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Earth's First Time Resolved Mapping of Air Pollution Emissions and Transport from Space

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Summary

We describe a near term mission that powerfully addresses Earth science and applications from space. Geostationary orbit uniquely provides continuous access to the wide temporal and spatial variability of atmospheric composition by observing the continental distribution of air pollution, cloud formation and dispersion, and diurnal changes to Earth's lower atmosphere. A tropospheric chemistry mission from geostationary orbit meets needs of public health and policy applications related to assessing and managing national air quality, determining the impact of daily human activity on both chemical weather and climate, and assessing policy implications of international (long-range) transport of air pollution. The required observations use well-understood measurements and well-validated retrieval techniques already employed in space, and advance these techniques to geostationary orbit in order to capture hourly around-the-clock (IR) and dawn-to-dusk (UV) observations. Time resolved observations from geostationary orbit provide the temporal and spatial measurement sampling required to match the anticipated tropospheric chemistry model resolutions of the near future, to support the air quality research, forecasting, and assessment mandates of NASA, NOAA, and EPA. These time-resolved observations will complete the network of surface-based, process study, and existing global, though non-synoptic, observations for air quality applications, and make such data useful in predictive models.

This paper discusses the merits of such missions in terms of a notional near-term mission, GeoTRACE (Geostationary Observatory for Tropospheric Air Chemistry). The GeoTRACE time-resolved tropospheric chemistry mission would discover the spatial and temporal emission patterns of the precursor chemicals for tropospheric ozone and aerosol across continents throughout the nominal 5 year duration of the mission. For the first time, we could understand the influences of weather in transforming and dispersing pollutant emissions, the subsequent

Time-resolved tropospheric chemistry provides significant contributions to important Decadal Survey themes

Theme	Contribution
1. Earth Science and Societal Needs	• Provide scientific foundation for comprehensive environmental assessment of tropospheric pollution and the quality of the air we breathe. • Quantify pollution emissions via inverse modeling and data assimilation.
3. Chemical Weather	• Document chemical weather across the nation and observe important meteorological tracers. • Provide observations on temporal and spatial scales useful to models for assimilation and chemical weather prediction. • Map tropospheric ozone and precursors to enable interpretation of effects on plant growth and crops.
4. Climate Variability and Change	• Improve knowledge of regional tropospheric ozone and carbon budgets to quantify climate forcing from air pollution. • Observe effects of changing climate on frequency and intensity of air pollution events. • Identify wildfire frequency, and assess extent and emissions.
6. Human Health and Security	• Improve prediction of summer smog for sensitive populations. • Monitor and predict extreme pollution events; track plumes from wildfires. • Assist in assessment of long range (international) transport of air pollution.

generation of ozone, and the resultant effect on large-scale air pollution.

The unique observing capabilities from geostationary orbit that have been traditionally used for water vapor and cloud observations are particularly important for chemical weather (air quality). Chemical weather evolves on time-scales that are similar to traditional weather due to the strong influences of transport and precipitation processes on atmospheric composition, but has the additional complexities of highly heterogeneous precursor and primary emissions and strong diurnal variations in production, loss, and transformation rates of the pollutants ozone and aerosol. Anthropogenic emissions have strong diurnal variations associated with urban commute cycles, while biogenic emissions are dependent on diurnal variations in leaf temperature and photosynthetically active radiation. Measurements from geostationary orbit can observe these processes over the continental domain with the required temporal sampling.

Time-resolved measurements are particularly important for linking regional air quality with global chemical composition. Long-range transport is most efficient in the free troposphere due to the strong winds within the subtropical and polar jet streams. This free tropospheric transport is coupled to the continental boundary through diurnal growth and decay of the continental boundary layer, deep convective exchange, and moist ascent within synoptic storms. These coupling processes occur on synoptic and sub-synoptic time-scales and must be observed from geostationary orbit since they are severely aliased by polar orbiting platforms. The time resolved trace chemical measurements would provide new insight into the role of deep convection in venting boundary layer emissions into the free troposphere, allow assessment of the role of low-level transport of residual pollution layers within the nocturnal jet in the evolution of regional pollution events, identify the synoptic transport of continental emissions into the global environment, and allow us to test our nascent predictive tools for national and international policy.

