DRAFT RESEARCH PROPOSAL

Collection of Activity Data from On-Road Heavy Duty Diesel Vehicles

Principal Investigator:
Josias Zietsman, Ph.D., P.E.

Co- Principal Investigator:
Mohamadreza Farzaneh, Ph.D., P.E.

Prepared for:

State of California Air Resources Board
Research Division
PO Box 2815
Sacramento CA 95812

Prepared By:

Texas A&M Transportation Institute
400 Harvey Mitchell Parkway; Suite 300
College Station TX 77845-4375

January 31, 2013

Check if applicable:
Animal subjects _____
Human subjects ___X_____

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Abstract

The goal of this proposed research is to develop activity profiles of different types of vocational uses of on-road heavy-duty diesel vehicles (HDDVs) in California, through which effectiveness of Selective Catalytic Reduction (SCR) systems can be studied. Another goal for this research is to assess the representativeness of the current HDDV certification cycle to real-world conditions, including emissions of NO_x based on SCR functionality. The results of this study will help the California Air Resources Board (ARB) to improve heavy duty NO_x emissions models and take a critical look at whether certification and compliance procedures need to be updated to account for the functionality of SCR.

While SCR has been established as the primary technology for reducing NO_x emissions from diesel engines, a major challenge of the SCR systems is that they require temperatures above 200°C to achieve significant NO_x reductions. Certain vocational uses of HDDVs may not provide adequate engine loads to maintain these temperatures. Therefore, it is critical to develop activity profiles of heavy-duty diesel trucks for their different vocational uses, as SCR functionality can vary greatly based on activity, even for the same truck/engine types.

The Texas A&M Transportation Institute (TTI) is uniquely qualified to lead this research project for ARB. TTI has performed numerous studies for a variety of public and private sponsors collecting and utilizing vehicle activity data using GPS, on-board diagnostics (OBD), engine control unit (ECU), and exhaust temperature loggers for different purposes such as emissions measurement, air quality analyses, and mobility and travel time analyses. In this regard, TTI has worked with different vehicle types including light-duty vehicles, medium duty trucks, buses, drayage trucks and long-haul trucks, and even off-road construction equipment. TTI also has extensive experience in conducting travel surveys including regional commercial vehicle surveys in Texas. TTI will partner with a California-based public university to conduct this project.

The study will involve executing eight major tasks in two parallel phases over 24 months. Phase 1 will deal with the truck surveys while Phase 2 will address data collection and analysis of drive cycles for different vocational uses of HDDVs. The final results will be delivered in the form of an HDDV Activity Profile Database and a comprehensive research report.

The results of the study will help ARB to make more realistic estimates of NO_x reductions from SCR-equipped trucks, and to develop optimized emission reduction deployment policies based on vocational uses. The findings can also be used to update default activity data in future EMFAC releases based on the collected field data, and to modify HDDV certification tests to be more representative of SCR functionality challenges.

TTI's extensive experience and qualifications, combined with the robust test plan and quality assurance and data management processes will ensure that the goals of the project are met. TTI will ensure that ARB is provided with high-quality research results ready for immediate implementation.

Introduction

Background

The upcoming ambient air quality standards for ground-level ozone and particulate matter (PM) levels will create challenges for areas that are in nonattainment for ozone and PM. As the main pre-cursor of ground-level ozone, controlling the emissions of oxides of nitrogen (NO_x - including NO and NO2) is the key to meeting new ozone standards.

Heavy-duty diesel trucks have been a major source of NO_x emissions. In California and elsewhere, they have been the target of stringent vehicle emissions standards and emissions control measures. The most recent NO_x emission standard for new heavy-duty on-road engines requires 90 percent reduction in tailpipe NO_x emissions compared to the previous standards. To meet this stringent NO_x level, diesel engine manufacturers have explored a variety of advanced technologies. Selective Catalytic Reduction (SCR) was found to be the most cost-effective and fuel-efficient technology available to help reduce NO_x emissions from diesel engines. SCR can reduce NO_x emissions by up to 90 percent, while simultaneously reducing HC, CO and PM. SCR systems can also be combined with a diesel particulate filter (DPF) to achieve even greater emission reductions for PM.

A major challenge of the SCR systems is that they need to be operated at temperatures of 200°C and above to allow for significant NO_x reductions to be achieved. However, this temperature requirement is often not met when the engine does not operate at a sufficiently high load. For example, right after engine start and during low load operations such as idling or slow cruise on flat terrain. This means that the effective functioning of the SCR system is dependent on the vehicle's duty cycle and type of vocation. For example, an SCR system on a long-haul truck that operates mostly at high-speed cruise has higher efficiency than a truck with the same engine which operates with frequent stops in a local delivery application.

Because the effectiveness of the SCR is a function of the vehicle's operational characteristics, it is critical to understand heavy-duty diesel truck activity profiles for different vocational uses. Building a database of factors such as duty cycles, number of engine starts, and engine soak time distributions can help build an accurate profile of heavy-duty truck activities by vocation. These factors are considered among the most suitable parameters to use in developing vocation-based truck activity profiles.

These activity profiles help assess NO_x emissions and SCR effectiveness for heavy duty trucks, and allow for quantification of real-world NO_x emissions from trucks, including those meeting the new 2010 NO_x certification standard. The profiles also provide the basic information required to update and improve new emission inventories. Additionally, truck activity profile information can be utilized to assess the representativeness of current engine certification duty cycle and help determine whether certification standards should be updated.

Research Team and Relevant Experience

This research project will support the California Air Resources Board (ARB) by characterizing heavy duty truck activity profiles by vocational uses, with a view of identifying the effectiveness of SCR systems. The Texas A&M Transportation Institute (TTI) is in discussion with more than

one California-based University as a potential partner for this research project. All the relevant information regarding the California-based partner will be included in the final proposal to be submitted in April 2013.

TTI is uniquely qualified to lead this research project for ARB. TTI is the nation's largest University-based transportation research institute, and a member of the Texas A&M University System (TAMUS). TTI's Air Quality Program (http://tti.tamu.edu/group/airquality/) is a part of the Environment and Air Quality Division and has conducted numerous research projects for public and private sector sponsors. TTI also has extensive emissions testing capabilities which include an environmental test chamber, test tracks, portable emissions measurement systems, and other emissions measurement devices.

