OBSERVING WEATHER AND CLIMATE FROM THE GROUND UP

A NATIONWIDE NETWORK OF NETWORKS

Committee on Developing Mesoscale Meteorological Observational Capabilities to Meet Multiple National Needs

Board on Atmospheric Sciences and Climate

Division on Earth and Life Studies

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Summary

Meteorological observations at the mesoscale (see Box S.1) play a vital role in promoting the health, safety, and economic well-being of our nation. Mesoscale observations capture atmospheric phenomena such as thunderstorms, squall lines, fronts, and precipitation bands at horizontal scales ranging in size from the area of a small city up to the size of a state such as Iowa. The data support such services as weather and air quality forecasting, as well as decisionmaking in many sectors including transportation, agriculture, and homeland security.

Although the federal role in weather and climate information services is pivotal, a number of state and local governments, universities, and private-sector interests have developed and deployed dense networks of meteorological observing systems, known as "mesonets." The advent of inexpensive digital electronics and high bandwidth communications lowered barriers to investment and enabled literally thousands of small businesses, Fortune 500 corporations, agricultural producers, recreation providers, and many others to enter the field of mesoscale observations, driven by a wide range of missions and markets at various investment levels.

Despite this widespread participation, all is not well with atmospheric and related environmental observations. The current U.S. enterprise has a solid synoptic scale core (observations of atmospheric phenomenon on a national scale), but its mesoscale observational capabilities are highly variable in quantity, quality, accessibility, instrument set, site selection, and metadata. The U.S. national radar network remains the best in the world, but not by much, and it has some significant deficiencies. The vertical com-

BOX S.1
The Meaning of Mesoscale

The term mesoscale derives from the Greek *meso*, which translates approximately to *intermediate* in English. In meteorology, this term refers to weather phenomena occurring at horizontal sizes that range from the size of a small city to that of an average Midwestern state (e.g., Iowa). The *Glossary of Meteorology* (Glickman, 2000) defines mesoscale as:

> Pertaining to atmospheric phenomena having horizontal scales ranging from a few to several hundred kilometers, including thunderstorms, squall lines, fronts, precipitation bands in tropical and extratropical cyclones, and topographically generated weather systems such as mountain waves and sea and land breezes.

The Glossary notes that from a physical or dynamical perspective, the horizontal extent of mesoscale features ends just short of where the Earth's rotation exerts a significant influence on air motions. Beyond that are macro- ("large") scale features, including *synoptic* features. Synoptic Meteorology, whose name derives from the Greek *sunoptikos*, meaning "seen together," includes the commonly understood low and high pressure systems often shown on weather maps by broadcast meteorologists. Synoptic low and high pressure systems usually come in pairs ("seen together"), and their evolution governs general regional and national weather patterns on the time scale of a few days (e.g., low pressure/stormy days followed by high pressure/fair days). However, mesoscale features embedded within larger synoptic-scale systems, including individual thunderstorms, rainbands, and frontal passages, often provide the high-impact weather at a particular location.

In mesoscale features, vertical air motions can be intense and vary significantly over short horizontal distances, resulting in strong fluctuations in the temperature, moisture, momentum, and chemical species concentrations observed at any given location. These are some of the quantities associated with the weather "sensed" by humans where they live. In general, the vertical variations of these quantities in the ambient atmosphere (i.e., the vertical gradients) are relatively large near the surface of the Earth. Thus, large vertical motions near the surface of the Earth can be very effective at redistributing temperature, moisture, momentum, and chemical constituents. It is this interplay of vertical air motion with sharp vertical gradients in these quantities that results in high-impact weather and air quality events at the mesoscale. Observations of these conditions are the key to improving predictions of high-impact events, because the sophisticated computer models that provide such predictions are inherently limited by the quality and quantity of observations, which serve as a starting point for the calculations.

Standard weather observations typically resolve larger-scale features that enable a computer model to provide skillful predictions of those features while also producing events that are mesoscale in scope. However, because they lack observations that resolve more of the antecedent mesoscale structure, models are limited in their ability to predict specific high-impact mesoscale events. Therefore, a more effective meteorological and chemical weather observing system must include nationwide observations that are faster in time, more densely spaced horizontally, and are designed to capture the detailed vertical structure of the lower atmosphere.

ponent of U.S. mesoscale observations—the ability to measure atmospheric conditions at various heights—is particularly inadequate.

