Section 6 - Technology

6.1 Introduction

This section of the Strategy focuses on the technologies the EPA and its SLT partners will use to deliver timely ambient air monitoring data from the NCore network.

During the planning stages of the Strategy, the Technology workgroup, with input from the Quality Assurance and Regulatory Review workgroups, NMSC, CASAC, and SAMWG, identified three overall needs for technology investments for the NCore networks. In addition to the new investments, the existing infrastructure for programs such as the ozone network will continue to be employed. Other technologies such as routine CO, SO_2, and NO_2 monitoring may be reduced depending on network assessments that take into account the new investments. While other technology investments will likely be made during implementation of the Strategy, most of those technologies will be supporting one of the three major technology needs:

- Timely reporting of high quality, highly time-resolved ambient monitoring data;
- Collocated characterization of trace levels of CO, SO_2, NO and NOy; and
- Highly time resolved, spatially rich $PM_{2.5}$ data.

The timely reporting of high quality, highly time-resolved ambient monitoring data will require a coordinated effort to ensure data management systems are meeting desired performance needs. These data management systems will need to provide validated data, to the extent possible, in near real time to multiple clients within minutes from the end of a sample period. For NCore to realize its full potential as the Nation's ambient air monitoring network, the data management systems used will need to not only provide efficient processing and validation of data, but also provide appropriate communication of that data in a format appropriate and available for multiple users. The main driver for improved data management systems is providing near real-time, high quality hourly data from all NCore Level 2 continuous monitors as well as ozone, trace level CO, NO, NOy, SO_2 and $PM_{2.5}$ continuous data from all other NCore sites. By having an emphasis on availability of data in near real-time, NCore will better serve its clients by having data available as episodes are occurring. This will allow technical and policy staff to better understand the exposure and interactions of air pollutants in the atmosphere of most interest - today. The characterization of trace levels gases and $PM_{2.5}$ in near real time are part of the monitoring technologies being emphasized in NCore. The use of monitoring technologies in the NCore networks is generally limited to reference and equivalent methods for gaseous criteria pollutants. However, for trace gas analyzers of CO, SO_2 and NO_2, instrument manufacturers are expected to be utilizing their base reference or equivalent methods with modifications to improve their detection limit and therefore performance at low concentrations relative to NAAQS levels. For PM criteria pollutants, EPA is moving toward a base network of reference or equivalent methods with a larger network of *approved* continuous PM monitors that meet appropriate data quality objectives.

While one or more agencies may already be operating with some of the technologies listed in this section, the challenge for implementation will be to produce a framework that encourages widespread adoption of these technologies. Requiring specific technologies will be avoided in most instances; however, the measurement of select parameters will be required at NCore Level 2 sites, as appropriate. The concern on requiring specific technologies is that over time new technologies will be become commercially available that make existing technologies obsolete. One of the main tenets of the Strategy is adopting Performance Based Measurement Systems (PBMS). By adopting PBMS for each parameter of interest in the NCore network, future technologies may be able to enter the market place and become accepted over existing technologies when the data demonstrates they are a better solution for the network. This is part of the Strategy's emphasis on utilizing a PBMS for inclusion of methods that can achieve multiple monitoring objectives. For parameters of interest that do not have reference methods, the strategy will be to use PBMS through a DQO process to identify both a relative standard approach to the method and acceptable error rates.

6.2 Timely Reporting of High Quality, Highly Time Resolved Ambient Air Monitoring Data

Over the last several years one of the most important emerging uses of ambient monitoring data has been public reporting of the AQI. This effort has expanded on EPA's AIRNow web site from regional based near real-time ozone mapping products color coded to the AQI to a national multi-pollutant mapping, forecasting, and data handling system of real-time data. Since ozone and $PM_{2.5}$ drive the highest reporting of the AQI in most areas, these two pollutants are the only two parameters currently reported from AIRNow. While other pollutants such as CO, SO_2, and NO_2, and PM_{10} may not drive the AQI, they are still important for forecasters and other data users to understand for model evaluation and tracking of air pollution episodes. Therefore, this Strategy seeks the following goals for sharing of NCore data in near real time:

- Share all continuous O3, $PM_{2.5}$ and PM_{10} data, where available, across the nation;
- For NCore Level 2 sites, share all gaseous CO, SO_2, NO and NOy data across the nation; and
- For NCore Level 2 sites, share all base meteorological measurements across the nation.

6.2.1 Reporting Interval of Shared Ambient Monitoring Data

The NCore networks serve multiple monitoring objectives such as support for health effects studies, AQI reporting, trends, NAAQS attainment decisions, and accountability of control strategies. For most of these objectives the current minimum 1-hour sampling period for continuous instrumentation is adequate to fulfill the needs of the data. However, there is a need from time to time to evaluate data at a higher time resolution. Examples for this include, but may not be limited to: tracking air pollution episodes, providing data for exposure studies, model evaluation, and evaluating shorter averaging periods for potential changes to the NAAQS.

Gaseous pollutant monitors are generally capable of highly time resolved data such as 5 minute averages, while only select PM instrumentation are capable of sub-hourly measurements. The hardware and software necessary in data management systems to log and report shorter averaging periods are generally already available within the agencies system. However, due to conventional telephone modem polling, many agencies may not be able to handle the timely reporting of shorter averaging periods. One widely available solution to this would be the use of internet connectivity, especially when individual monitoring sites push their data to a central server rather than being polled.

One consequence to collecting sub-hourly data is a potential increased need for validation resources. This is believed to be largely associated with the perceived need to manually validate all criteria pollutant measurements. Since validation of data generally takes place at the reporting interval of the standard, the ambient monitoring network is at a point analogous to a catch-22. That is, there is not enough motivation to move to lower averaging periods, since data need to be validated and certified at intervals that correspond to the NAAQS, yet without a robust dataset of short term data for health and exposure purposes, EPA may not have the information necessary to move toward NAAQS with shorter averaging periods, if necessary. However, sub-hourly data could still be reported with data aggregated and validated at the reporting interval of the NAAQS. Another concern is that the standard 1-hour reporting interval serves data reporting purposes for most agencies almost all the time and it is only the occasional episode where shorter term exposure data is most useful. Yet it is these very episodes that may be dictating why a monitor has been located in the area of interest. To provide a nationally consistent approach for the reporting interval of data, the NCore Level 2 and 3 networks will take a tiered approach to data reporting. At the top tier hourly data intervals will remain the standard for data reporting. Long term, the NCore networks will be capable of providing at least 5 minute intervals for those methods that have acceptable data quality at those averaging periods. For QA/QC purposes such as utilizing calibration gases, agencies should be capable on assessing data on at least a 1-minute interval.