TTI has been routinely collecting and utilizing vehicle activity data using GPS, on-board diagnostics (OBD), engine control unit (ECU), and exhaust temperature loggers for different purposes such as emissions measurement, air quality analysis, and mobility and travel time analysis, for different vehicle types including light-duty vehicles, medium duty trucks, buses, drayage trucks and long-haul trucks, and even off-road construction equipment. Appropriate data quality control procedures have been developed and utilized by TTI to ensure the quality of the data and results. This section describes a selected TTI projects relevant to the proposed research.

Currently, TTI is using GPS data collected throughout the state of Texas to develop local-specific drive cycles to be used with the EPA's MOVES model[1]. GPS data have been collected from over 200 vehicles of different vehicle classes and metropolitan areas. A small sample of ECU/OBD data were collected for data quality control purposes. These data are currently being analyzed and local drive cycles are developed for different classes of vehicles by road type. Upon the approval of the consultative partners, these local drive cycles are anticipated to replace MOVES' default drive cycles for all official air quality analysis in Texas.

In another on-going study, the research team is using GPS units as well as field activity observation at the border crossings in El Paso to develop a MOVES-based emission estimation tool for the border crossing activity of different vehicle classes[2]. This study is sponsored jointly by Texas Commission on Environmental Quality (TCEQ) the Center for International Intelligent Transportation Research (CIITR). The research team has completed the data collection and is currently processing and analyzing the data. GPS data will be used to develop drive cycles representing different traffic states at border crossings while the information from the field observations will be utilized to establish accurate age profile of the crossing vehicles.

TTI partnered with the Texas Department of Transportation and was awarded a grant by the USEPA through its Clean Diesel Emerging Technologies Program, in which performance of SCR units installed on heavy-duty off-road construction equipment was measured using PEMS before and after SCR installation. This study also involved data logging to measure various parameters including temperature, to identify proportion of the duty cycle in which SCR units

[1] Texas-Specific Drive Cycles and Idle Emissions Rates for Using with EPA's MOVES Model, sponsored by TxDOT, in-progress.
[2] Emission Estimation Tool for Ports of Entry, sponsored by TCEQ, in-progress

operated effectively[3]. In a recently-completed study, TTI worked with the City of Houston in identifying high-emitters among their heavy-duty vehicle fleet. This study involved determining representative drive cycles using GPS units and performing emissions testing at TTI's environmentally controlled test chamber and the test tracks located at Texas A&M University[4]. In another past study, TTI used GPS data to develop drive cycles for emissions testing of a fleet of five school buses using regular diesel as well as two types of biodiesel fuels (soy-based and market blend).[5]In 2007, TTI used GPS to collect activity data for a sample of HDDVs that were engaged in cross-border drayage activity between Laredo, TX and Nuevo Laredo, Mexico[6]. The data were analyzed and a series of drive cycles were developed. Emissions testing of a sample of 10 Mexican trucks were carried on based on these drive cycles. The same set of GPS data was used in combination with an instantaneous emissions model for a Texas Department of Transportation (TxDOT) project to determine the total emissions impacts of Mexican trucks in Texas[7].

In another study, GPS data collected for three classes of vehicles (heavy-duty trucks, medium-duty trucks, and light duty vehicles) driving on high speed freeways in west Texas were used in a study for HARC and EPA to develop a methodology for extending emissions rates of MOBILE6 model for speeds higher than 65 mph[8]. Two sets of drive cycles were developed based on the collected data. The first set of drive cycles were used for emissions data collection. The second set that included realistic representative drive schedules of real-world high speed driving was used to determine the emissions rates for different average speeds.

In an ongoing study, TTI researchers are collecting and analyzing large amounts of engine data from heavy-duty diesel dump trucks in the Texas Department of Transportation fleet using J1939 protocol engine data loggers[9] in order to develop an improved preventative maintenance model for these vehicles. Over the past eight years, TTI has conducted numerous emissions measurement and characterization studies. TTI is currently performing a set of emissions measurement tests in its state of art environmental chamber to characterize the idling emissions from Class 8 tractor-trailers. A wide array of testing equipment has been used, and a broad range of emissions including MSATs are measured.

TTI also has extensive experience in conducting travel surveys. TTI assists TxDOT in the design, quality control, and analysis of all the surveys its statewide travel survey program. The TxDOT travel survey program is designed to conduct surveys on a rolling basis across the state. For the commercial/heavy-duty vehicle surveys, TTI has assisted TxDOT with about 15 regional

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[333] Deployment of Nett BlueMAX SCR System in TxDOT's Construction Fleet – Grant # DE-8342001-0, USEPA Clean Diesel Emerging Technologies Program.

[4] Characterization of Exhaust Emissions from. Heavy Duty Diesel Vehicles in the HGB Area, D. W. Lee, J. Johnson J. Zietsman L. Yu , M. Farzaneh, February 2012.

[5] Farzaneh, M., J. Zietsman, D. G. Perkinson. School Bus Biodiesel (B20) NO_x Emissions Testing. Capital Area Council of Governments. Interlocal Contract No. R08-04/05-TTI-2. August, 2006.

[6] Zietsman, J., Farzaneh, M., Storey, J. Villa, J.C., Ojah, M., Lee, D., and Bella, P. Emissions of Mexican Domiciled Heavy-Duty Diesel Trucks Using Alternative Fuels, Prepared for the Alamo Area Council of Governments, 2007.

[7] Farzaneh, M., Zietsman, J., and Lee, D. Emissions Impact of Mexican Trucks in Texas' Non-attainment Areas, prepared for Texas Department of Transportation, 2007.

[8] Zietsman, J., Farzaneh, M., Lee, D., Park, S., and Rakha, H. Expanding MOBILE6 Rates to Accommodate High Speeds, prepared for Houston Advanced Research Center (HARC), 2007.