Time-resolved tropospheric chemistry measurement strategy

Air quality comprises many chemical species present in trace amounts in the air we breathe, as well as their time and horizontal spatial variations near Earth's surface where life is sustained. US EPA designates 'Criteria Pollutants', toxic atmospheric constituents with regulatory consequences, which include ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and particulate matter (PM, or aerosol). To be most effective for applied science objectives, GeoTRACE uses proven techniques in backscattered UV-visible spectroscopic measurements and retrievals to determine O_3, NO_2, formaldehyde (HCHO), and aerosol; and gas filter correlation radiometry to determine CO, from solar backscatter at the surface, and in the mid-infrared all day and all night. This carefully selected suite of atmospheric trace constituents represents the key chemical processes in air quality. These measurements are based on spectral signatures in the near UV-visible (300-650 nm) and mid-IR (2.3 µm and 4.7µm) that can be measured from space. GeoTRACE employs large format focal plane array detectors operating in these spectral regions in nadir view. Measurements can be obtained every hour with nominal 5 km x 5 km spatial resolution over the continental domain. Both UV-visible spectrometry and IR correlation radiometry are robust measurement techniques with long records of space operation. The development and validation of detailed retrieval techniques for trace constituents are an important contribution of the existing observations. These well-validated retrieval methods can be applied to the first time-resolved observations, provided

Table 1. Time-Resolved Air Pollution Measurement Requirements

All observations are delivered with unprecedented 1 hour time resolution, at nominal 5 x 5 km^2 horizontal spatial resolution, with vertical resolution similar to low Earth orbit science observations of these constituents.

Observation	Band	Accuracy	Sensitivity
Tropospheric O_3	Huggins (325-340 nm)	4 DU	* 2 x 10^{-3}
	Hartley (290-307nm)	4 DU	* 4 x 10^{-3}
Tropospheric NO_2	Visible (420-460 nm)	1×10^{15} cm^{-2}	* 2×10^{-3}
Cloud Height	Ring Effect/ Fraunhofer	50 hPa	
Total/boundary layer CO	SWIR (2.3 μm)	15 ppbv	3×10^{-8} W m^{-2} sr^{-1}/cm^{-1}
Free troposphere CO	MWIR (4.67 μm)	15 ppbv	3×10^{-7} W m^{-2} sr^{-1}/cm^{-1}
Column HCHO	UV (335-360 nm)	2.5×10^{15} cm^{-2}	* 1×10^{-3}
* indicates fraction of full scale radiance			

that the same measurement techniques and sensitivities are used.

Ozone and NO_2, observed in the UV-visible spectral regions, feature high horizontal variability in the troposphere, and have substantial stratospheric components to the total column. The slowly-varying stratospheric layer can be determined from existing and planned low-Earth orbit observations and from assimilations of such observations. Direct techniques have been developed based on existing low-Earth orbit measurements, including determination of tropospheric O_3 from fitting the altitude-dependent spectrum, and determination of tropospheric NO_2 from spatial filtering, both of which are well established [1,2].

The approach of determining a tropospheric O_3 column by subtracting the limb observations of stratospheric O_3 (SBUV, SAGE) from observed total column (TOMS) O_3 began in the 1970s[3]. Preliminary studies for direct tropospheric O_3 retrievals begun in the 1980s for SCIAMACHY, have been advanced by several research groups, and extended to retrieval algorithms for NO_2, and HCHO[4, 5] In the near future, use of the visible Chappuis band of O_3 along with the UV Hartley-Huggins bands will improve the lower altitude weighting of the measurements. Ten years of GOME measurements, three of SCIAMACHY, and almost a year from OMI have provided substantial heritage in tropospheric algorithms that can be applied to interpret measurements from geostationary orbit that have adequate signal-to-noise.