National priorities demand ever more detailed meteorological observations at much finer spatial and temporal resolutions than are widely available today. These priorities include tracking atmospheric dispersion of chemical, biological, and nuclear contaminants from industrial accidents and terrorist activities, as well as smoke dispersion monitoring and prediction for wildfires, prescribed burns, and seasonal agricultural fires; more extensive air quality forecasting, high-resolution "nowcasting," and short-range forecasting of high-impact weather; high-resolution weather information for aviation, surface transportation, and coastal waterways; and support to regional climate monitoring.

The agency sponsors[1] of this study, recognizing numerous national vulnerabilities and unmet needs related to their missions, asked the National Research Council to convene a committee to help define affordable and effective solutions. The Committee on Developing Mesoscale Meteorological Observational Capabilities to Meet Multiple National Needs was appointed to develop an overarching vision for an integrated, flexible, adaptive, and multi-purpose mesoscale meteorological observation network.

This report offers steps that can be taken to affect near-term improvements in U.S. mesoscale observations and the investments that could be made to strengthen capability over the longer term. Although many of the recommendations specify actions to be taken by the federal sponsors of the report, federal agencies alone are unlikely to satisfy the breadth of national needs for mesoscale data. Therefore, the recommendations specifically address the broader community of private, public, and academic partners.

KEY FINDINGS

The committee finds that, overall, the status of U.S. surface meteorological observation capabilities is energetic and chaotic, driven mainly by local needs without adequate coordination. While other providers act locally to satisfy particular regional monitoring needs, the federal government is unique in its capacity to act strategically and globally in the national interest. An overarching national strategy is needed to integrate disparate systems from which far greater benefit could be derived and to define the additional observations required to achieve a true multi-purpose network that is national in scope, thereby fully enabling mesoscale numerical weather prediction and other applications.

[1]This study was sponsored by the Departments of Commerce (DOC), Transportation (DOT), Homeland Security (DHS), the Environmental Protection Agency (EPA), and the National Aeronautics and Space Administration (NASA).

Increased coordination among existing surface networks would provide a significant step forward and would serve to achieve improved quality checking, more complete metadata, increased access to observations, and broader usage of data serving multiple locally driven needs. A major challenge in implementing this collaboration is to retain the energy, enthusiasm, and diverse investments that have led to our current condition, while also introducing an appropriate degree of centralization for the purposes of coordination, integrity, and integration to maximize the national benefit.

The Committee envisions a distributed adaptive "network of networks" (NoN) serving multiple environmental applications near the Earth's surface. Jointly provided and used by government, industry, and the public, such observations are essential to enable the vital services and facilities associated with health, safety, and the economic well-being of our nation. The recommendations in this report are offered in the spirit of the Committee's broad vision of a NoN.

A NoN cannot deliver a net benefit to users unless comprehensive metadata are supplied by all operators. Although provision of quality metadata is an exacting and demanding task, metadata are the key to the effective accommodation of diverse data sources and the widest possible utility of such information. Comprehensive metadata enable customized network configurations to best meet custom user needs as specified by the users themselves, including all aspects of observing system performance that are germane to a given application.

Infrastructure Needs

Beyond collaboration among existing surface networks, additional types of observations are critical to achieving the desired result of a comprehensive and integrated national mesoscale observing network of networks. Mesoscale observations above and below the atmosphere's lowest 10 meters are particularly inadequate. Assets required to profile the lower troposphere above the lowest 10 meters are too limited in what they measure, too sparsely or unevenly distributed, frequently limited to regional areal coverage, and clearly do not qualify as a mesoscale network of national dimensions. Likewise, subsurface temperature and moisture observations are made only at relatively few locations in most states, limiting our ability to forecast mesoscale atmospheric processes and high-impact weather. The solutions to these particular deficiencies require leadership and infrastructure investments from the federal agencies.

The highest priority observations needed to address current inadequacies are:

- **height of the planetary boundary layer**
- **soil moisture and temperature profiles**
- **high-resolution vertical profiles of humidity**
- **measurements of air quality and related chemical composition above the surface layer**

No systematic national capability exists for these quantities, which are critical to the dynamical prediction of high impact weather and/or chemical weather.