[9] Fleet Equipment Performance Measurement Preventive Maintenance Model (sponsored by TxDOT, in-progress.)

commercial vehicle surveys over the past 12 years. While the current Texas approach does not include a GPS component in the commercial vehicle survey, all household surveys conducted in the past decade have included an in-vehicle GPS component designed by TTI staff and the staff have a well-established system for comparing GPS data streams to travel diary data.

These experiences and the highly-trained staff have placed TTI in a leadership position with regard to in-use emissions testing, GPS/ECU/OBD data collection, and activity surveys. Sponsors from as far away as Europe are working with TTI on PEMS-related projects. Besides a comprehensive PEMS emissions testing equipment, TTI has the largest environmental test chamber in the nation that can accommodate a full-sized tractor trailer.

Goals and Objectives

The goal of this research is to develop activity profiles of different types of vocational uses of on-road heavy-duty diesel vehicles (HDDVs), through which effectiveness of SCR systems can be studied. Another goal for this research is to assess the representativeness of the current HDDV certification cycle to real-world conditions, including emissions of NO_x based on SCR functionality.

To achieve these goals, the specific research objectives include:

- To identify the types of vocational uses of HDDVs in California with regards to expected SCR effectiveness and resulting NO_x emissions;
- To identify the data requirements and to develop data collection plans and protocols;
- To collect field data from different vocational uses of HDDVs in California;
- To analyze and evaluate the HDDVs' duty cycle characteristics with regards to NO_x emissions and suitability for effective SCR deployment. A specific target is to identify what fraction of the vehicle operation falls under conditions that reduces SCR system functionality and efficiency; and
- To perform an analytical comparison of real-world HDDV duty cycles and the current certification cycle with regards to accounting for SCR functionality in certification tests.

The results of this study can be of immediate use to ARB to:

- Improve heavy duty NO_x emissions models; and
- Take a critical look at whether certification and compliance procedures need to be updated to account for the functionality of SCR.

The results of the study can also be utilized by ARB to:

- Modify HDDV certification tests to be more representative of SCR functionality challenges related to specific vocational types;
- Develop optimized emission reduction deployment policies and strategies by identifying and targeting the vocational uses that are most suitable for a specific strategy such as SCR; and
- Update default activity data in future EMFAC releases based on the collected field data.

Technical Plan

The overall approach for this research project will involve the execution of eight tasks over a 24-month period. A 24-month project is proposed to allow enough time to collect activity data for an adequate number of vehicles, as well as performing thorough analysis of the results. The study will be performed in more than one California nonattainment area, and the final locations will be selected in collaboration with ARB.

The project will be divided into two phases which will be executed in parallel. Phase 1 will deal with the truck surveys while Phase 2 will address data collection and analysis of drive cycles for different vocational uses of HDDVs.

During Phase 1, a truck travel diary survey will be conducted to collect truck, engine and activity information as well as information regarding the number of engine starts per day and soak time distribution per day for each truck use type by vocation. The TTI research team has administered and conducted numerous truck survey studies in the past. The detailed protocols and diary survey forms will be developed by TTI and their local partner university, in collaboration with ARB.

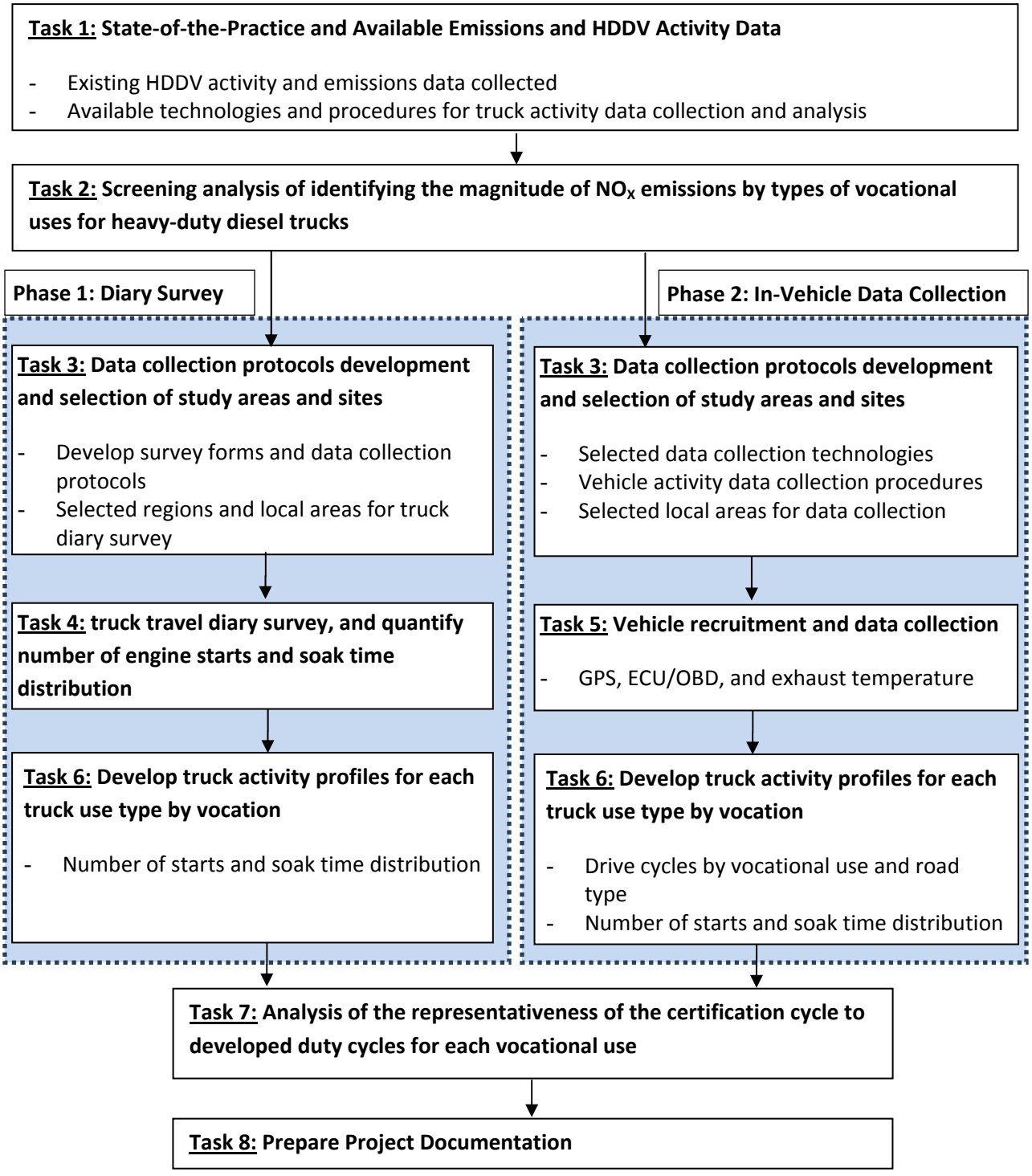
During Phase 2, vehicles from target truck groups will be recruited and instrumented with the selected activity recording instruments, and the activity data will be collected. The normal daily activity of recruited participants will be captured by data logging instruments. The collected data will include second-by-second speed and location information for all the vehicles, and engine parameter readings for a smaller subset of the test vehicles.