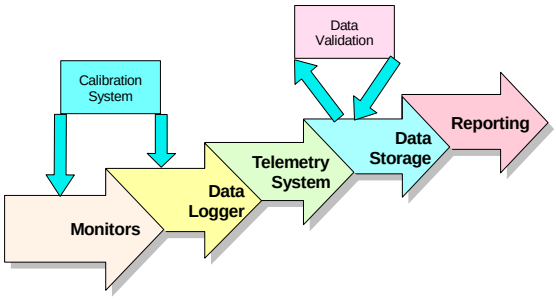
6.2.2 Reporting Frequency and Lag Time for Reporting Data

Continuous monitoring data that are being shared in near real-time from NCore monitoring stations are to be reported each hour. Data should be reported as soon as practical after the end of each hour. For the near term, the goal is to report data within twenty minutes past the end of each hour. This will provide enough time for data processing and additional validation at the Data Management Center (DMC); generation of reports and maps; distribution of those products to a variety of stakeholders and web sites; and still allow enough time for staff review before the end of the hour. This is an important goal to support reporting of air pollution episodes on news media programs by the top of the hour. The long term goal is to report all data within five minutes after the end of an hour. This will further enhance NCore's ability to deliver timely data within a reasonable time period that takes advantage of existing commercially available technology.

6.2.3 Information Technology Components

The areas of information technology currently run in most State and local agencies may be the most ripe for new investment. This is largely due to both the need for a national network of air monitoring that can be available in real-time to support public information needs of the data and the substantial areas of improvements that have been made in information technology since most air monitoring stations were implemented. Although commercially available information technologies may be substantially more efficient than what are currently being used by many State and local agencies, there are a number of issues to consider such as: making the best choice for investment - as today's technology may be outdated soon, costs of technical support, and how easy would it be to move to another generation of this technology once the current generation is outdated. This section identifies some of the key issues with each area of information technology supporting an ambient air monitoring program as well as desired performance capabilities of an information transfer system to serve Level 2 and 3 NCore sites.

Data flow in Ambient Air Monitoring Systems



a. Instrument to Datalogger. Most continuous monitors have the ability to output data at least two ways. For realtime or near realtime monitors, analog outputs usually have a DC voltage corresponding to a range of the concentrations. For example, in an ozone monitor, a 0 to 5 volt output might correspond to a 0 to 500 part per billion range. The analog output is fed into a data logger that has been programmed to receive the DC voltage and interpret it as a concentration of ozone. An RS232 or other digital output may also be employed. These outputs can carry a substantial amount of information beyond the concentration value. For instance: operating temperature; light intensity, if applicable; and concentration range may all be carried in addition to the actual concentration. Despite the wealth of information that can be carried across an RS232 connection, these connections are rarely used. The primary reasons for using DC voltage outputs over RS232 connections are the simplicity of receiving the concentration data by DC voltage and the lack of standard formats for the fields among vendors for the RS232 connections. Despite not using these other data available via the RS232 connection, some of the information may actually be very useful for validating data and remote troubleshooting of instruments. With the cost of storing data becoming cheaper, having an archive of these data may be an effective way to improve validation of the monitoring data. Therefore, a strong recommendation is made to utilize digital connectivity from the back of the instrument to the datalogger. Although there are several digital connectivity options that are commercially available such as RS232, ethernet, USB and Firewire, most ambient monitoring instrumentation only have RS232 available. Since the commercial world is migrating to Firewire, due to its increased speed and functionality over other options, there will be a long term goal in NCore to

do the same. However, any of the digital connectivity solutions are acceptable so long as they allow for two way communication with the instrument. Note in some cases it is possible to report data directly from a monitor to a database without the use of a station datalogger. This solution is acceptable so long as the monitor is capable of data storage for periods when telemetry on off-line.

b. Datalogger to Database. Once data are on the datalogger at the ambient air monitoring station, they need to be sent to servers where they can be summarized and disseminated to data users. In most cases this will occur by using a server at the office of the SLT agency. The conventional way to get data from the monitoring stations has been to poll each of the stations individually. With more widespread availability of the internet, pushing data from monitoring sites on a regular basis will be especially effective in mapping and public reporting of data.

c. Reporting. The need to provide data to a number of users will require multiple reports of the information. For example, the public may need a near real time simple message that the air is clean or moderate. A health researcher or modeler may want a very detailed accounting of the available data in the shortest time intervals possible. Atmospheric scientists typically desire data in a relatively unprocessed yet comprehensive form with adequate descriptions (meta data) to allow for further processing for comparability to other data sets. Regulatory users generally want the data in the form that they can be compared to the NAAQS.

(i) Public Reporting and AIRNow. The area of public reporting for air monitoring data may provide the largest number of users of data. This area has been growing rapidly in the last few years as a result of the increased availability of air quality reporting, especially for ozone and $PM_{2.5}$. For public reporting of the AQI, the AIRNow web site will remain the EPA's primary medium for distribution of air monitoring data. The additional continuous monitoring parameters collected from NCore will also be reported to AIRNow. These parameters are expected to be made publicly available for sharing throughout technical user communities. However, they are not expected to be widely distributed through AIRNow as products for public consumption.

(ii) AQS Reporting. Air monitoring data from NCore level 2 and 3 are to be supplied to AQS after validation by the SLT Agency. In early 2002, EPA implemented its new AQS system. The new system has much more functionality than the previous main-frame system. However, while AQS is fully functional, there remains a perception that data access is difficult.