Just below the aforementioned highest priorities are quantities for which some capabilities currently exist but fail to meet a serviceable national standard for one or more reasons:

- direct and diffuse solar radiation
- vertical profiles of wind
- subsurface temperature profiles (e.g., under pavement)
- icing near the surface
- vertical profiles of temperature
- surface turbulence parameters

Geography and Demography

The Committee repeatedly returned to concerns about urban, coastal, and mountainous regions as they affect the mix of surface-based mesoscale observing systems. Mountains, coastlines, and cities have greater importance than their surface areas would imply. Ironically, they are consistently undersampled relative to their needs. All three create their own weather, which is often poorly resolved in synoptic-scale models. Considering the danger of traveling in the winter or fighting forest fires in the summer, the need for observations in the mountains goes beyond that for weather forecasting alone. Coastlines and cities, both of which are heavily populated, also take on special importance, particularly when one considers the critical role for observations in response to a release of toxic substances, to treat the roads in response to an ice storm or blizzard, or evacuate people in advance of hurricane landfall.

RECOMMENDATIONS: STEPS TO ENSURE PROGRESS

Several steps are required to evolve from the current circumstance of disparate networks to an integrated, coordinated NoN. First, it is necessary to firmly establish a consensus among providers and users that a NoN will yield benefits in proportion to or greater than the effort required to establish it. This consensus-building step is essentially political, requiring agreement in principle at various levels of public and private participation, which leads to the collaborative development of an implementation plan. The new elements of a NoN are twofold: (1) the provision of services and facilities that enable individually owned and operated networks to function, more or less, as one virtual network, and (2) the provision of new observing systems or facilities to enable national objectives. The first is largely separable from the second, since considerable benefit may be achieved from improved functionality with existing observational assets.

Recommendation: Stakeholders, including all levels of government, various private-sector interests, and academia should collectively develop and implement a plan for achieving and sustaining a mesoscale observing system to meet multiple national needs.

The plan should recognize and account for the complexity associated with the participants' differing roles, responsibilities, capabilities, objectives, and applications, as well as lessons learned from past experiences. To launch the planning process

- A mesoscale environment observing system summit should be convened to discuss and recommend the implementation of a NoN and to prescribe a process through which a plan will be developed. Participants from the private sector, federal executive branch, U.S. Congress, national organizations of governors and mayors, and key professional societies should attend.
- Forums to further discuss and recommend implementations of the mesoscale observing system should be organized by professional societies and associations such as the American Meteorological Society, National Council of Industrial Meteorologists, American Geophysical Union, Commercial Weather Services Association, National Weather Association, American Institute for Chemical Engineering, American Society for Civil Engineering, and American Association of State Highway and Transportation Officials. A leading role should be assumed by the Commission on the Weather and Climate Enterprise of the American Meteorological Society, the constitution of which is particularly well suited to this task.

Recommendation: To ensure progress, a centralized authority should be identified to provide or to enable essential core services for the network of networks.

Essential core services are defined as those services required to derive levels of function and benefit from a NoN that markedly exceed those currently realized from the assemblage of relatively independent networks. Essential core services include but are not limited to

- definition of standards for observations in all major applications,
- definition of metadata requirements for all observations,
- certification of data for all appropriate applications,
- periodic "rolling review" of network requirements and user expectations,
- definition and implementation of data communication pathways and protocols,
- design and implementation of a data repository for secure real-time access and a limited period for post-time access,
- generation of a limited set of products based upon the raw observations, most notably, graphical presentations of data fields and analyses thereof,
- pointers to more sophisticated products generated externally, such as analyses produced from a short-term model prediction and multiple observation sources,
- pointers back to data providers, where more products and services are available,
- establishment of a link to the National Oceanic and Atmospheric Administration's (NOAA's) National Climate Data Center (NCDC) for archival of selected data, as deemed appropriate by NCDC,
- development and provision of software tools and internet connectivity for data searches, information mining, and bulk data transmissions,
- development and provision of a limited set of end-user applications software, which would enable selection of default network data configurations for major applications as well as tools for creation of custom network data configurations, and
- provision of a data quality checking service with objective, statistically based error-checking for all major categories of data, including manual intervention and feedback to providers.