After a predetermined data collection period, the data collection instruments will be removed from the participant vehicles and data will be downloaded and labeled properly, following standard processes developed in a quality assurance/data management plan. This data will be processed and a database of speed and other vehicle parameter profiles for different types of vocational uses of trucks will be developed. The database will also include vehicle activity data obtained from other relevant sources identified and obtained in Task 1. This database will be analyzed along with data obtained from Phase 1 (truck travel diary surveys) and representative drive schedules and operating mode distributions for different vocational uses of trucks and road types will be identified. The corresponding number of starts and soak time distributions will also be developed for the different vocational uses. Comparisons will be made between these activity profiles and certification testing cycle to determine the representativeness of the current cycles with regards to NO_x emissions and SCR functionality.

The project team will maintain regular contact with the assigned ARB Project Manager to keep her/him abreast of the progress and to gain input during key junctures of the project. In addition to the regular and less formal interactions, four meetings are scheduled at critical points during the project to discuss the progress and get feedback and approval of ARB staff, for example, on the data collection plan and vehicle selection criteria (Task 3).

Work Tasks

The proposed approach for this research project will involve the execution of eight tasks over a 24-month period. The following figure shows a flow diagram of the project and how the various tasks will fit together. As shown on the diagram, the project is divided into two phases that will be executed in parallel. The flow diagram also shows that the project tasks are developed in such a way that Phase 1 and 2 can benefit optimally from each other. In the following sections the eight tasks are described in more detail.



Task 1: State-of-the-Practice and Available Emissions and HDDV Activity Data

Purpose

The purpose of this task is to:

- To study in further detail EMFAC's methodologies with regards to vocational types of HDDVs, data sources, and other relevant aspects;
- Develop a further understanding of NO_x emissions from HDDVs and selective catalytic reduction (SCR) with a focus on vehicle activity profiles;
- Investigate different aspects of HDDV certification testing with a focus on NO_x emissions and NO_x control strategies;
- Investigate previous and on-going studies that use second-by-second activity data collection and other means to develop standard drive cycles;
- Identify and compile the available activity data for different vocational types of HDDVs; and
- Investigate and examine data collection technologies and procedures, and data analysis methodologies that can be used for truck diary survey and vehicle activity data collection analysis.

Methodology

This task can be divided into two related subtasks: Subtask1.1. will cover general literature review and assessment of the practice while Subtask 1.2 will focus on identifying and obtaining HDDV activity which have been collected previously.

The study team will conduct searches of published and unpublished materials on databases such as the Transportation Research Board's TRIS database, ORNL's data bases, TAMU and TTI libraries and databases, EPA and ARB websites and libraries, MPOs mobility data collection efforts, and general internet searches to obtain information on the abovementioned topic areas. The research team will also conduct informal interviews with ARB staff and other relevant agencies to identify and obtain information regarding these topics.

The research team will succinctly document the findings from each topic area and will compile the findings into a technical memorandum.

Results

The result of this task will be documented and will cover the following items:

- An understanding of vehicle types and vehicle activity data sources used in developing the EMFAC model;
- An overview of NO_x emissions from HDDVs and control strategies with a focus on SCR and its operational characteristics;
- A collection of vehicle activity information and HDDV NO_x emissions data based on previous and on-going studies;
- An overview of diary survey and vehicle activity data collection technologies and procedures and tools used to deal with such options;
- An understanding of methodologies used and findings from previous projects that used second-by-second vehicle activity data for vehicle activity profile development; and
- An understanding of the existing processes of HDDV certification testing.

Task 2: Screening analysis of identifying the magnitude of NO_x emissions by types of vocational uses for heavy-duty diesel trucks

Purpose
The purpose of this task is to perform a screening analysis of NO_x emissions from HDDV trucks to identify the magnitude of emissions associated with each vocational use type of HDDVs.

Methodology
The research team will use a step by step process to determine the NO_x emissions contribution of different truck vocational uses. The research team will begin by identifying different vocational uses of HDDVs followed by investigating available NO_x inventory results for different metropolitan areas of California. This step will follow the EMFAC vehicle types by identifying and documenting possible vocational uses for each HDDV type per EMFAC documentation. The research team will then identify and obtain a sample of inventory analyses which have information regarding different vocational uses of trucks along with additional information from the agencies that performed the analysis. In addition to these sources, the research team will utilize activity data sources identified in Task 1 to improve estimates for the NO_x contribution of each vocational use type.

Results
The following results will be achieved with this task:
- Identification of potential vocational use types for EMFAC's heavy-duty truck classes;
- An estimate of overall NO_x contribution of the identified vocational uses;
- A qualitative assessment of duty cycle for different vocational use types with regards to SCR functionality.

Task 3: Data collection protocol development and selection of study areas and sites

Purpose
The purpose of this task is two-fold:
1. To develop detailed data collection protocols for vehicle activity data collection and truck diary surveys. Appropriate experimental design methods will be also identified for vehicle selection for data collection (Task 5) to ensure the data are representative of the target HDDV vocational use types.
2. To identify and select the HDDV vocational use types and study areas that are most suitable for vehicle activity data collection as well as the truck travel diary surveys.