As a first step to better integrate the AIRNow and AQS datasets, a common format will be sought that will allow for reporting to both databases in the same format. By moving to a common format, data analysis tools that are developed for one system should be able to be applied to both systems. This should help alleviate perceptions about AQS access as these tools will allow users to access and interface with AQS. The format is expected to be in XML. Use of XML as a data format is consistent with EPA and Federal guidelines towards better data integration and sharing.

d. Summary of Desired Performance for Information Transfer Systems to Support National Core Network of Ambient Air Monitoring Stations. Currently, most agencies are using the same information technology systems to record and move data from ambient monitoring stations that were implemented in the 1980's. Due to incredible improvements in processing speed and storage capacity as well as the throughput capabilities to move data, some information technology systems currently in use may be antiquated. If one considers future needs of NCore network stations such as automated low level validation and national near-real time delivery of multi-pollutant data, very few systems as currently run can meet these needs. However, in some cases systems may be adaptable to desired performance capabilities simply by upgrading the telemetry or adding additional features to existing systems. Other systems may need to be replaced entirely to meet the needs of NCore. This section summarizes the desired performance capabilities of an information transfer system to serve NCore Level 2 and 3 sites.

(i) Information Technology Performance Criteria. To define the needed performance criteria of a state-of-the art information technology system, a table of needs has been developed. This table provides performance needs for an optimal information technology system, but is not intended to address what the individual components should look like. For instance, once low level validated data for a specific time period were ready to leave the monitoring station a number of telemetry systems may actually accomplish moving those data. By identifying the needed performance criteria of moving data rather than the actual system to move it monitoring agencies may be free to identify the most optimal system for their network. Table 6-1 summarizes the performance elements of the Data Management Systems used to log, transfer, validate, and report data from NCore ambient air monitoring stations.

Table 6-1.National Core Network (Level 2 and 3) Information Technology Performance Needs		
Performance Element	**Performance Criteria**	**Notes**
Sample Periods	5 minutes (long term goal), and 1 hour data (current standard)	5 minutes and 1 hour data to support exposure, mapping and modeling. 1 hour data for Air Quality Index reporting and NAAQS. Sample period may need to be higher for certain pollutant measurement systems depending on method sample period and measurement precision when averaging small time periods.
Data Delivery	Near Term goal - Within 20 minutes nationally each hour. Long term goal - Within 5 minutes nationally each hour.	As agencies migrate to new telemetry systems the goal will be to report data within 5 minutes. This should be easily obtained with broadband pushing of data to a central server.
Low Level Validation	- Last automated zero and QC check acceptable - Range check acceptable - Shelter parameters acceptable - Instrument parameters acceptable	Other validation should be applied as available: - site to site checks - rate of change - lack of change
Data Availability	- all qc data, operator notes, calibrations, and pollutant data within network - Low level validated pollutant data externally	Create log of all monitoring related activities internally. Allow only validated data to leave agency network.
Types of monitoring data to disseminate - externally	- continuous and semi-continuous pollutant data - accompanying meteorological data	- associated manual method supporting data (for instance FRM ambient Temperature) should be collected, but not reported externally
Additional data for internal tracking	- Status of ancillary equipment such as shelter temperature, power surges, zero air system, calibration system.	
Relevant site information	Latitude, longitude, altitude, land use category, scale of representativeness, pictures and map of area.	Other site information may be necessary
Remote calibration	Ability to initiate automated calibrations on regular schedule or as needed.	
Reviewing calibrations	- allow for 1 minute data as part of electronic calibration log	
Initialization of manual collection methods	Need to be able to remotely initiate these or have them set at an action level from a specific monitor	
Reporting Format	Short Term - Maintain “Obs” file format and pipe delimited formats for AIRNow and AQS reporting, respectively Near Term - XML	Need to coordinate development of XML schema with multiple stakeholders. XML is an open format that will be able to be read by most applications.

(ii) Other Performance Considerations. While some of the desired performance criteria can be identified in units such as sample period or data delivery time, others are more

qualitative in nature. The following list identifies some of the other important considerations of an information transfer to support NCore:

Allow for network time synchronization of all monitoring stations:

- Have battery back-up such as a UPS to ensure no data loss during power outage;
-
- Have information transfer system be self initializing so that if power is interrupted (even with a UPS) the system will go back on-line;
-
- Graphical display of data;
- Ability to provide math operations of data;
- Automated AQS reporting after full validation.

6.3 Measurement Methods for Use within NCore

This section focuses on the measurement methods to be implemented at Level 2 and 3 sites, with a focus on the additional measurement methods for NCore Level 2 that are not currently part of the routine monitoring networks.

When possible, continuous methods should be implemented over manual methods. This is important for several reasons. The highest motivating factor for this is the need to deliver data with a high temporal resolution so that the atmosphere can be characterized on a time scale relevant to how it changes and how people are exposed. On the resource side, continuous instruments are usually much less resource intensive to operate, have a higher sample frequency, provide for greater precision due to reduced human intervention, are easier to automate with respect to data delivery, and their data are easier to validate. Realistically, there will continue to be a necessary mix of continuous and integrated (e.g., filter, canister, cartridge, denuder) sytems in the networks for three important reasons:

- Integrated samples allow for more extensive chemical and physical property analysis in the laboratory,
- Due to uneven performance characteristics exhibited by continuous methods, collocated integrated measurements enable appropriate transformations of continuous data that improve the quantification attributes of continuous data (the basis for regional approved continuos $PM_{2.5}$ methods), and
- Retention of integrated methods allows for smooth transitioning to new continuous technologies with minimal compromising on the ability to construct air quality trends analyses.

The broad longer term goal is to transition from a network that consists of nearly 80% integrated and 20% continuous methods to a near reversal where continuous methods are the dominant moniotring approach. The descriptions below provide the specific monitoring areas of investment being considered in this Strategy.

The minimum requirements for measurements at Level 2 and 3 are as follows:

- **NCore Level 2 Measurements:**
  - Continuous PM_{10} (or $PM_{(10-2.5)}$) and $PM_{2.5}$ Mass
  - Filter-based FRM $PM_{2.5}$ Mass
  - Continuous, trace level CO, SO_2
  - Ozone
  - Continuous NO and NOy
  - Monthly averaged nitric acid and ammonia through denuders
  - Surface meteorology (temperature, relative humidity, wind speed, wind direction)

- **NCore Level 3 Measurements (criteria pollutants):**
  - Mostly $PM_{2.5}$ and ozone
  - Lead, CO, SO_2, and PM_{10} only as needed

The principal pieces of the NCore Level 2 and 3 sites are summarized in the following subsections.