The premise for these services is to:

- have expert assistance in establishing and maintaining standards for the data provided,
- know which additional data are available and suitable to one's own application,
- have compatibility with and ease of access to selected observations and analyses,

- ensure the archival of selected data commensurate with their useful lifetimes, and
- gain ease of access to the products and services of other providers.

Initially the focus of such activities should be on markedly improved use and value of data from existing observing systems. As new observational, computational, and communications infrastructure is added, the focus should shift to the prompt and seamless accommodation of these new elements and their related objectives. The provision of core services is essential for adequate access to and the utility of mesoscale observations as applied to multiple national needs.

The recommendation for a modest degree of centralization is tightly focused on essential core services. It specifically excludes centralization for the purpose of acquisition and operation of observing systems, which are owned and operated by agencies, corporations, and other organizations to serve their specific missions. The centralized authority is an enabling element of the broader enterprise that comes into play only as is necessary to derive added utility and functionality from the network of networks. It does not speak to the ownership, operation, upgrading, or maintenance of the individual networks themselves. It follows that the centralized authority is envisioned as a relatively small but vital fraction of the entire NoN enterprise.

Recommendation: The centralized authority should require metadata of every component in an integrated, multi-use observing system.

Observational data have high value only if they are accompanied by comprehensive metadata. Provision of metadata should be mandatory for membership in the NoN, and incentives should be offered to the operators of networks to provide it. The contents of a metadata file should be carefully defined, and, once assembled, a national database of metadata should be frequently updated and accessible to all. If action is taken to improve metadata and fill gaps by supplying comprehensive information on undocumented systems, the value and impact of existing data will be improved far beyond the cost of gathering the metadata.

Recommendation: A national design team should develop a well-articulated architecture that integrates existing and new mesoscale networks into a national "network of networks."

To serve multiple national needs, the United States needs a system that is a network of networks in an architectural sense. The term "architecture" includes the fundamental elements as well as the organizational and interfacial structure of the mesoscale network. It also describes the internal interfaces among the system's components, and the interface between the system and its environment, especially the user. This architecture should facilitate a thriving environment for data providers and users by promoting metadata, standards, and interoperability, and enabling access to mesoscale data, analysis tools, and models. The effort must also include a process that continually identifies critical observational gaps, new measurement systems and opportunities, and the evolving requirements of end users.

Recommendation: The national network architecture should be sufficiently flexible and open to accommodate auxiliary research-motivated observations and educational needs, often for limited periods in limited regions.

If history is a proper judge, many of the research-motivated sensors and observations will evolve to operational status, serving existing societal needs better and future societal needs as well. The impact of research-based systems is likely to be felt at or near the Earth's surface, relevant to both managed and natural terrestrial and marine ecosystems, and issues unique to the heavily built environment. A more seamless blending of formal university education with observations, operational forecasting, and research will promote the capacity building required to satisfy personnel needs of the future.

Recommendation: Federal agencies and partners should employ testbeds for applied research and development to evaluate and integrate national mesoscale observing systems, networks thereof, and attendant data assimilation systems. Among other issues, testbeds should address the unique requirements of urbanized areas, mountainous terrain, and coastal zones, which currently present especially formidable deficiencies and challenges.

Applied research and development should include but not be limited to transitional activities, including the operation of prototype networks and evaluation of their forecast impact; development of tools to facilitate data access for real-time assimilation; development of additional tools to serve the general public and educate the citizenry; and exploration of advanced and innovative technologies to serve multiple national needs better, cheaper, and sooner than otherwise might be possible. Testbeds may be operated by national labs, universities, or joint institutes as appropriate to the application, and may have focused limited terms of activity that integrate users in the transition to operations.

Recommendation: The United States should establish a robust and economically viable organizational structure to effect the national

implementation of a multi-purpose environmental observing network at the mesoscale. It may be preferable for this organization to take the form of a publicly chartered, private nonprofit corporation. A hybrid public-private organizational model would stimulate both public and private participation over a wide, dynamic range of investment and applications; maximize access to mesoscale data; and effect a synergism between the public good and proprietary interests.

Historically, the U.S. Congress has chartered private non-profit corporations for various purposes, where the scope of activity is truly national, yet major components of the effort are cooperatively resourced federally and locally through both governmental and private resources. While all of the entities providing mesoscale data are important to the enterprise, all have a limited mission and therefore a limited role where provision of infrastructure and services is concerned. A hybrid public-private organization would encourage the leadership and prominence of pivotal federal agencies such as NOAA, while also protecting, facilitating, and enabling the role of other interests, which are essential to the success of the collaborative enterprise.