GeoTRACE measures tropospheric CO using gas filter correlation radiometry. Using both surface reflected sunlight at 2.3 μm and thermal emission at 4.6 μm, GeoTRACE measures both the total column and free tropospheric CO layers. The boundary layer concentration (air quality) is the difference of the total and free tropospheric CO columns. This boundary layer information is only available when both infrared measurements are made with sufficient precision. The layer information enables studies of pollutant vertical transport, boundary layer venting and convection, as well as horizontal transport. When the layered information is time resolved from geostationary orbit, the CO measurement provides a tracer of the 4D evolution of pollutant fields. CO measurements require spectral resolution on order of the rotational line width (0.2 cm^{-1}) to separate the CO signature from spectral interference by other gases. Gas filter correlation radiometry provides such precise spectral resolution by using the gas of interest as the optical filter, with substantially larger throughput and sensitivity, stability of instrument line shape, and tractable data volume compared to IR spectrometers. Measurements of global

Table 2. Notional GeoTRACE payload information

Item	Value/Summary	
Sensor type	IR correlation radiometer	UV-visible spectrometer
Spectral bands/range	2.3 μm, 4.6 μm	300 nm -650 nm
Number of spectral channels	20	2 x 1024 [2]
Size, meters x meters x meters	0.7 × 0.4 × 0.5	0.5 × 0.4 × 0.5
Mass with contingency, kg and %	37 (20%)	65 (20%)
Power with contingency (nominal, peak, duty cycle, standby), watts and %	300 incl. 20% contingency for all 4 operating states	
Data rate with contingency, Mbps and %	50 including 66% contingency	
Ground and on-orbit calibration scheme	Ground radiometric, spectral, spatial, and polarization response cal.	
	In-flight blackbody simulator, reflected solar, 170K cold patch, and space view	In-flight solar diffuser, Tungsten-halogen lamp (*WLS*), and Solar Fraunhofer lines for λ-calibration

tropospheric CO from space were first obtained by the MAPS experiment using correlation radiometry[6] and subsequently by MOPITT[7,8]. GeoTRACE provides these crucial CO measurements using this robust technique.

A science traceability matrix for the GeoTRACE mission is provided in a companion paper to this Decadal Survey, entitled "Observations of Tropospheric Air Chemistry Processes from a Geostationary Perspective" [Atmospheric Chemistry and Dynamics Branch at GSFC].

Geostationary observations of air quality are identified as high priority in national and international plans (Criteria A and J)

The Integrated Global Observing Strategy (IGOS) provides a framework for space-based and in-situ systems for global observation of the Earth. IGOS operates under the United Nations Educational, Scientific and Cultural Organization, and serves as an international agent that brings together world experts to identify the observation products that are needed, and to suggest suitable responses to needs in the science and policy communities, which are documented in Theme Reports. IGOS members (European Space Agency, Global Observing System/Global Atmosphere Watch, International Geosphere-Biosphere Programme, Japan Aerospace Exploration Agency, NASA, NOAA, and the World Meteorological Organization) released the IGOS Theme Report for atmospheric chemistry in 2004[9]. The Theme Report identifies four grand challenges in atmospheric chemistry, the first being tropospheric air quality. The Report articulates a specific requirement "**to provide an operational network consisting of the appropriate combination of LEO and GEO satellites to give the required coverage and time resolution for the tasks envisaged; *immediate action* is required from the agencies involved to avoid a time gap in global surveillance."** NASA leadership in pioneering GeoTRACE will enable international cooperation on this crucial international science focus.

During the formulation of this Theme Report, the Earth Observation Summit convened in Washington in August 2003 and launched the ad hoc Group on Earth Observations with the goal of furthering a comprehensive, coordinated, and sustained Earth observing system of systems. The IGOS findings are amplified by the Interagency (now US) Group on Earth Observations' recently released Strategic Plan for the US Integrated Earth Observations System[10] which calls for "**a global system of Earth observations [that] would provide us with tools to make national and global air quality forecasts in the same way we currently make weather forecasts**". The GeoTRACE suite is specifically designed to enable this capability.