6.3.1 NCore Trace Gas Monitoring

One of the major areas of investment in the Strategy is the use of trace gas analyzers for the characterization of CO, SO_2, NO_2 and NOy at NCore Level 2 monitoring stations. These trace gas analyzers are basically the same instrumentation as approved reference and equivalent methods; however, modifications to improve the sensitivity of the measurement have been made. By utilizing trace gas analyzers instead of conventional gas analyzers, not only can agencies still determine compliance with the NAAQS but they can also provide valid measurements at much lower detection limits. The ability to provide data at lower detection limits will allow for better characterization of confounding factors associated with air pollution episodes since trace gas measurements at NCore Level 2 sites will be collocated. Also, improved gas monitoring data will allow for reducing uncertainties in datasets used to model air pollution episodes and enhance an array of multiple factor based source apportionment analyses. However, the true measurement objective is to characterize actual levels of these gases. In most cases, conversion to trace gas methods and associated calibration regimes will be necessary given the low levels of these pollutants in many “representative” NCore Level 2 sites. There will be locations in urban

areas where the levels of these gases remain in the more conventional ranges and, therefore, not require conversion to new trace gas monitors. Clearly, these situations need to be addressed on a case- by-case basis.

The majority of ambient air gas analyzers in operation across the United States were implemented for purposes of comparing data to the NAAQS. Analysis of these data has shown that the majority of areas of the country are in attainment for the CO, SO_2, and NO_2 standards. NOy measurements are used to characterize total reactive nitrogen and there is no NAAQS for this. However, when measuring for NOy and the concentrations are below the NAAQS for NO_2, it can be assumed the monitor is demonstrating attainment of NO_2.

6.3.2 Ozone Monitoring

The ozone monitoring network is expected to remain one of the spatially rich monitoring programs implemented throughout the United States. Through network assessments their may be opportunities to relocate a small number of ozone monitoring sites from areas of high monitor density to areas of low density.

Although a large network of ozone monitors exists in the United States, there may be opportunities to make better use of the ozone network. This could potentially involve areas of technology and planning associated with ozone monitoring identified below:

- Realignment of monitors: as described in other sections there may be a large opportunity to divest of some redundant urban monitoring and relocate those monitors in areas outside the urban environment in order to detect the spatial gradient of ozone. This is expected to be largely accomplished through the assessments performed across regional areas.

- Providing enhanced ozone QA such as increased use of ozone calibrators.

- Maintaining a minimum number of ozone monitors at NCore Level 2 sites ***operating on a year round basis*** to provide a better understanding of ozone seasonal differences and interactions with other pollutants.

6.3.3 PM Continuous Mass Monitoring

A strong push for PM continuous methods is a major component of the Strategy. EPA has developed an ambitious continuous monitoring implementation plan that was borne out of requests from State and local agencies (specifically through SAMWG) and from the CASAC Subcommittee on PM monitoring. Revision two of the plan is available within Section 6 of the Monitoring Strategy Document web site at:
http://www.epa.gov/ttn/amtic/files/ambient/monitorstrat/sec6.pdf

Some of the major features of the PM continuous monitoring strategy include:

- support for a hybrid network of several hundred PM continuous monitors with a lesser number of FRM samplers;

- using performance based criteria developed in a DQO process to determine the acceptability of PM continuous monitors in the individual networks that they are used; and

- a parallel DQO approach for approval and applicability of methods on a national basis.

The goal of the PM continuous monitoring strategy is to have a PM monitoring network that can meet multiple monitoring objectives at lower cost.

6.3.4 Continuous Speciation Monitoring

Continuous or semi-continuous monitoring provides the ability for monitoring networks to deliver data with a high temporal resolution so that the atmosphere can be characterized on a time scale relevant to how it changes and how people are exposed under dynamic processes. The NCore sites are not required to operate continuous speciation samplers, with the exception of 22 National Air Toxics Trend Sites (NATTS) that include light absorbing carbon measurements through aethalometry. Nevertheless, there should be a gradual evolution of continuous sampler operations at NCore Level 2 and comparable sites. Indeed, EPA is committed to supporting a 10-site continuous speciation network, including carbon, sulfate and nitrate, that evolved from early discussions with the health effects community related to a series of recommendations forwarded by the National Academy of Sciences in the late 1990's and continued by CASAC. EPA is taking a decidedly cautious approach toward continuous speciation monitoring, based largely on findings from the Supersites and other programs indicating mixed performance across a variety of monitors.

a. Continuous Carbon, Ions and Trace Metals. Within the past two years, continuous monitors for these three species have become commercially available. Based on similar sample collection and analysis methodologies, these devices involve the impaction of atmospheric $PM_{2.5}$ aerosols on a metal strip with subsequent flash volatilization of the species, thermal/catalytic conversion, and final detection with either ultraviolet (uv) fluorescence, chemiluminescence, or infrared absorption, as appropriate. EPA and selected State agencies have been conducting a comparative assessment of these technologies collocated with conventional 24-hr filter collection speciation samplers at five STN sites across the country. Results from that work indicates operational issues with the effectiveness of the flash volatilization process and/or thermal/catalytic conversion efficiencies. Current work involves modification/adjustment of the monitors to resolve these issues after which EPA plans to expand the further use of the monitors to a minimum of 10 STN sites (Table 6-2).

New research has focused on the application of coupling ion chromatography with aerosol collection and in parallel with criteria air pollutant sampling to provide complete gaseous and aerosol species monitoring. These methods may offer the advantage of freedom from artifacts but may also present design and operational challenges with adapting liquid media-based chemical analysis to routine field monitoring use.

