal stated that when better representation is achieved, hopefully the issue will be resolved. If not, then it will be addressed as a bias.

A caller asked if there would be a recommendation or round robin discussion with labs that gather data so that agreement could be reached on a standard format and a standard set of parameters. Mr. Koupal replied that EPA's goal is standardization of all inputs. He offered to send the data to interested parties. The raw dataset is quite large, but the pre-binned dataset fits on three CDs. Mr. Tierney added that EPA is in the process of establishing standard procedures for obtaining Portable Emissions Monitoring Systems (PEMS) data on an SBS basis. Carl Fulper, who leads the data acquisition management team, has been asked to put together a shell to distribute to data collection agencies. This data format will be used to populate the database. Hopefully that will spread the word that SBS data needs to be standardized.

MOVES Demonstration

Mr. Cumberworth (EPA) provided a demonstration of the MOVES prototype. He explained how the model worked and then provided an example.

Next Steps and Action Items

- The next meeting is planned for March in Washington, DC, and will coincide with the MSTRS Subcommittee meeting. [Note: As of February 9, 2004, the date has not been set, but will likely be later in the spring of 2004.]

- Presentations will be posted on the web and will be available by email. The ERG report on cycles as well as an advanced technology report may be available in January. The ERG report is not final, but it can be shared as a draft. The other report will be available in the early part of 2004.

- Bob Slott will send an e-mail to Mr. Pienta with an attachment of the California Bureau of Automotive Repair report that used remote sensing to identify high emitters. The Orange County, California remote sensing/high emitter repair study report done for the SCAQMD is available upon request from Fred Minassian at the AQMD.

Workgroup Participants/Attendees

Name	Affiliation	Email
Chad Bailey	U.S. EPA	bailey.chad@epa.gov
Rick Barrett	Colorado Department of Health	Rick.Barrett@state.co.us
Megan Beardsley	U.S. EPA	beardsley.megan@epa.gov
John Byun	Federal Highway Administration	joon.byun@fhwa.dot.gov
Jeremy Heiken	Air Improvement Resources, Inc. (AIR, Inc.)	jheiken@airimprovement.com
Albie Hochhauser	ExxonMobil	albert.m.hochhauser@exxonmobil.com
Thomas Darlington	AIR, Inc.	tdarlington@airimprovement.com
Dennis Kahlbaum	AIR, Inc.	kbomb@umich.edu
Sue Kimbrough	U.S. EPA	kimbrough.sue@epa.gov
John Koupal	U.S. EPA	koupal.john@epa.gov
Larry Landman	U.S. EPA	landman.larry@epa.gov
Doug Lawson	NREL	doug_lawson@nrel.gov
David Lax	API	lax@api.org
Chris Lindhjem	ENVIRON	clindhjem@environcorp.com
Bob Maxwell	consultant	r.maxwell@email.sae.org
Rick Middleton	Daimler Chrysler	ram12@dcx.com
Ed Nam	U.S. EPA	nam.ed@epa.gov
Mani Natarajam	Marathon-Ashland	mnatarajan@mapllc.com
Michael Reale	Daimler Chrysler	mjr2@dcx.com
Carl Scarbro	U.S. EPA	scarbro.carl@epa.gov
Bruce Spear	FHWA	bruce.spear@fhwa.dot.gov
Gene Tierney	U.S. EPA	tierney.gene@epa.gov
Mike Vaillancourt	Ford	mvaillan@ford.com
James Warila	U.S. EPA	warila.james@epa.gov
Ken Wright	Conoco-Phillips	ken.wright@conocophillips.com

Name	Affiliation	Email
Ted Younglove	UC-Riverside	tyoung@cert.ucr.edu

Workgroup Participants Via Phone

Brent Bailey	CRC	bkbailey@crcao.com
Rick Baker	Eastern Research Group	rick.baker@erg.com
Kevin Black	FHWA	kevin.n.black@fhwa.dot.gov
Larry Caretto	CSU-Northridge	lcaretto@csun.edu
Frank DiGenova	Sierra Research	
Phil Heirigs	Sierra Research	pheirigs@sierraresearch.com
Rob Ireson	consultant	rireson@ix.netcom.com
Mike Keenan	NYDEC	mxkeenan@gw.dec.state.ny.us
Chris Loreti	Battelle Memorial Institute	loretic@battelle.org
Behshad Norowski	NCDOT	bnorowzi@dot.state.nc.us
Dilip Patel	CARB	Dpatel@arb.ca.gov
Walt Pienta	NYDEC	wjpienta@gw.dec.state.ny.us
Bob Slott	consultant	rslott@alum.mit.edu

Technical/Logistical Support Staff

Kathy Boyer	EC/R Inc. (EPA contractor)	kboyer@ecrweb.com
Jennifer Haynie	EC/R Inc. (EPA contractor)	haynie.jennifer@ecrweb.com