Methodology
The research team will select the target vocational uses and areas for data collection efforts and develop detailed test protocols involving aspects such as:
- Target locations and vocational uses for truck diary surveys;
- Truck diary survey forms and instructions;
- Field procedures for the diary surveys;
- Vehicle sample size of each target vocational use type for vehicle activity data collection using GPS and ECU/OBD loggers;
- Vehicle activity data collection technologies and methodologies;
- Number of required data collection days;

- Procedures for protecting participants privacy as related to protection of human subjects process;
- Data download, verification, and labeling procedures;

The research team will use the findings from Task 2 to identify the most suitable target areas and HDDV vocational use types for both data collection efforts (Tasks 4 and 5). EMFAC vehicle types per ARB documentation will be the basis of identifying the vocational use types; i.e. different vocational use types will be considered for each vehicle class.

The proposed GPS data for Task 4 will include exact location of the recruited vehicles at any instance in order to identify the type of road facility. Because these data can reveal individual's whereabouts, the data collection will require procedures to ensure that participants' identity and location information are properly protected per instructions of Title 45 CFR (Code of Federal Regulations) Part 46. The research team will prepare and implement data collection and analysis procedures following TAMU's Institutional Review Board (IRB) procedures and will obtain necessary approvals from the IRB.

Each of the above aspects directly influences the data collection processes of this study. The protocols will be developed based on the past experience of the research team, relevant literature, discussion with ARB staff and other relevant resources. These protocols will be documented and discussed with the project management for approval.

Results
The following results will be achieved with this task:

- Target areas for truck diary surveys of task 4;
- Identification of areas and HDDV vocational use types to be used in Task 5;
- Survey forms, instructions, and field procedures for Task 4;
- Protocols for vehicle activity data collection equipment, procedure, and recruiting test vehicles; and
- A human subject protection plan and required applications will be filed with Texas A&M University's Institutional Review Board (IRB).

Task 4: Conduct truck travel diary survey, and quantify number of engine starts and soak time distribution

Purpose
The purpose of this task is to conduct a travel diary survey and develop truck activity profiles which include information on number of engine starts and soak time distributions.

Methodology
TTI and its local partner will identify and recruit vehicles from areas and vocational types selected in Task 3 to participate in the truck travel diary surveys. TTI and its local partner will utilize different methods to recruit vehicles for data collection. This will include but not limited to local advertising as well as working with public and private fleet owners and operators such as cities, Caltrans, ARB, and private freight and delivery companies. The research team will compensate the owners of the vehicles that participate in the study by paying them a fee for their participation, with the approval of the ARB project manager. It is anticipated to recruit up to 100 individual vehicles to participate in truck diary surveys. The exact number of vehicles will be determined based on the finding of the previous tasks.

Once a driver is selected to participate in the study, the research team members will verify that the vehicle meets the selection criteria and record the detailed vehicle information before providing the survey forms along with detailed instructions,

Results
The following results will be achieved with this task:

- A plan for recruiting vehicles to participate in the truck diary survey;
- A list of vehicles to be used in data collection;
- A database of truck diary survey results; and
- An activity profile for the target HDDV vocational uses.

Task 5: Vehicle recruitment and ECU/OBD and GPS data collection

Purpose
The purpose of this task is to recruit the vehicles to participate in the data collection and then collect second-by-second vehicle activity data. The data will include vehicle's instantaneous speed and location information for all the selected vehicles as well engine and exhaust temperature data for a smaller subset of these vehicles.

Methodology
TTI will work with its local partner to recruit vehicles from the areas and vocational types identified in Task 3 to participate in the data collection activities. TTI and its local partner will utilize the same approach as the vehicle recruitment for the truck travel diary surveys (Task 4). While the prime target will be the same pool of vehicles recruited in Task 4, the research team will pursue other participants as well.

It is anticipated to recruit approximately 50 individual vehicles for GPS data logging and a minimum of 5 vehicles for GPS, ECU/OBD, and exhaust temperature data collection. The exact number of vehicles will be determined based on the findings from the previous tasks.

The data collection will involve collecting instantaneous vehicle speed, location, engine data, and exhaust temperatures for the selected vehicles. All the recruited vehicles will be equipped with the instantaneous speed data collection technology that will be selected in Task 3. The data collection will follow an unsupervised format; i.e. drivers will be given data loggers and instructed to follow their normal driving activities for a certain period of time. The drivers will be provided with instruction materials and contact information of the research team in case any unforeseen problems occur during the data collection period. Based on the previous experience of the research team, it is anticipated that a period of two week of data collection per vehicle would provide adequate information. After this period, the data recording units will be removed from the vehicles and data will be downloaded unto a TTI computer, verified, and labeled properly.

As in Task 4, TTI research team members will verify that participating vehicles meet the selection criteria prior to installing the data collecting equipment and recording the detailed information of the vehicles.

Results
The following results will be achieved with this task:

- A plan for recruiting vehicles to participate in the data collection;

- A list of vehicles to be used in data collection;
- A database of second-by-second speed for all participating vehicles; and
- A database of an engine parameters and exhaust temperature data for a minimum number of five HDDVs.

Task 6: Develop truck activity profiles for each truck use type by vocation

Purpose

The purpose of this task is to process and analyze the vehicle activity data obtained from Task 1, Task 4, and Task 5 for each selected truck use type, in order to develop truck activity profiles as well as representative drive cycles by road and vocation types.

The vehicle activity data from previous studies obtained through Task 1 and Task 5 will be analyzed to obtain a set of representative drive schedules or its equivalent operating mode bin distribution for different average speeds, roadway facility types, and vehicle classes.

Methodology

The proposed data processing and analysis approach will pursue the following general steps. The first step involves examining the data from all the sources to determine their validity, compatibility with the objective of the study as well as to identify errors and outliers in the data. The erroneous information will be filtered out and a database of verified unprocessed data will be developed. The engine data will be compared with the speed information and if necessary, correction algorithms will be developed to improve the accuracy of the speed data. Summary tables and simple statistics will be used for the quality control of survey results.