(i) Support for health effects studies. The 10 speciation sites with continuous speciation monitors was initiated largely in response to the National Academy of Sciences recommendation to provide a set of daily operating speciation sites to support health effects studies. Uneven performance of continuous monitors exhibited through the comparative assessment study and the $PM_{2.5}$ Supersites program has delayed implementation of this network.

Table 6-2. Current and Planned Continuous Speciation Sites (urban)

Site Location	Current or Planned Measurements	Comments
Deer Park, TX	NO_3, SO_4, C	one of first five evaluation sites
Indianapolis, IN	NO_3, SO_4, C	one of first five evaluation sites
Chicago, IL	NO_3, SO_4, C	one of first five evaluation sites
Phoenix, AZ	NO_3, SO_4, C	one of first five evaluation sites
Seattle, WA	NO_3, SO_4, C	one of first five evaluation sites
Atlanta, GA	NO_3, SO_4, C	
Salt Lake City, UT	NO_3, SO_4, C	
Fargo, ND	NO_3, SO_4, C	
Los Angeles, CA	NO_3, SO_4, C	
Fresno, CA	NO_3, SO_4, C	
NYC (Bronx), NY	NO_3, SO_4, C	
Raleigh, NC	NO_3, SO_4, C	

(ii) Regional Planning Organizations (RPO's) . RPOs formed for the purpose of assessing regional haze have initiated continuous speciation monitoring in rural locations (Table 6-3). Typical suite of measurements at these sites include:

- continuous [hourly] $PM_{2.5}$
- surface meteorology
- $PM_{2.5}$ speciation, trends or IMPROVE or "IMPROVE protocol" 3rd-day filter 24-hour average measurements for carbon, ions/elements and $PM_{2.5}/PM_{10}$
- visuals (HazeCam)
- continuous sulfate
- hourly EC/OC/OP

- light scattering [(NGN-2 (wet) "Improve-like" nephelometer]
- trace level sulfur dioxide
- ozone

Table 6-3. Regional Planning Organization (RPO) sites with a subset of continuous speciation monitors.

Location	RPO/site type	Known or expected measurements beyond the standard suite
Raleigh, NC (Milbrook)	VISTAS RPO/ suburban scale	standard suite
Look Rock, TN	VISTAS RPO/rural Great Smokey Mountains NP (Class I)	standard suite
Cape Romaine, SC (Near Charleston, SC)	VISTAS RPO/rural Cape Romain NWR (Class I area) Southeast Coastline	standard suite
Frostburg, MD	Mane-VU/MARAMA/rural Western Maryland	trace CO; NOy; Profiler
Cornwall, CT:	Mane-VU RPO/rural Mohawk Mtn	standard suite
Bar Harbor, ME:	Mane-VU RPO/rural Acadia NP/(Class I)	trace CO
Bondville, IL	Midwest RPO /suburban	continuous ammonia, nitric acid, nitrous acid, sulfur dioxide
St Louis, MO	Midwest RPO, urban (original EPA funded supersite)	Sunset Lab continuous carbon monitor

b. Nitric Acid and Ammonia Monitoring. Both nitric acid and ammonia are important precursor gases to major aerosol components nitrate and sulfate. There is an important need for these measurements to support air quality model and emission inventory evaluations, and to track the long term progress of emission reduction strategies targeting nitrogen species. Combined with the critical multi-media roles associated with watershed acidification and eutrophication, measurements of these compounds demand a place in the national networks. To initiate national level ammonia and nitric acid monitoring, the NCore Level 2 sites will include integrated samples at a one-per-month interval to limit operator burden and overall resource expenditures. The expectation is that the inclusion of integrated measurements will foster the development of continuous methods that can be used in routine network operations.

(i) Nitric acid. In the past, time-integrated systems for sampling and collection of nitric acid have been widely used. These systems use either filter packs or a combination of coated diffusion tubes followed by filter packs for sampling at the monitoring site, and the samples are then transported to a laboratory for analysis. These systems typically collect samples over a time period of several hours and are therefore limited in providing fine temporal concentration resolution. A major problem associated with nitric acid detection by point monitors is transport

through the system inlet. Studies are needed to identify the best transport tubing for real-time measurements.

Thermal denuders with selective coating, such as tungstic acid, have been used for semi-continuous monitoring with data resolution of 30 minutes or less. The denuders are thermally desorbed and measured by a chemiluminescence detector. Several versions of parallel-operated denuder systems have been developed which also are coupled to chemiluminescent detectors for semi-continuous measurement of nitric acid and ammonium nitrate by difference calculations. Commercial chemiluminescence monitors for NO have been modified to design real-time nitric acid detectors using two inlets, one with only a particle filter and the second with a particle filter and a nylon filter. The difference signal is attributed to nitric acid.

Wet denuders have been developed in which nitric acid is captured in a aqueous system using diffusion scrubbers, or parallel-plate-wetted denuders followed by ion chromatographic or colorimetric analyses. Prototype instruments have been field tested which provide up to 10-minute resolution at a detection limit of 10 ppt.

Real-time measurement of nitric acid has been possible using chemical ionization mass spectrometry with detection limits of less than 15 ppt for a one-second sample interval. Systems employing tunable diode laser absorption spectroscopy and open-path, multi-pass Fourier transform infrared spectroscopy have been successfully operated for monitoring nitric acid by interpretation of IR spectra. For nitric acid, the published detection limits are 4 ppb for the diode laser and 10ppb for the Fourier transform instrument.

(ii) Ammonia Monitoring. Similar to measurement of nitric acid, ambient ammonia monitoring can be accomplished using a variety of time-integrated sampling methods and continuous, real-time, or near real-time measurements. The most prevalent time-integrated methods involve the use of acid scrubbers such as sulfuric acid, phosphoric or boric acid to collect ammonia followed by laboratory analysis using ion chromatography. Although these methods are inexpensive and relatively simple to implement, they do have the limitation that temporal resolution is dictated by the sample collection time, and the concentrations are not known until after laboratory analysis. Other time-integrated methods involve the use of gas sorbent detector tubes or passive diffusion devices or denuders of various designs (annular or honeycomb) coated with boric, oxalic, phosphorous and citric acids or sodium bisulfate.

