BNL-67902

The Vision of A Smart City

Presented at the
2nd International Life Extension Technology Workshop
Paris, France
September 28, 2000

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* This work was performed under the auspices of the U. S. Department of Energy under Contract No. DE-AC02-98CH10886.

1. Introduction

The vision of "Smart Cities" is the urban center of the future, made safe, secure environmentally green, and efficient because all structures - whether for power, water, transportation, etc. are designed, constructed, and maintained making use of advanced, integrated materials, sensors, electronics, and networks which are interfaced with computerized systems comprised of databases, tracking, and decision-making algorithms.

The research and engineering challenges along the way to this vision encompass many technical fields including physics, chemistry, biology, mathematics, computing science, systems, mechanical, electronics and civil engineering. At the simplest level is the basic component and its associated "feedback" or self-monitoring mechanism(s). Each must be identified or, if already existing, tailored for the appropriate application. At the next level is the design of the system making use of these components. Associated with this would be the interface to the computerized "monitoring" capability for each given function. Next, is the full structure or service supplied, and lastly, the integration of information across all related and seemingly unrelated aspects of an urban centers essential infrastructure.

A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rail/subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens. Emergency response management to both natural as well as man-made challenges to the system can be focused and rapid. With advanced monitoring systems and built-in smart sensors, data can be collected and evaluated in real time, enhancing city management's decision-making. For example, resources can be committed prior to a water main break, salt spreading crews dispatched only when a specific bridge has icing conditions, and use of inspectors reduced by knowing condition of life of all structures.

In the long term Smart Cities vision, systems and structures will monitor their own conditions and carry out self-repair, as needed. The physical environment, air, water, and surrounding green spaces will be monitored in non-obtrusive ways for optimal quality, thus creating an enhanced living and working environment that is clean, efficient, and secure and that offers these advantages within the framework of the most effective use of all resources.

This paper discusses a current initiative being led by the Brookhaven National Laboratory to create a research, development and deployment agenda that advances this vision. This is anchored in the application of new technology to current urban center issues while looking 20 years into the future and conceptualizing a city framework that may exist.

2. Background

Recent developments in smart materials and smart structures can be classified under two categories: those in which truly new materials are developed (that self sense and diagnose), and those in which newer, smaller and more numerous micro sensors or optical systems are deployed and interfaced with response systems. In the first category, developments such as improved

liquid crystal displays and artificial muscles reflect developments which push the limits of miniaturization to the molecular level. Another example is the development of improved membranes for separation processes that are more sensitive and specific to particular chemical species.

The second category has been of more interest to designers and engineers in that application of sensors and response mechanisms in structures provides an opportunity to reduce mass and overall costs. The benefits realized from these applications are also being extended to civil infrastructures such as bridges and dams. However, although the initiative starts with this category, the long-term goals of the smart cities concept are embedded in the first.

Several of the identified research issues are: categorization of critical infrastructure identification of parameters to be monitored; resolution of measured parameters to manageable performance measures; application of current R&D on smart sensors, development of material, sensors and measurement technologies; and the expansion of transmission computational, networking and integration capabilities.

Over the past twenty years, Smart materials and structures, also known as 'intelligent,' or 'adaptive' materials and structures have been the focus of considerable research. Lately, civil applications, of interest to both government and academia have evolved from what was originally and primarily a military and aerospace focus.

Military and aerospace applications/research, from embedded micro-actuators to control flow over airfoils and in micro-valve arrays, to the investigation of shape memory alloys and diagnostic monitoring of composite structures, have been well supported by the U.S. Department of Defense, and by NASA, with considerable research at academic affiliated research centers, such as the Structures and Composite Laboratory at Stanford University and the Center for Dynamics and Control of Smart Structures, Harvard University.

More recently, a diversified base has been evolving along with the technological needs and expectations of the civil and industrial sectors to address biological, infrastructure and transportation needs. As a result, dynamic and multi-disciplinary research work is under way at a number of university and government-sponsored institutes. The smart cities vision builds on these efforts and focuses on integrating them for use in the urban setting.

Examining and investigating complex 'mega-systems' beyond the component or even the discrete system, will require innovations based on integrative and holistic approaches. These mega systems encompass sustainability – avoiding environmental harm, efficient use of energy and materials, and life cycle engineering, as integrated solutions. In addition to the already evolving and broadening funding base for these technologies, viable solutions will need to include sponsorship from new players, such as the Department of Energy and the Environmental Protection Agency, as well as international cooperation. Furthermore, Congressional Bill, H.R. 115, National Infrastructure Development Act of 1999, indicates the strong need (and governmental interest) for even more creative and efficient methods of financing infrastructure-related initiatives, and marshaling the resources necessary to meet existing and projected infrastructure funding demands.