In the second step, a VSP-based approach will be used to develop representative drive cycles. The corresponding location information (e.g. GPS coordinates) will be screened to identify the type of roadway. The speed profile corresponding to driving on selected road facilities will be separated and stored based on the truck use type by vocation, vehicle class, and roadway facility type. In the next step, the VSP values and operating mode bins for each second of speed data will be determined using MOVES model's internal algorithms and then the operating mode distribution of each speed profile will be determined. These data will be analyzed according to drive schedule selection algorithm selected in Task 3 to develop representative drive schedules by vocational use and road type.

The third step will consist of an analysis of the engine parameters and engine exhaust temperature reading along with the speed data from GPS. The focus of this analysis will be to characterize the NO_x emissions contribution of each vocational use type as well as to create a SCR-compatibility profile for each selected truck use type based on a set of criteria that will be developed in consultation with ARB staff. Parameters such as engine exhaust temperature, speed, and engine RPM are examples of potential factors to be considered in setting these criteria.

In the final step, the second-by-second vehicle activity data will be utilized to develop truck activity profiles, which include duty cycles, the number of starts per day and the soak time duration per day for each truck use type by vocation. The resulting truck activity profiles will be then compared to the truck diary survey results obtained from Task 4. All the collected data will be processed and analyzed according to TTI's current Quality Management Plan (QMP) and Quality Assurance Project Plans (QAPPs) developed for similar studies (discussed further in the Data Management Plan section).

Results
The following results will be achieved with this task:
- Representative drive cycles for each selected truck use and road type;
- Representative truck activity profiles for the selected truck use types; and
- Comparisons with the results from Task 4.

Task 7: Analysis of the representativeness of the certification cycle to developed duty cycles for each vocational use

Purpose
The purpose of this task is to develop an assessment of the representativeness of the certification cycle to observed duty cycles for each vocational use from Task 6.

Methodology
The certification cycle will be compared to the drive cycles for each selected truck use type emissions developed in Task 6. At a minimum, the comparison will include statistics representing the differences in speed, travel duration, acceleration, deceleration and other parameters such as operating mode (opMode) distribution and SCR compatibility.

The focus of the comparison is the representativeness of the current certification cycle with regards to real-world NO_x emissions of HDDVs and the functionality of SCR. For this purpose, the research team proposes an approach based on MOVES' operating mode distribution concept. The field data will be processed to build a profile of operating modes with regards to the SCR functionality using exhaust temperature readings. These operating mode profiles will be then compared to opMode profile of the certification cycle to determine the differences in terms of SCR functionality.

Results
The following results will be achieved with this task:
- Comparison of developed drive cycles with the certification cycle. This comparison will focus on NO_x emissions and SCR functionality.

Task 8: Prepare project documentation

Purpose
The purpose of this task is to compile the study results including HDDV activity profile and technical memoranda into a spreadsheet database and research report.

Results
HDDV Activity Profile Database
This spreadsheet database will include the final drive schedules and truck activity profiles along with all other relevant data collected.

Research Report
This comprehensive research report will describe the research performed under this study. It will incorporate the literature review, vehicle and study area selection, vehicle activity data collection and analysis, comparisons with certification testing process, and conclusions and recommendations.

Data Management Plan

TTI's Air Quality Program has a standing Quality Management Plan (QMP) that documents in detail TTI's data management and quality control practices that are standard practice for all TTI projects. Where required, TTI has also developed Quality Assurance Project Plans (QAPPs) for individual studies. These documents will be shared with ARB staff upon request, and a project-specific QAPP will be developed if required by ARB. This section describes the data management and quality control processes relevant to this study.

The following list of information/data will be collected, processed, and analyzed during the course of the proposed study:

- Truck Diary Survey: The following table shows the minimum information collected in this survey.

Vehicle Information	Vehicle and Engine Activity Information
Vocational use; Vehicle type; Axle configuration; Vehicle model year; VIN number; Vehicle weight; Engine make; Engine size; Engine model; and Engine model year.	Engine start time Engine stop time Trip purpose Odometer reading at the first engine start Odometer reading at each engine stop PTO use time (if applicable)

- ECU/OBD and GPS Data Collection: The table below shows the minimum information collected in this data collection effort.

Vehicle Information	Vehicle and Engine Activity Information
Vocational use; Vehicle type; Axle configuration; Vehicle model year; VIN number; Vehicle weight; Engine make; Engine size; and Engine model; Engine model year.	Vehicle speed Engine horsepower Engine RPM Fuel rate Exhaust temperature Truck location (optional)

It is anticipated that up to 100 vehicles to be recruited for the truck diary survey. A sample of up to 50 vehicles will be recruited for GPS data collection of which a small subsample of a minimum 5 vehicle will be equipped with ECU/OBD and exhaust temperature loggers in addition to GPS devices.

Paper form will be the primary means of the information collection for the truck diary surveys. The research team will also utilize alternative approaches such as web-based forms and email communication when appropriate. Automatic GPS, ECU/OBD, and exhaust temperature loggers will be used to collect data on the desired parameter listed above.

TTI and its local partner will collect and analyze data and it is anticipated that this project will produce a significant amount of data. A clear chain of custody has been developed for the data and the data will be handled in a manner consistent with the study's Institutional Review Board application. In order to comply with the federally-mandated IRB process and its principles of confidentiality and anonymity, only the research team members that have gone through IRB training will have access to vehicle ownership data that links the tested vehicles with vehicle owners. TTI will store the data in an electronic format. Processed data will be provided to ARB on CD-ROMs or via a secure online sharing service. Raw data that are archived by TTI will also be made available to ARB upon request, subject to IRB compliance. Data will only be made available to other organizations upon completion of the quality assurance and quality control processes and with the consent of ARB and IRB approval.

At the conclusion of each set of data collection, the team will review results and identify any results inconsistent with expectations or results from similar studies. This includes visual quality control of GPS, ECU/OBD, and exhaust temperature data and continuous monitoring of the data collection crew by a supervisor during the field data collection effort as well as cross-referencing data with other data sources; e.g. checking VIN numbers with registration records.

The team will review the raw data, generate graphs and tables, visually inspect the graphical data, and if necessary, perform statistical analysis to identify outliers. In addition to the visual inspection, GPS data will be validated using the procedures developed by TTI and documented in relevant project QAPPs. Validation of field survey results is based on the comparison to license plate/VIN information to the state department of motor vehicles' database or commercial VIN databases.