RECOMMENDATIONS: MEASUREMENTS AND INFRASTRUCTURE

Recommendation: As a high infrastructure priority, federal agencies and their partners should deploy lidars and radio frequency profilers nationwide at approximately 400 sites to continually monitor lower tropospheric conditions.

Humidity, wind, and diurnal boundary layer structure profiles are the highest priority for a network, the sites for which should have a characteristic spacing of ~125 km but could vary between 50 and 200 km based on regional considerations. Such observations, while not fully mesoscale resolving, are essential to enable improved performance by high-resolution numerical weather prediction models and chemical weather prediction at the mesoscale. Through advanced data assimilation techniques, data from these 400 sites, when used in combination with advanced geostationary satellite infrared and microwave soundings, Global Positioning System (GPS) constellation radio occultation measurements, and commercial aviation soundings, will effectively fill many of the critical gaps in the national observing system.

Recommendation: To meet national needs related to public health and safety, including the growing need for chemical weather forecasts, a core set of atmospheric pollutant composition parameters should be

part of the mesoscale observing system. The core set should include carbon monoxide, sulfur dioxide, ozone, and particulate matter less than 2.5 microns in size at approximately 200 urban and rural sites (~175 km spacing).

These observations would constitute a national pollutant constituent backbone and should be especially effective in enabling air quality (chemical weather) prediction when collocated with surface meteorological observations and related vertical profiles. The selected core chemical species have various impacts, such as on human health; may be harmful to natural and managed landscapes; may also serve as precursors to additional hazardous compounds; and can help to extend the utility of parameters observed from space. Additional important parameters (e.g., nitrogen dioxide) should be added as soon as appropriate and affordable technology is developed for the applications envisioned. The proposed network would enable chemical weather prediction nationally and also would support urban air pollution monitoring, for which it is not a substitute.

Recommendation: A national, real-time network of soil moisture and soil temperature observations should be deployed nationwide at approximately 3000 sites.

This number corresponds to a characteristic spacing of about 50 km for a network that is spatially distributed across the continental United States. Although this spacing is insufficient to capture the full spectrum of short-term spatial variability of surface soil wetness, it is small enough to represent seasonal variations and regional gradients, thereby supporting numerous important applications such as land data assimilation systems in support of numerical weather prediction, water resources management, flood control and forecasting, and forestry, rangeland, cropland, and ecosystems management. This characteristic spacing also would provide data at a resolution that complements historical and relevant datasets. Site selection should be biased toward existing networks, provided that the instrument exposure and all siting standards are acceptable and real-time communication is possible.

Knowing soil moisture at any location is critical for apportioning heavy rainfalls into ground absorption and runoff into streams. Soil moisture also exerts a strong control on the partitioning of the sun's energy into evaporation and sensible heating, which feeds back into the atmosphere to influence the evolution of precipitation and clouds. Moisture in the top layers of soil acts on shorter time scales, to influence day-to-day weather, whereas the amount of soil moisture at deeper levels impacts slower processes at regional scales and acts as a source for water that deep-rooting plants bring to the atmosphere during extended periods without precipitation.

Recommendation: Emerging technologies for distributed-collaborative-adaptive sensing should be employed by observing networks, especially scanning remote sensors such as radars and lidars.

Some high-impact weather phenomena (e.g., tornadoes) of limited size and near-surface location can escape detection or be only poorly resolved by the current low-density network of weather radars. Collaborative and adaptive sensing and related technologies can efficiently enhance the detection and monitoring of adverse weather for hazard mitigation and other applications, particularly for convective scales and in complex terrain and coastal and urban environments. High-density networks of less expensive sensors are capable of operating "intelligently" to increase detection efficiency while controlling costs. If current trends in technologies are a guide, many new instrumentation networks will be composed of intelligent sensors that can be tasked to make measurements in a collaborative manner. These networked sensors will respond to feedback based on input from users and the prevailing environment. Current state-of-the-art communication, computing, and remote sensing technologies facilitate this new paradigm for operation of networked instruments.