Chemiluminescence monitors are widely used and are probably the most popular means of measuring ambient ammonia concentrations. These monitors do not actually measure ammonia directly, rather they determine the ammonia concentration by difference. In these monitors, the ammonia must be oxidized to nitric oxide by a thermal converter and the nitric oxide is then further oxidized using ozone to produce nitrogen dioxide whose luminescence is measured. By using two thermal convertors operating at temperatures which either oxidize all nitrogen species or all components excluding ammonia, a difference signal is produced to represent the ammonia concentration. However since organic nitrogen compounds and nitric acid are known interferences, ammonia specific scrubbers have been adapted to the monitors to

adjust the measurements. These types of instruments can typically detect ammonia down to approximately 1 ppb.

Several optical systems have been adapted for use in real-time ammonia monitoring. These include: differential optical absorption spectroscopy (DOAS), Fourier transform infrared spectroscopy (FTIR), tunable diode laser absorption spectroscopy (TDLAS), photoacoustic spectroscopy, and ion mobility spectroscopy. Recently, several research field studies using photoacoustic spectrometers have monitored ammonia concentrations as low as 0.1ppb with good accuracy over a range from 1 ppb to 3ppm.

c. Deployment of Continuous Speciation Monitors. All of the identified monitoring technologies, whether under development or commercially-available, offer the potential for providing either real-time, or short time-averaged species data which will undoubtedly aid the health effects research and model development communities who both are in need of highly temporally-resolved monitoring data. However, given the limited practical field applications of emerging monitoring technologies, EPA strongly advises that these new systems be collocated with integrating methods for ensuring comparative assessments and eventual data transformation. Such technologies should be encouraged for use at NCore Level 2 sites where there will be both time-integrated samplers as well as continuous gaseous monitors which will offer the ideal opportunity for both comparative assessments and data integration.

(i) Aethalometers. The SAMWG Subcommittee recommended the use of Aethalometers™ at every urban site in the NATTS. These instruments have been added to the network to measure black carbon (BC). The intent of using this instrument is to develop an indicator for diesel emissions. Technical guidance can be found in the NATTS Technical Assistance Document (TAD) found at http://www.epa.gov/ttn/amtic/airtxfil.html.

Aerosol BC is a primary emission from combustion sources. BC is ubiquitous and absorbs light. It can be found in diesel exhaust, but it is also emitted from all incomplete combustion sources together with other species such as toxic and carcinogenic organic compounds. The Aethalometer is a semi-continuous instrument that measures BC using a continuous filtration and optical transmission technique. The light attenuation through a sample spot and a blank reference are used to determine light absorption. The absorption is converted to black carbon (BC) using an absorption coefficient. The single beam Aethalometer (880 nm) is being used for the NATTS. An estimated detection limit of 0.05 $\mu g/m^3$ BC for a 5-minute average is expected. Since no BC or elemental carbon (EC) particulate standards are available for use in calibrating this monitor, only flow rate calibration using a NIST-traceable device is possible. Although the Aethalometer will not specifically measure diesel PM, it will be used in conjunction with other supportive information (e.g., meteorology, measurement of other toxic pollutants, traffic patterns) to assess the impact of diesel emissions in the NATTS.

6.4 Method Implementation Strategy

6.4.1 NCore Level 1

The Level 1 sites will have a great amount of flexibility and will serve to develop methods, perform research and transfer new technologies and information to the Level 2 network. Because of this flexibility, the actual methods to be implemented are largely unknown; however, these platforms will be structured to meet the overall Strategy method development needs.

6.4.2 NCore Level 2

The minimum measurements required at NCore Level 2 sites require the implementation of some advanced continuous and semi-continuous measurement technologies. With the exception of trace level CO, SO_2 and NOy, Level 2 measurements can be made using methods that are currently available in 40 CFR and the QA guidance provided in the QA Handbook http://www.epa.gov/ttn/amtic/qabook.html. Trace level CO, SO_2 and NOy will require the development of additional technical guidance to allow implementation at NCore. The following provides and outline of the implementation strategy by measurement type needed.

- ***Filter-based FRM $PM_{2.5}$ Mass and Ozone**:* Approved FRM and FEMs will be used to implement the procedures described in 40 CFR Part 50, Appendix D and L.

- ***Continuous PM_{10}/$PM_{10-2.5}$***: EPA anticipates a forthcoming requirement to measure $PM_{10-2.5}$ to support implementation of emerging PM NAAQS. Forthcoming guidance on $PM_{10-2.5}$ monitors will provide the basis for implementation. Clearly, $PM_{10-2.5}$ will be phased in the latter stages of NCore 2 network.

- ***Continuous $PM_{2.5}$ Mass**:* These methods will be implemented through the strategy outlined in the "Continuous Monitoring Implementation Plan. These methods may include, but are not limited to TEOMs, beta attenuation monitors (BAM), beta gauges, and nephelometers. A summary of the continuous monitoring implementation plan is provided in Section 6.5.4b, below.

- ***Basic Surface Meteorology**:* Temperature, relative humidity, wind speed, and wind direction measurements will obtained through a variety of methods described in the guidance provided in "Meteorological Monitoring Guidance for Regulatory Modeling Applications", EPA-454/R-99-005, February 2000 (http://www.epa.gov/scram001/guidance/met/mmgrma.pdf). These methods include (but are not limited to) anemometers, wind vanes, resistance temperature detectors, and hygrometers.

- ***Total Reactive Oxides of Nitrogen (NO_y):*** NO_y measurement methods will be based on the technical guidance prepared for PAMS in June of 2000. This guidance lacks calibration procedures that include difficult-to-convert organic nitrate compounds (e.g., n-propylnitrate) to provide a more stringent test of converter efficiency. Implementation of NO_y monitoring methods will require an update to the existing PAMS guidance to incorporate new calibration procedures.

- ***Continuous, trace level CO:*** Commercially available, non-dispersive infrared (NDIR) monitors that include modifications to enhance performance and offer "high-sensitivity"options to meet the requirements of monitoring non-urban air will be implemented. The principal constraints on lower detection limits of these devices are water vapor interference and background drift. These limitations can be reduced by drying the sample air and frequent chemical zeroing of the baseline and are modifications currently done manually by the user. Prior to implementation, technical guidance will be developed that includes a detailed description of the interferences and limitations and how to address them to obtain trace level measurements.