In March, 2004, U.S. EPA convened an expert panel to provide recommendations related to Earth Observing Systems, with a focus on Air Quality[11]. The Panel, which included EPA, NASA, NOAA, NCAR, university and private sector scientists, issued a primary recommendation concerning measurements and sampling needs. The Panel's advice supported "the specific recommendation of IGACO 'to proceed with the immediate implementation of satellites in support of air quality applications.' In particular, **priority should be given to a satellite system that includes geostationary instruments, since only these offer the necessary time and spatial resolution to support air quality forecasting**." GeoTRACE's instruments deliver this capability.

Time-resolved tropospheric chemistry contributes to important science questions facing Earth science today (Criteria C)

"What are the effects of local and regional air pollution on the global atmosphere, and what are the effects of global pollution on regional air quality?" In answering this question, a geostationary tropospheric chemistry mission directly addresses public health and policy applications related to assessing and managing national air quality and the impact of daily human activity decisions on both chemical weather and climate. The use of a geostationary platform provides unique insight into the interaction of small scale processes and global pollution problems by capturing the daily time evolution of human-driven changes.

GeoTRACE measures a suite of tropospheric trace constituents that are key to identifying and understanding air quality, using proven techniques, from geostationary orbit. Of the US EPA designated Criteria Pollutants, CO is an excellent tracer of transport in the atmosphere, plays important roles in the oxidizing capacity of the atmosphere, and is a precursor to tropospheric O_3 formation. Trends in O_3, a greenhouse gas, and in aerosol drive climate change; global warming may, in turn, increase air pollution[12]. Tropospheric O_3 production is strongly affected by the amount of NO_x (NO_x = NO+ NO_2) present; NO_2 is the proxy for NO_x that can be measured from space. Consequently, hourly observations of O_3, CO, and NO_2 form a minimum critical set of air pollution observations that are strongly linked to human health and activity. Formaldehyde, a measure of volatile organic compounds including biogenic isoprene has also been demonstrated[5], and SO_2, a combustion product, can be obtained with further algorithm development. The mission leverages the world monitoring meteorological and forecasting. The vast array of atmospheric state information (especially for temperature, water vapor, and clouds) from the

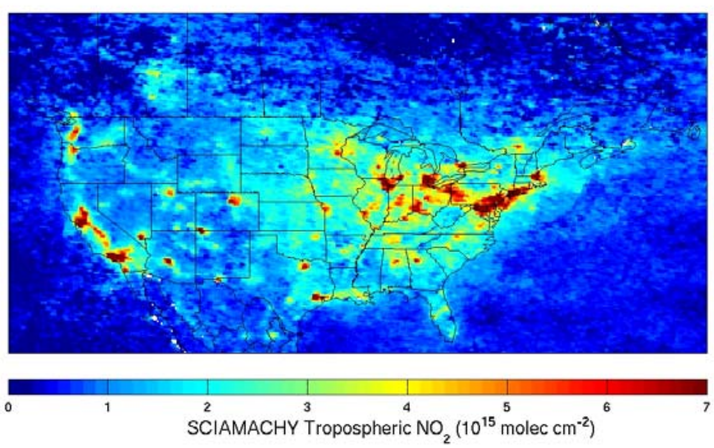

Figure 1. SCIAMACHY tropospheric NO2 in August 2004, analyzed as part of the ICARTT field study linking surface, aircraft, and space based measurements, and models in an Integrated Observing System. Courtesy K. Chance, Harvard-Smithsonian Center for Astrophysics.