Recommendation: As a high satellite instrument priority, the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA), in cooperation with foreign space agencies, should seek to improve the quality of geostationary satellite water vapor and temperature soundings within continental atmospheric boundary layers.

Infrared hyperspectral soundings and soundings from microwave synthetic thinned aperture arrays, each in geostationary orbit, offer unique opportunities to improve mesoscale prediction. When assimilated in conjunction with ground-based profiling data, the benefits from improved geostationary soundings will be large, likely enabling more skillful forecasts of convective rainfall and attendant severe weather and flooding. The geostationary platform is unique among satellites, offering the sampling frequency required in this application.

Recommendation: Existing surface observations and observing platforms associated with road and rail transportation, as appropriate, should be augmented to include World Meteorological Organization (WMO)-standard meteorological parameters. Conversely, existing WMO-standard meteorological observing stations near highways and railways should be augmented, as appropriate, to meet the special needs of the transportation sector.

While continuing to satisfy the fundamental needs of the transportation sector, some existing roadway and railway observing stations could easily be integrated into the NoN to provide a broader complement of meteorological and soil measurements at minimal cost. The addition of another measurement or two at existing sites avoids the major expense of establishing a new station altogether, and wireless communication gives the flexibility to locate individual instruments optimally. Likewise, meteorological stations near roads and railroad tracks could have sensors added to them that would provide data that are beneficial to transportation, for example, water depth measurements near culverts.

Recommendation: The Department of Transportation should assess and eventually facilitate the deployment of high-density observations through the Vehicle Infrastructure Integration initiative. Similar concepts should be considered for general aviation and marine transportation vehicles.

The Vehicle Infrastructure Integration initiative proposes to harness the measurements made by vehicle sensors, for example, temperature and rain rate (from wiper speed), employed in the U.S. automotive and truck fleet. Additional development of nanosensor technologies should realize "measurements on a chip," which would replace the 20th-century sensor paradigm.

RECOMMENDATION: THE HUMAN DIMENSION

Recommendation: The stakeholders should commission an independent team of social and physical scientists to conduct an end-user assessment for selected sectors. The assessment should quantify further the current use and value of mesoscale data in decisionmaking and also should project future trends and the value associated with proposed new observations. Upon implementation and utilization of improved observations, periodic assessments should be conducted to quantify the change in mesoscale data use and its added societal impact and value.

In addition to the involvement of known data providers and users, a less formal survey should capture user comments from blogs and webpage feedback. Such a survey would actively seek comments from people who are registered for or who regularly access the data. The broad objectives of a survey would be to

- identify priority areas where training and outreach can be developed to broaden the number and types of users and uses of network data,

- develop ways to acknowledge and broaden the uses of environmental monitoring information beyond weather, to include examination of societal vulnerability and resilience to a broader range of hazards,
- examine whether and how the partnership agreements and applications within one state, group, or region can be used elsewhere,
- discover metrics that measure how well current initiatives meet the data needs of the citizenry, for example, teachers, students, hospital administrators, golfers, homeowners, and individuals of all ages, and
- identify novel ways to build capacity for using environmental monitoring data in society.

THE CHALLENGE FOR THE FUTURE

Today we are faced with a complex collection of mesoscale networks clearly driven by market forces. This condition is both energetic and chaotic and possesses local strengths, national gaps, and operational weaknesses. Local strengths are heralded by the proliferation of surface meteorological stations, which are often tailored to satisfy the monitoring needs of a particular application. National gaps result from weaknesses in the federal government's observational infrastructure pertaining to mesoscale numerical weather prediction and chemical weather forecasts. Observational deficiencies in the mountains, at the coasts, and near urbanized areas require special attention. With respect to mesoscale numerical weather prediction and chemical weather forecasts, three-dimensional observations are paramount and involve heavy infrastructure to which federal agencies must be major contributors.

Nearly every dimension of participation in mesoscale observation is important and worthy of cultivation. The challenge is to harness the strengths of our current condition while creating an organizational circumstance that can stimulate and coordinate diverse assets to serve similarly diverse interests. The Committee believes that it has offered constructive and sometimes novel alternatives toward that end while avoiding prematurely prescriptive or excessively centralized solutions. Much work remains, especially with regard to the elaboration of architecture, the design of networks, and the forging of new relationships among all levels of government, industry, and the earnest contributiosn of our citizenry.