- ***Continuous trace level SO_2:*** Measurements of SO_2 suffer similar issues with sensitivity in rural areas as CO. Technical guidance will be developed prior to implementation of trace level SO_2 measurements.

- ***Direct NO_2:*** Measurement methods will be incorporated as the measurement technology advances and is commercially available. The EPA Office of Research and Development (ORD) is currently evaluating prototype instruments.

- ***Integrated nitric acid and ammonia***: Low volume denuder methods will be deployed at all Level 2 sites operating on a one sample per month frequency to minimize operator burden and laboratory anlysis costs. Sampling through denuders and subsequent extraction and analysis is considered a routine operation, and will initiate the developnment of a consistent and reliable national data base on these important precursor gases. The introduction of simple integrated measurements is expected to spur development of routine continuous monitors for eventual deployment.

6.4.3 NCore Level 3

NCore Level 3 sites will continue to implement the FRM and FEM (or Network approved methods as is expected to be developed for regional equivalency of $PM_{2.5}$ continuous methods) required for criteria pollutant monitoring and attainment/non-attainment decisions as currently described in 40 CFR, Part 50. Level 3 sites will mainly target ozone and $PM_{2.5}$ mass. No new monitoring technologies or methods will need to be developed for implementation.

6.4.4 Organic aerosol speciation (not required)

The EPA is working with technical experts in the field of molecular markers for organic carbon to develop a technical assistance document (TAD) on the use of molecular marker measurements to assess the origin of carbonaceous particulate matter. This TAD will be used to help educate, inform and guide SLTs in the use of molecular markers or tracers for source attribution. The primary focus will be on the source attribution aspects with a lesser focus on sampling and analysis. The document will provide a discussion of the current molecular markers and their sources, strategies to address unknown sources, new tracer species, the use of tracers in source apportionment modeling, strategies for atmospheric sampling, considerations for source sampling, and requirements for chemical analysis. It is expected that this document will be completed by Fall 2004.

a. Implementation Products and Deliverables. Technical method guidance documents will be prepared to guide SLT's in the proper installation and operation of NOy and the trace level CO and SO_2 instruments. This method guidance will provide information on the setup, installation, configuration, operation and calibration of these instruments. This guidance is expected to be completed by the end of 2004. In addition, SOPs that are prepared for EPA's on-site operation of these types of equipment will be shared with SLT monitoring agencies.

The implementation of NCore Level 2 and 3 measurement methods will require training. It is expected that training will be provided by the EPA, equipment manufacturers, and SLT monitoring agencies. The EPA's ambient methods training program will focus on instrument operations and procedures. The EPA uses a variety of mechanisms for both formal and informal training. These include workshops, satellite and video training, technical assistance, guidance documents and the EPA 's Ambient Monitoring Technology Information Center web site at http://www.epa.gov/ttn/amtic/. A public forum area is also available on this page which allows users to submit questions on monitoring. The overall monitoring Strategy training implementation program is discussed as part of the implementation plan outlined in Section 11.

b. PM Continuous Monitoring Implementation Plan Summary. An enlarged continuous PM monitoring network will improve public data reporting and mapping, support air pollution studies more fully by providing continuous (i.e., hourly) particulate measurements, and decrease the resource requirements of operating a large network of nearly 1000 filter-based reference particulate samplers. The continuous monitoring implementation plan provides recommended directional guidance to move forward in deploying a valued continuous PM monitoring program operated by SLT governments. A range of topics are addressed, including relationships between continuous and reference measurements, performance analyses of collocated continuous and filter based samplers, recommended performance criteria, regulatory modifications, and identification of outstanding technical issues and actions to be taken in the near future.

The plan proposes a hybrid network of filter based and continuous mass samplers. The hybrid network would include a reduced number of existing FRM samplers for direct

comparison to the NAAQS and continuous samplers that meet specified performance criteria related to their ability to produce sound comparisons to FRM data. Two approaches for integrating continuous mass monitors are proposed to maximize flexibility: FEMs and an expanded use of non-designated approved methods identified as Regional Approved Methods. For FEMs, new equivalency criteria will be derived, based upon a data quality objective exercise that match the required performance criteria with the needs of the data. Regional approved methods are analogous to the Regional Equivalent Monitors (REMs) described in the continuous monitoring implementation plan. These monitors will be approved in individual SLT NCore networks where data quality meets specified criteria.

For Regional approved methods, three performance criteria are proposed to determine whether the adjusted continuous measurements are sufficiently comparable to be integrated into the $PM_{2.5}$ network. These criteria are bias (relative to a filter-based reference method) between -10% and +10%, measurement precision (data from two collocated continuous monitors) less than 10% coefficient of variance (CV), and a correlation coefficient of 0.93 (squared correlation of 0.87). The bias and precision criteria are the result of a DQO analysis that is based on data from the existing $PM_{2.5}$ network and an assumption that the annual $PM_{2.5}$ air quality standard is the principal decision driver. In a DQO analyses for the daily standard, continuous monitors, which provide what amounts to a daily sampling frequency were demonstrated to have less uncertainty around a potential decision than filter based referenced methods at lower sample frequencies, all other things being equal. Thus, use of approved continuous monitors at sites near the daily standard should be an improvement over filter based samplers with lower sample frequencies. Also, the DQO result is conservative in that the goals estimate decision error rates for the "worst case" scenarios. In cases that are not "worst," the DQO approach allows for additional flexibility beyond the stated bias and precision goals. The correlation criteria identified was selected based on the empirical evidence of the current $PM_{2.5}$ continuous monitoring network and a DQO exercise to determine what observed correlation coefficient is acceptable for use with $PM_{2.5}$ continuous methods. These performance criteria preferably would be demonstrated by monitoring agency staff independently or in cooperation with instrument manufacturers under actual operational conditions, a departure from the very tightly controlled approach used for national equivalency demonstration. Continuous monitors would be validated periodically in recognition of changing aerosol composition and instrument performance. Performance criteria for use on a national basis for FEMs are being derived in a DQO exercise that in on-going. The major emphasis in this DQO exercise is to tie historical equivalency criteria that use Slope, intercept, and correlation with network operation DQOs that use bias and precision. The major advantage from a DQO perspective for using $PM_{2.5}$ continuous monitors over filter based FRMs is that they provide data every day. Many FRM sites operate on sample frequencies of once every third day or once very sixth day. Having a method that provides a sample every day will reduce the uncertainty of a decision with the data as compared to a method on a lower sample frequency, all other inputs being equal.

