Recognizing and Addressing Problems of Scientific and Technological Complexity

Many problems of their scientific and technological complexity are not being adequately recognized, understood, or addressed.

1) Examples of Problems of Scientific and Technological Complexity

~ Y2K (Technical expertise was essential to problem definition, policy development, action, reporting, monitoring, and assessment. An understanding of the disincentives to report problems was also essential. Questions remain.) (See http://users.rcn.com/pgordon/homeland/ . Also see John Koskinen's Responses to Questions from Paula Gordon Concerning National and Global Aspects of Y2K, 3/22/2000 at the Y2K website linked to http://users.rcn.com/pgordon/homeland/.

~ Homeland Security (Some approaches used for Y2K could be used to help address homeland security challenges. What is keeping them from being used?) (See "Strategic Planning and Y2K Technology Challenges: Lessons and Legacies for Homeland Security" at http://users.rcn.com/pgordon/homeland/.)

~ The Challenger and Columbia Disasters (Technical expertise, safety concerns, conflicting priorities, and organizational factors all played roles in the Challenger and the Columbia disasters. Why didn't the understanding gleaned as a result of the Challenger disaster help prevent the Columbia disaster?)

~ Infrastructure Challenges (Policymakers are failing to address in a comprehensive manner physical as well as cyber-related infrastructure vulnerabilities. They also do not seem to grasp the nature and scope of the ongoing impacts of 9/11 on the nation's infrastructure and assets. In addition, they do not seem to understand the national and economic security implications of the deterioration of the nation's infrastructure in evidence long before 9/11.)

~ Some Specific Infrastructure Challenges (Examples of some specific areas of infrastructure vulnerability that are not being addressed in a comprehensive manner include vulnerabilities associated with the Global Positioning System (GPS) and with Programmable Logic Controllers, Digital Control Systems, and Supervisory Control and Data Acquisition Systems.)

~ Some Specific Challenges Involving Weapons of Mass Destruction (Many problems were apparent in the response to the anthrax attacks in October 2001. Key policymakers have either not acknowledged or have failed to deal with these problems. There is a need to address the conflicts that arose. There is also a need to advance state of the science understanding concerning anthrax attacks.)

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2) Why Are So Many Problems That Involve Scientific and Technological Complexity Not Being Adequately Recognized and Addressed?

~ No one organization or institution may "claim" or "own" the problems or have a mandate to address the problems. The result can be "problems without owners".

~ Those in key positions may not have sufficient understanding and expertise to identify and address a problem in a comprehensive way. They may not realize that their understanding and expertise is insufficient. They may not recognize the qualifications of those who do have needed understanding and expertise. They may also fail to ask qualified individuals to help address the challenges for any of a variety of personal, professional, cultural, organizational, or political reasons.

~ Few organizations or institutions seem to be organized in a way that enables them to identify, understand, and address complex issues and challenges, especially issues and challenges that span multiple areas of knowledge and expertise. Even fewer organizations or institutions include individuals who have significant competence in change agentry, knowledge transfer, and innovation diffusion.

~ Groups of individuals who have expertise in different disciplines needed to address complex problems and sets of problems.

(Warren Bennis and Philip Slater write of the need for groups with multi-disciplinary expertise that are facilitated by generalists. See **The Temporary Society**, New York: Harper and Row, 1968)

~ Some problems require scientific and technological expertise as well as organizational, psychological, and political insight and understanding. Ideally, those in roles of public responsibility need to be schooled in organizational behavior, psychology, political behavior, communications, and change agentry. Without such a broad background, it is difficult for those in roles of public responsibility to recognize, understand, and address problems and challenges that that involve scientific and technological complexity.

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3) Why Are So Many Problems That Involve Scientific and Technological Complexity Not Being Adequately Recognized and Addressed? (Continued)

~ Those who understand the complexities of a problem may not be adept at communicating their understanding to others.

~ Those who possess understanding of a problem and needed expertise may be unable to act or disinclined to act.