3. The Approach

In order to realize this vision, this initiative has been undertaken to build an alliance of universities, government, business associations, the private sector and Brookhaven National Laboratory. The intent is to develop a structure that can link the needs of urban centers to the resources of the academic and laboratory community, thereby efficiently identify technologies in their respective portfolios that can be rolled out through demonstration project to commercialization in cities. When technology does not exist, to then begin an applied research effort to address these needs. The model chosen to begin this initiation is that of the northeast region of the U.S.A. This was based on a simple need analysis that looked at the population density and the age of the regions urban center, starting with New York City. The regional model, described below can then be expanded nationally and internationally.

3.1. Brookhaven National Laboratory – The Knowledge Center and Test Bed

The creation of the Smart Cities initiative at BNL will bring together the diverse and multi disciplinary aspects of smart technologies by leveraging capabilities in basic sciences, technology, engineering, and biosciences and by utilizing BNL's unique facilities and resources to transfer these capabilities to address specific societal needs. Furthermore, the BNL site can be a test bed for innovative smart technologies. The Laboratory's infrastructure, which is scheduled to undergo revitalization, would be an excellent testing ground for smart materials, components, systems, and structures. Initial field testing and demonstrations can be conducted in a real world, yet controlled setting, by using the Laboratory. Consequently, attributes, benefits, and lessons learned can be effectively identified and derived, further significantly optimizing resources. Currently, there is no single, focused, research initiative that aims to coordinate and integrate smart technologies for the purpose of rebuilding or retrofitting our crumbling urban centers, controlling urban sprawl, and promoting sustainable growth so that our cities can be models for efficiency, environmental health and security. A Smart Cities Center will be a key element in helping bring basic research to commercial application and productive and effective utilization in the market place.

3.2 Long Island & Environs – An Extended Resource

Long Island, with its growing sci-tech industries, universities, and other research centers, is becoming a growth center of opportunities and scientific achievements. The recently launched Life Sciences Initiative, The Long Island Technologies Center, The Long Island Software and Technology Network (LISNET), the proposed Millenium Technology Research Center, the high-tech incubators, and other advanced technology-oriented initiatives on Long Island all create a rich spectrum of additional knowledge capabilities and resources to dovetail with the Smart Cities Initiative. At the same time, these regional resources offer tremendous synergies and possibilities for idea and product commercialization, economic growth, and developing a high-tech profile with enough substance to get serious national [and even global] attention. Such attention will help further build our sci-tech businesses and resources and attract qualified, knowledgeable workers and further energize Smart Cities-related research.

3.3 New York City and State – The Perfect Proving Ground

New York City is the perfect proving ground for such technologies. Many of the attributes and benefits of the Smart Cities Initiative already mentioned do not do justice to the very real and tangible good that can be derived from its realization. Smart Cities has a very human and simple ultimate goal: a greatly improved living and working environment for our urban populations. Commerce, transportation, a multitude of human services, education, and housing along with a greatly improved environment and greatly enhanced safety and security can be achieved sooner and more cost effectively with this Initiative. The Green Buildings area is expected to be the first major effort to this end.