c. Use of Performance Based Approaches. A PBMS approach will be built into the Strategy for non compliance-based measurements. This approach allows for flexibility in the measurement methods used and will help to foster the development and implementation of

newly-advanced, continuous measurement technologies. The PBMS concept is a process that defines data quality needs and develops data quality 'indicators' (DQIs) or criteria for which to select or accept new or revised methods. PBMS will be developed and implemented in concert with the QA strategy and DQO processes that are necessary to develop and identify specific method acceptance criteria. At this time, the PBMS process for the Strategy has not been developed. The will be a critical component of the Strategy as new technologies are ready for implementation into the routine Level 2 monitoring network. It would be expected that Level 2 sites would begin development in 2004 and the full suite of Level 2 sites would be completed by January 2007.

6.5 Issues

Despite the need to invest in many areas of the ambient air monitoring program, investing blindly may never result in an improved system. Some concerns that have been brought to the attention of the Technology workgroup from both within the group and external to it are identified below. As appropriate, some possible solutions to each of these issues are also presented:

- Making the right choice for a technology. For any one type of technology there may be several choices to consider. The most cost effective choice right now may be outdated in a year. Making the right choice needs careful consideration and even then the choice may be optimum.

- Transition from current to new technology. Need to consider things such as downtime of systems and a contingency plan if the new systems fail.

- Training of Staff. New technologies may require a higher level of expertise than the old system it was replacing. Need to adequately plan for major shifts in technology.

- Technical service. Need to consider what, if any service plan would accompany any new technology. This may affect the true cost of the technology. Also, need to consider the responsiveness of technical service.

- Use of proprietary software. Need to consider the issues regarding the use of software that is not in the public domain.

- Ability to transfer to new technologies at a future time. Agencies need to be careful to select technologies that do not prevent them from selecting a newer technology down the road.

- Identification of appropriate technical specifications to be included on purchase requests so that air monitoring agencies make the right purchase of equipment. This is especially important regarding technologies that may have similar

features; however, the lower cost product is inferior and leads to substantial problems to the end user. If purchasing agents are given an appropriate amount of detail in the technical specification selection of the inferior technology may be avoided.

6.6 Implementation - Technologies to Use in NCore

The technologies used in the ambient air monitoring program cover all hardware and software used in the measurement, calibration, logging, transfer, storage, validation, and reporting of data. Many of the areas identified are already using state of the art technologies. For instance, much of the gaseous criteria pollutants are measured using continuous monitors with automated features for calibration and data output. However, other areas such as data transfer are relying on technologies that may be outdated. In some cases a technology may be somewhat antiquated; however, because it is operating smoothly and satisfying the needs of the data users, it may not be an opportune area for investment.

Table 6-4 below breaks down the major technology areas of the ambient air monitoring program into individual technology elements, summarizes the state of technology used in a typical ambient air monitoring program, provides recommendations for each technology element and provides a statement of the expected benefit of moving to this element:

Table 6-4 National Monitoring Strategy Technology Implementation Investments			
Technology Element	**State of Technologies used in typical Program**	**Recommendations**	**Expected Benefit**
Data Management Systems - recording of data from back of instrument to datalogger	Analog connection	Move to digital capture of data. Could be RS232, Ethernet, FireWire...	Allows tracking of instrument performance beyond just concentration. Allows for improved remote troubleshooting and two way communication directly to instrument.
Telemetry systems	Everything from low baud modems used on standard telephone lines to satellite, cable modem, DSL and other high speed internet systems.	Focus on performance needs of moving low interval data very quickly to support real time reporting and other data uses. Choose most optimal telemetry system depending on availability in area of monitoring.	Improves timely reporting of data. In many cases there may actually be a reduced cost for utilizing broadband over dial-up modems due to avoiding long distance charges
Data Validation	Limited range checks are used on most systems.	Move toward comprehensive automated QC systems with graphical display of data and point and click validation	Reduced manual validation. Automated QC features improves quality of real-time reported data.
Data Reporting Format	For AQS reporting, bar delimited format is used. For AIRNow reporting, "Obs" file format is used.	Move to common "XML" schema that can serve both reporting needs	XML is an open format that will be able to be read by most applications. By utilizing one format data analyses tools that are developed for one system will be compatible with both systems.
Gas pollutants - CO, SO_2, NO_2/NOy	Approved Reference and Equivalent Methods.	Trace gas analyzers that are also approved as Reference and Equivalent Methods	Allows for tracking of trends and signals that may be important. Allows for better model evaluation.
Gaseous criteria calibration systems	Mixed - Everything from fully automated to manual	Move all agencies towards fully automated systems	Improved data quality
$PM_{2.5}$ monitoring	Approximately 1000 filter based FRMs and over 300 $PM_{2.5}$ continuous monitors	Develop hybrid network of continuous and filter based monitoring to reduce dependency on filter network and optimize resources	Better spatial characterization of $PM_{2.5}$ for episodes. Improved temporal characterization. Reduced operating costs.

6.7 Recommendations

There are several recommendations to include in the Strategy. Although many of the details are described above, this section summarizes those recommendations in a concise manner:

- Reporting of all continuous data from NCore Level 2 as well as all ozone and $PM_{2.5}$ from all Level 3 sites in 1-hour intervals each hour to a real-time data base;
- Implementation of trace gas analyzers for CO, SO_2, NO_2 and NOy at NCore Level 2 monitoring stations;

- Optimization of gaseous pollutant quality assurance, including automation of routine calibrations at all sites;

- Implementation of a hybrid network of PM monitors that provides for a substantial divestment of filter based monitoring and investment in continuous monitoring.