Project Schedule

As mentioned previously, the study will involve the following eight major tasks, which will be performed in two phases:

Task 1- State-of-the-practice and available emissions and HDDV activity data;
Task 2- Screening analysis of identifying the magnitude of NO_x emissions by types of vocational uses for heavy-duty diesel trucks;
Task 3- Data collection protocols development and selection of study areas and sites;
Task 4- Conduct truck travel diary survey, and quantify number of engine starts and soak time distribution;
Task 5- Vehicle recruitment and ECU/OBD and GPS data collection;
Task 6- Develop truck activity profiles for each truck use type by vocation;
Task 7- Analysis of the representativeness of the certification cycle to developed duty cycles for each vocational use; and
Task 8- Prepare project documentation.

The next page contains the proposed scheduling for the project showing key milestones and deliverables.

	Task	Month																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	State-of-the-Practice	m		p																					
2	Screening Analysis					m																			
3	Data Collection Protocols							p		m															
4	Conduct Diary Survey																								
5	GPS/ECU/OBD Data Collection											p		m											
6	Develop Activity Profiles															p		m							
7	Analysis of the Representativeness																								
8	Prepare Project Documentation																		d						f

p = Quarterly progress report
d = Deliver draft final report (to be submitted 6 months prior to contract expiration)
f = Deliver final report
m = Meeting with ARB staff

Key Scientific Personnel

Josias Zietsman, Ph.D., P.E., Head, Environment and Air Quality Division, Texas A&M Transportation Institute, Gilchrist Building, 3135 TAMU, The Texas A&M University System, College Station, Texas 78743-3135, Phone: 979-458-3476, Fax: 979-845-7548, E mail: zietsman@tamu.edu

Professional Experience

Dr. Zietsman is the Head of the Environment and Air Quality Division at TTI. He has more than 20 years of transportation engineering and research experience. He holds a Ph.D. in Civil Engineering from Texas A&M University and is a registered professional engineer in the state of Texas. The focus of his doctoral research was on developing a methodology to quantify environmental performance measures such as vehicular emissions. Dr. Zietsman has been principal investigator on numerous studies dealing with the environment, greenhouse gases, and air quality. The sponsors for his work include TxDOT, EPA, the Texas Commission on Environmental Quality (TCEQ), Department of Energy, State Energy Conservation Office, Commission of Environmental Cooperation, Border Environment Cooperation Commission, and several private sector companies. These studies covered the areas of emissions testing, emissions modeling, and policy analyses. Modes covered by these studies include on-road mobile (light and heavy duty), transit, and marine. Dr. Zietsman's work on air quality and emissions measurement and modeling has led to more than 30 technical papers and reports. Dr. Zietsman is very active with the Transportation Research Board (TRB) where he is Chair of the Committee on Sustainable Transportation (ADD40), the secretary of the Committee on Performance Measurement (ABC30) and member of the Committee on Transportation and Air Quality (ADC20). He is also member of several subcommittees and task forces.

Mohamadreza Farzaneh, Ph.D., Associate Research Engineer, Texas A&M Transportation Institute, Gilchrist Building, 3135 TAMU, The Texas A&M University System, College Station, Texas 78743-3135, Phone: 512-467-0946 x12106, Fax: 512-467-8971, E-mail: mfarzaneh@tamu.edu

Professional Experience

Dr. Mohamadreza Farzaneh is currently an associate research engineer in the Air Quality Program at TTI. He has over five years of experience with transportation air quality and emissions measurement and analysis. He has been one of the key researchers on several air quality studies in Texas including "School Bus Biodiesel NO_x Emissions Testing" and "Emissions of Mexican-Domiciled Heavy-Duty Diesel Trucks using Alternative Fuels." Dr. Farzaneh has developed drive cycles and drive schedules for numerous TTI emissions data collection and analysis studies including "Expanding MOBILE6 Rates to Accommodate High Speeds," "Emissions Impact of Mexican Trucks in Texas' Non-attainment Areas," and "RMC0-6237: Characterization of Exhaust Emissions from Heavy Duty Diesel Vehicles in the HGB Area." He is currently the PI of RMC 0-6629, "Texas-Specific Drive Cycles and Idle Emissions Rates for Using with EPA's MOVES Model" and "Emission Estimation Tool for Ports of Entry." His expertise includes algorithm development, programming, data analysis, and emissions and activity data collection and modeling.

Prior to joining TTI in 2006 he was a Senior Research Associate in the Center for Sustainable Mobility of Virginia Tech Transportation Institute (VTTI), Blacksburg, VA. In that position he completed a study for Federal Highway Administration (FHWA) on the impacts of inclement weather conditions on traffic flow parameters. Dr. Farzaneh has also conducted research on signal timing, traffic flow theory, traffic flow models, and traffic micro-simulation as part of his graduate research work.

Doh-Won Lee, Ph.D., Associate Research Scientist, Texas A&M Transportation Institute, Gilchrist Building, 3135 TAMU, The Texas A&M University System, College Station, Texas 78743-3135, Phone: 979-862-2232, Fax: 979-845-7548, E-mail: leedw@tamu.edu

Professional Experience

Dr. Lee is an Associate Research Scientist in the Air Quality Program at TTI. Dr. Lee has more than 10 years of research experience in Environmental Science and Engineering both in Korea and the U.S. He has conducted various research projects related mainly to air quality studies. While conducting the research projects, he has led and been involved in numerous field measurement campaigns with using various instruments including both gaseous and PM measurement systems. At the National Transportation Research Center in Oak Ridge National Laboratory, Dr. Lee performed emissions measurement studies with various engines and automobiles using engine and chassis dynamometers. Those studies involved determining the effects of different fuels including biodiesel and emulsified diesel fuel on both gaseous and PM emissions. Using PEMS at TTI, Dr. Lee conducted more than a dozen of gaseous and PM emissions measurement and analysis projects with various types of vehicles including PHEVs. Dr. Lee is also active on emissions measurement methodology development. He is a full voting member of the Vehicle and Engine Emissions Standards Committee, a Society of Automotive Engineers (SAE) technical standards committee. For gaseous, PM, and other pollutants measurements, and characterizations using PEMS and other instruments, he has published more than 10 research papers on scientific peer-review journals, and presented his works more than 30 times as reports and at conferences.