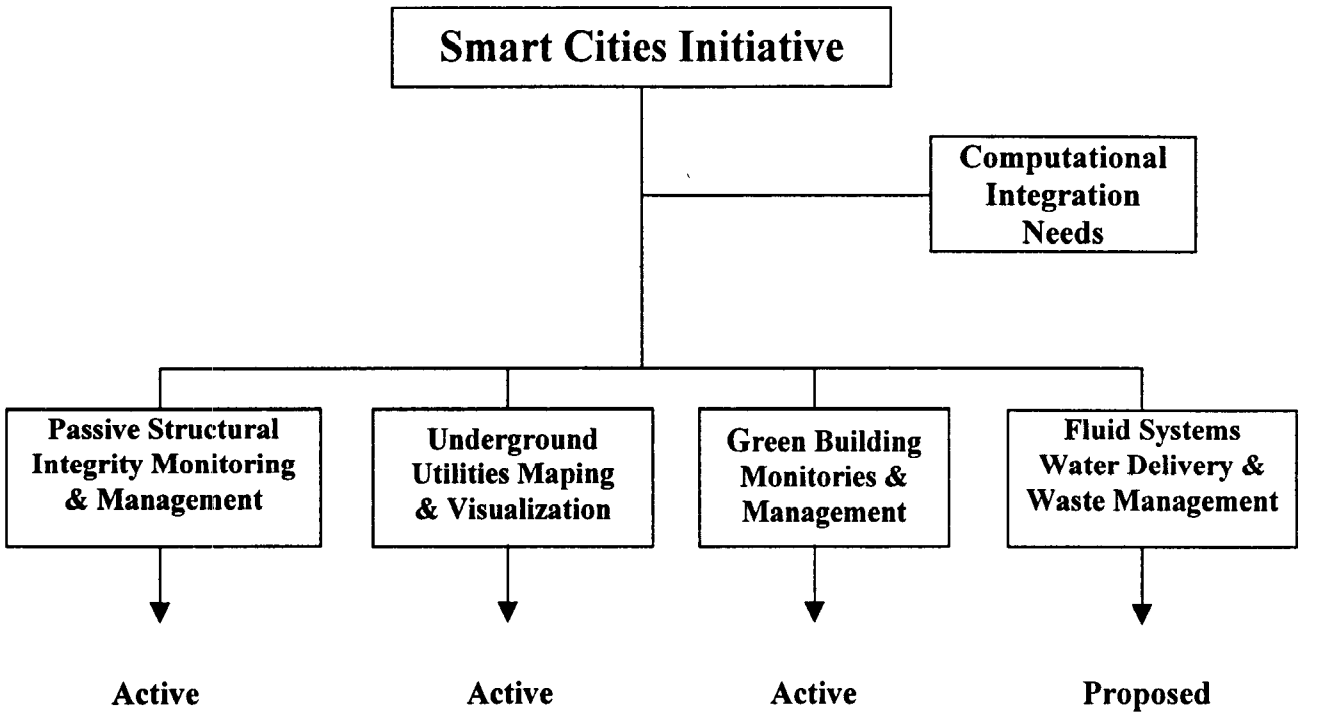
The NYC Management and other public entities and resources should be involved in the Initiative and will be essential elements since they are the ones who can best define the market and customer needs.

4. Progress

The smart cities concept, although in a planning stage since late 1998, received its first funding in January 2000. Since that time the alliance has begun to form with 2 regional universities joining the team along with a New York State Authority engaged in a major urban development program. Additionally the Environmental Business Association of New York State has agreed to convene a council of business representatives to continue the process of needs identification and R&D prioritization. During the month of August 2000 the initiative saw its first private and public utility funds materialize.

At this point the concept has matured, through the interchange with the members of the alliance and an active R&D program has begun. Fig. 1 shows that status pf the R&D agenda with three thrust areas supported, passive structures, underground utilities and Green Buildings. A fourth, that of fluid systems, is in the proposal review stage. As the initiatives continue to mature it is anticipated that new thrust areas will be added as the current ones start to deliver a product stream to the commercial sector.

Fig. 1: Current R&D Agenda



5. The Future

With the early success of the vision, the initiative is expected to grow and take on national prominence. The next 12 to 18 months should see the first two products immerge to address city needs. The passive structure thrust is expected to complete the research or a remote full-field optical sensor with capabilities to measure structural degradation from ages of bridges to delamination of brick building facades. The second, coming from the underground utilities thrust, will be a detection and imaging system with high resolution capability to locate, not only selected systems, such as underground gas and water mains but also their troublesome joints.

As will any major undertaking such as this, its success will lie in the ability to creatively match end user needs to practical R&D and through the establishment of a sustaining funding engine. These two areas will be high priority items over the next year.

Education is a vital part of the future of Smart Cities. The initiative plans to hold 2 workshops over the next 12 months to begin the process of educating our business and governmental leaders. In addition, an outreach process has begun to look at current college engineering curriculum with the thought of the needs of future graduates.

Lastly, it is time to expand the vision to solicit input from the international community. Urban centers around the world face similar challenges. This international Life Extension Workshop, by bringing together representatives of New York City and Paris, represents the beginning of this effort.

6. Conclusion

A vision of the city of the future has been presented - one that rests on the integration of science and technology through information systems. A future that will require a re-thinking of the relationships between government, city managers, business, academia and the research community. The title of this vision is Smart Cities.