Table 3. Specific GeoTRACE Earth Science and Applications Objectives

Tropospheric Chemistry and Air Quality	
	Determine variability in air quality (boundary layer chemistry) due to local emissions and regional transport
	Identify drivers of local high pollution events and improve their prediction
	Assist in model evaluation by simultaneous measurements of ozone and precursors
	Determine lightning NO_x emissions and their contribution to ozone production.
	Use hourly time samples to enable evaluation of chemical transport model representation of diurnal variations in tropospheric chemistry.
	Identify the roles of meteorological variability, increased emissions due to increased demand for household cooling, increased biogenic emissions due to changes in isoprene emissions, and changes in ozone export on the interannual variability of ozone pollution.
Transport of Air Pollutants	
	Facilitate investigations of pollution transport from the boundary layer to free troposphere, and then allow upper troposphere plume tracking after convection has dissipated using the suite of measured constituents and CO profiling
	Identify and monitor important pollution events in remote areas, such as wildfires, and continuously monitor fire growth and plume propagation.
	Evaluate model representation of synoptic transport/subgrid-scale parameterizations of boundary layer height, turbulent mixing, and convective venting
Improve Emission Characterization and Inventories	
	Separate local primary pollution production from the contributions of transported and secondary pollution.
	Using inverse modeling, identify emissions at high time and space resolution, separating different processes and sources, including both fixed local sources (plants, factories), and diffuse sources (traffic, fires, domestic emissions, biogenic emissions).
	Contribute to improving EPA emission inventories

meteorological satellites increases the accuracy of the retrieval of the trace gas concentrations, the primary objective of this proposed mission.

Time-resolved tropospheric chemistry contributes to vital applications and national and international policy for societal benefit (Criteria D)

The integrated observing system approach serves both the research and operational needs of several Agency data uses. GeoTRACE provides measurements at the work-scale of the regional science chemistry and modeling efforts such as the Weather Research and Forecasting regional chemical transport model (WRF-CHEM). The continuous sampling provided by GeoTRACE will lead to rapid improvements in model predictions through verification and eventually data assimilation. Time resolved chemistry and transport observations are key to future efforts by NOAA to produce operational chemical weather predictions. Integrated observations are an important element in evaluating compliance with national and (future) international air quality policy. EPA is currently experimenting with using satellite data[13,14], most notably aerosol optical depth, in conjunction with ground network measurements in air quality monitoring. Such efforts benefit from the improved time sampling and horizontal spatial resolution that geostationary observations uniquely provide. Knowledge of the tropospheric layer structure also facilitates the extrapolation of surface data to remote regions not covered by the surface network.

GeoTRACE fulfils the 'immediate action' requirement[9] for a satellite capability in quantifying the anthropogenic impact on atmospheric chemistry and air quality. US EPA conducts environmental assessment of air quality and pollution transport from urban areas and wildfires to normally pristine remote regions; for example, the impact of pollution transported from Los Angeles on air quality in the Grand Canyon. The recent policy change to allow western US wildfires to burn has created a large, variable, and historically anomalous source of emissions over the US which is not adequately captured by the sparse ground observation network nor the once-per-day low-Earth orbit satellites, but could be determined by GeoTRACE. Validation of new capability in inverse modeling and data assimilation techniques with observations at comparable time and space scales enables the model to be used in policy formulation and evaluation (EPA), and further enables the models to be used for air quality forecasting (chemical weather). Key GeoTRACE observations of tropospheric O_3 and boundary layer CO are valuable meteorological tracers to improve weather forecasts through "feature tracking" wind estimation techniques similar to the current GOES water-vapor and cloud track winds used within the National Weather Service.

Changing rainfall patterns are affecting wildfire frequency, and therefore changing biomass burning emissions and air quality.

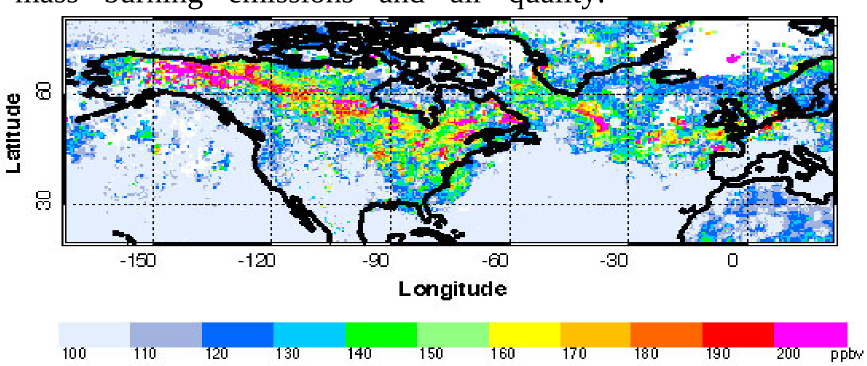

Figure 2 MOPITT free tropospheric CO mixing ratio for one week in July, 2004. Intense wildfires in Alaska produced plumes of pollution that can be traced across North America and the Atlantic Ocean. GeoTRACE will provide North American transport every hour. Courtesy D. Edwards, National Center for Atmospheric Research.