Tara L. Ramani, P.E., Program Manager, Air Quality Program, Texas A&M Transportation Institute, Gilchrist Building, 3135 TAMU, The Texas A&M University System, College Station, Texas 78743-3135, Phone: 979-845-9888, Fax: 979-845-7548, E-mail: t-ramani@ttimail.tamu.edu

Professional Experience

Ms. Ramani is the Program Manager for the Air Quality Program at TTI. She received an M.S. in Civil Engineering at Texas A&M University in August 2008. Since joining TTI in 2006, Ms. Ramani has worked on numerous projects involving transportation planning, performance measurement, air quality and emissions testing at the Center for Air Quality Studies. She is Principal Investigator on the project for the Texas Department of Transportation titled “Fleet Preventive Maintenance Performance Measurement Model” which involves engine data logging and analysis for heavy duty dump trucks in the TxDOT fleet. She has experience with several other emissions, data collection and fuel testing projects.

Ms. Ramani is Principal Investigator of a project on “Performance Measures for Transportation Planning and Operations for MPOs,” and is involved in numerous other ongoing or recently

completed research projects, including “Sustainability Performance Measures for State DOTs and Other Transportation Agencies,” “Developing Performance Measures for Sustainable Freight Movement,” “Transportation Air Quality Policy Analysis,” “Developing Sustainable Transportation Performance Measures for TxDOT’s Strategic Plan,” and “Prefeasibility Analysis for the Conversion of Landfill Gas to Liquefied Natural Gas to Fuel Refuse Trucks in India.” Ms. Ramani is active among the Transportation Research Board as friend of various committees, and is also certified as an Engineer in Training in the state of Texas.

Jeremy Johnson, Associate Research Specialist, Air Quality Program, Texas A&M Transportation Institute, Gilchrist Building, 3135 TAMU, The Texas A&M University System, College Station, Texas 78743-3135, Phone: 979-862-7253, Fax: 979-845-9873, E mail: j-johnson@ttimail.tamu.edu.

Professional Experience

Mr. Johnson is a Research Specialist in the Air Quality Program at Texas A&M Transportation Institute (TTI). Mr. Johnson has been involved with many different projects during his time at TTI and has expertise in collecting vehicle data from ECU/OBD units, developing data collection protocols and development of software applications for data logging and data processing. He has worked on multiple projects collecting and analyzing emissions data for various types of vehicles, including both on and off road studies. He has served as Principal Investigator of several emissions testing studies and has been responsible for several other field testing campaigns.

Nicholas S. Wood, Assistant Transportation Researcher, Mobility Management, Texas A&M Transportation Institute, 1106 Clayton Lane, Suite 300E, Austin, TX 78723, Phone: 512-467-0946, e-mail: nickwood@tamu.edu.

Professional Experience

Mr. Wood is an Assistant Transportation Researcher in the Austin Office of the Texas Transportation Institute. His experience is in the areas of GPS data collection, performance assessment, and transportation planning applications. Mr. Wood has designed methodologies for collecting and interpreting GPS-based data for a variety of projects. He has led the data collection and processing tasks of a TxDOT research project to create location-specific speed profiles using GPS-based data for the MOVES air quality model. Mr. Wood has created performance measures using third-party speed data from INRIX to support the creation of a congestion management plan for the Capital Area Metropolitan Planning Organization (CAMPO). He has worked on a project for the National Cooperative Highway Research Program (NCHRP) that investigated the potential for partnerships between the travel behavior, automotive, and energy sectors in the sharing of data on the use of electric vehicles and the respective impact on infrastructure. Additionally, Mr. Wood has interpreted “crowdsourced” GPS-based data that were collected from smartphone devices for a TxDOT research project. Smartphone data from the project were used to interpret how and where users traveled on bicycles throughout metropolitan Austin. Mr. Wood has collaborated on data-intensive research with the numerous State DOTs, local MPOs, and tolling agencies throughout the country.

Preliminary Cost Proposal

ESTIMATED BUDGET FOR THE TEXAS A&M TRANSPORTATION INSTITUTE

Collection of Activity Data from On-Road Heavy Duty Diesel Vehicles — **TTI Proposal No. P2013195**
State of California Air Resources Board — **OSRS Proposal No. 1312718**

Task	Labor	Employee Fringe Benefits	Subs	Equip	Travel Subsist	Copy Print	Materials & Supplies	Misc.; Study Participant Compensation	Misc.; Computer Operations*	Facilities & Administrative (F&A) Cost **	Total
1	11,089	2,563	5,000	0	3,316	0	0	0	336	10,105	**32,409**
2	8,535	1,882	10,000	0	0	0	0	0	224	9,392	**30,033**
3	7,600	1,753	5,000	0	0	0	0	0	217	6,602	**21,172**
4	15,558	3,668	25,000	0	6,632	20	7,500	5,000	491	19,954	**83,823**
5	15,863	3,705	35,000	0	6,632	20	22,500	5,000	491	24,711	**113,922**
6	15,074	3,361	8,000	0	0	0	0	0	415	8,480	**35,330**
7	12,174	2,706	7,000	0	0	0	0	0	322	6,845	**29,047**
8	12,642	2,861	5,000	0	3,316	22	0	0	356	8,667	**32,864**
Total	98,535	22,499	100,000	0	19,896	62	30,000	10,000	2,852	94,756	**378,600**

Notes:

All facilities and equipment necessary to accomplish the required work are available.

The Texas A&M University System serves people of all ages, regardless of socioeconomic level, race, color, sex, religion, disability or national origin.

* Computer use and network support services is an established rate and is not charged indirect.

** Per OMB Circular A-21 (rev 8/8/00) and F&A Agreement negotiated with DHHS, capital equipment purchases, rental costs, computer operations, technical support services, video operations, and the portion of subcontracts greater than $25,000 are excluded from Modified Total Direct Costs, and therefore not subject to F&A cost.