GeoTRACE can observe these emission changes and provide improved knowledge of regional tropospheric O_3 budgets to quantify forcing and climatic impact, and assess damage from wildfire disaster. GeoTRACE will provide critical details in the development, persistence, and eventual dissipation of summer smog in urban areas and its effects on human health. Current background levels of tropospheric O_3 and its precursors are comparable to those known to affect plant growth in the agricultural regions of the US, and can be monitored by GeoTRACE in the absence of any other chemical weather monitoring capability. Establishing pollution chemical concentrations in remote areas not covered by surface networks is an important role for satellites like GeoTRACE. This role is strengthened and enhanced by participation in an integrated system of surface and in situ observations, satellite data, and appropriate fine scale chemical and meteorological models.

GeoTRACE forms an essential part of an Integrated Observing Strategy (Criteria E and F)

No single measurement technique can meet all the requirements for tropospheric air quality, chemistry, and transport science because of the different spatial and temporal scales involved. Chemical process studies require measurement of many trace compounds by in-situ methods (balloon sondes and ground-based remote sensing techniques). Local scale atmospheric chemistry and dynamics are readily observable from aircraft. Satellite observations provide the context for localized observations, and extend local measurements to regional and global scales. Chemical transport models designed for global, regional and local scales help integrate these diverse measurements with the aim of providing a unified understanding. GeoTRACE offers the previously unattainable link between short time sampling scales that can be maintained for years, and fine spatial resolution over an extensive spatial domain.

Low-Earth orbiting sensors Terra/MOPITT (Measurement of Pollution in the Troposphere), Aura/TES (Tropospheric Emission Spectrometer), Aura/OMI (Ozone Monitoring Instrument), plus CALIPSO and MODIS presently, or soon, will provide CO, tropospheric O_3, NO_2, and tropospheric aerosol globally. These sensors provide the continental-to-global scale view of the atmosphere as a result of measurement resolutions on the order of the several days (temporal) and tens of kilometers (horizontal spatial). GeoTRACE's hourly update at the urban area-to-continental scale complements these observations.

Satellite observations are an important counterpart to surface network measurements, which are primarily located in urban areas, as well as a valued component of intensive field campaigns aimed at quantifying the tropospheric chemistry and transport of specific regions. The SAFARI-2K campaign (southern African biomass burning, 2000), and the TRACE-P campaign (Asian pollution outflow, 2001) explicitly provided validation opportunities for MOPITT. The INTEX-A campaign (pollution outflow from the eastern US, 2004) provided an opportunity for ENVISAT/SCIAMACHY and Aqua/AIRS CO validation. These validation activities use aircraft in-situ and other spectroscopic measurements coincident with the satellite overpasses. Conversely, low-Earth orbit satellite CO observations provided the global-to-regional context for the field measurements both for flight planning purposes and in subsequent analysis. Results have included plume tracing and inverse modeling of satellite observations to constrain emission sources [15,16,17].

An integrated observing system significantly enhances the overall scientific value of the separate observations and predictions. However, at the present time, there is a missing link in this measurement strategy at the regional scale. Satellite observations from geostationary orbit can fill this gap in the measurement of tropospheric pollutants. Because of the constant 'stare' obtainable from geostationary orbit, emissions from one region (from city sources, industry, or wildfires) may be traced to neighboring regions, and provide the link between isolated in-situ, ground-based network, and aircraft measurements, and the global-scale low-Earth orbit observations. While a single geostationary orbit system does not provide global coverage, the measurements from a single mission focused on North America can be combined with complementary observations from current and planned sensors in low-Earth orbit which provide the global perspective and necessary boundary conditions on intercontinental transport. Because of international treaties that govern data broadcast from geostationary orbit, a complete global picture from geostationary orbit, requiring 3-5 spacecraft, would best be accomplished through international cooperation, for example, as part of international meteorological agreements or under the auspices of the Group on Earth Observing System of Systems (GEOSS), which is interested in both the science and applications of such data. International scientists have studied concepts similar to GeoTRACE[18]. NASA leadership in pioneering the first platform will enable international cooperation on this critical international science focus.

Time-resolved air quality observing system provides unprecedented capability at affordable cost (Criteria G)

GeoTRACE's suite of crucial atmospheric constituents can be implemented in different ways to comply with program constraints, such as partnerships, schedule, and cost. The importance of measuring the time evolution of air pollution from space was first articulated[19] as a payload of opportunity on a government or commercial geostationary satellite. At the present time, an applied science mission under the sole direction of NASA over the continental U.S. responds to different programmatic needs within the Agency's (Earth) science programs.

The Payload of Opportunity scenario addresses NASA's limits on total mission costs, which historically have not provided adequate resources to achieve non-low Earth orbits. In particular, the GeoTROPSAT team[18] in 1996 surveyed the commercial communications industry to determine a business model, develop and document a standard interface envelope for commercial satellite accommodations, and define a set of program requirements for licensing, data broadcast, and mass to orbit. Recently, the NOAA GOES-R program of environmental data satellites has opened a discussion for payloads of opportunity on the meteorological satellites. For a payload of opportunity implementation, a minimum set of constituents (O_3, CO, and NO_2) would be provided by a highly integrated filter instrument package, to meet the typical 50 kg constraint for payloads of opportunity. The remaining resources (spacecraft, launch, and telemetry) would be provided under the payload accommodation agreement by a partner. This configuration is essentially that proposed to ESSP-1 for a peer-reviewed mission cost of $90M (1996 dollars). Recent revisions to NASA management practices (NPG 7120.5C) indicate additional funding would be required now to provide greater funding reserves, higher ('full') costs for mission-specific NASA employees, and additional management information systems such as Earned Value. The payload of opportunity mission can be implemented under present NASA guidelines for less than $200M as a small payload in partnership with meteorological or commercial platforms.

The applied science mission scenario would be conducted under NASA's sole direction and funding for the hardware aspects for the mission including payload, spacecraft, launch vehicle, and operations. This scenario corresponds to the resources and management practices of a NASA Earth System Science Pathfinder project. For this implementation, a highly capable UV-visible imaging spectrometer and an IR imaging correlation radiometer would be the typical payload. This configuration is similar to that proposed to NMP EO-3 opportunity in 1999, for a peer-reviewed cost of $120M (1999 dollars), excluding spacecraft and launch. The applied science mission, including spacecraft and launch vehicle, can be conducted as a medium size mission ($200 M - $500 M) under present NASA guidelines. Substantial additional resources from partner Agencies would be directed toward improving their decision making by using the satellite data. Their investments in staff and facilities exemplify the partnership required to rapidly transition from research to operational use of satellite data in their predictive models and decision tools.

GeoTRACE time-resolved observing system is ready to meet near term needs for science and societal benefit (Criteria H)

With the national and international community poised to improve their air quality assessment and management needs through sound science and information technologies, GeoTRACE forms a scientifically and technically ready solution for the present decade. GeoTRACE strongly meets Earth science and applications needs, provides data to evaluate chemical weather forecast accuracy, brings awareness to the relation between climate change and air pollution, and serves the human health and policy needs. GeoTRACE is fully aligned with national and international science and applications strategies, and uniquely meets their mandates for these observations. GeoTRACE observations will help advance current predictive modeling capability for both research and operational use. As part of an integrated observing strategy directed at the complex issues in air quality, GeoTRACE complements and supports the existing networks of surface, airborne, and low Earth orbit observations, and extends their value through the unique geostationary contribution of bridging time and space scales.

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