~ Problems may be addressed only when advanced symptoms appear. When efforts to address problems focus on manipulating or controlling symptoms, short term effects can be expected.

~ Individuals who in theory have responsibility for addressing a problem may be preoccupied with other problems or they may be oblivious to or unable to determine the importance of the problem.

~ Those in positions of responsibility for addressing a problem may lack understanding of contextual factors, such as the turbulence of the environment.

~ Those in roles of responsibility for addressing a problem may try to employ approaches that are ill-suited to addressing the problem, particularly if the problem has arisen in a context of turbulent change.

~ Simple explanations and solutions may be sought for problems that have no simple explanations and solutions.

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4) Why Are So Many Problems That Involve Scientific and Technological Complexity Not Being Adequately Recognized and Addressed? (Continued)

All of the following elements are essential to problem solving.

Essential Elements in Problem Solving

1) An understanding of the scope and nature of the problem;

2) A capacity to identify, develop, and implement viable approaches to addressing the problem;

3) A capacity to muster and utilize all relevant resources effectively;

4) Administrative expertise to wed understanding and knowledge to viable action;

5) An understanding of the political, organizational, and psycho-social factors influencing the environment and the capacity to combine such understanding with interest, common sense, ingenuity, creativity, knowledge, intuition, insight, experience, wisdom, commitment, a sense of responsibility, initiative, vision, and the exercise of leadership and good will.

(A version of this typology was introduced in Chapter 4 of Paula Gordon's doctoral dissertation **Public Administration in the Public Interest**.)

Efforts to address problems need to begin with sound problem definitions. Problems involving scientific and technological complexity pose special challenges. Those addressing such problems need to possess enough conversancy with the complexities of the problems to be able to identify individuals who possess the expertise to address the problems. They need to encourage individuals with needed expertise to join in efforts to address the problems.

(Note: A report entitled "Improving Homeland Security and Critical Infrastructure Protection and Continuity" by Paula Gordon focuses on the need for a comprehensive problem definition for homeland security. In that report a comprehensive approach to defining and addressing the problem of homeland security is compared with a fragmentary approach to defining the problem. See http://users.rcn.com/pgordon/homeland/. For a link to a White Paper on Y2K in which different approaches to defining and addressing Y2K technology challenges are described, also see http://users.rcn.com/pgordon/homeland/.)

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5) Why Are So Many Problems That Involve Scientific and Technological Complexity Not Being Adequately Recognized and Addressed? (Continued)

Approaches to defining and solving problems may be rooted in narrow rationality. The preeminence of "narrow rationality" can seriously impede efforts to recognize and address problems that involve scientific and technological complexity. Narrow rationality approaches to analysis, decisionmaking, and problem solving tend to be stressed in both academic and professional training and reflected in public as well as private sector endeavors.

	Narrow Rationality	Broad Rationality
Scope	Focus on short time horizon	Focus on longer time horizon
	Greater emphasis on analytic abilities	Greater emphasis on synthetic abilities
Rationality Dimensions	Concerned in a major way with feasibility	More inclined to take risks and entertain uncertainties
	Concerned with consistency	Less inclined to emphasize consistency
Learning Dimensions	Conducive to a specialized approach to knowing and action	Conducive to a generalist approach to knowing and action
	Conducive to working within a constricting methodological methodological framework	Not conducive to working within a constrictive methodological framework

(Based on a typology developed by Bertram Gross in **Organizations and Their Managing**. New York: The Free Press. 1968.)

A new mind set is needed that incorporates both narrow and broad rationality. Examples of such a mind set can be found the approach taken by the leadership of the Apollo 13 ground crew. The same can be said of the team that rescued the nine miners in the Que Creek Mine Disaster in Pennsylvania. A melding of narrow and broad rationality is also needed in addressing other problems that involve scientific and technological complexity, including infrastructure problems and vulnerabilities.

(Approaches to addressing infrastructure concerns are discussed in "Improving Homeland Security and Critical Infrastructure Protection" and in an article on infrastructure concerns, both by Paula Gordon. See http://users.rcn.com/pgordon/homeland/.)

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6) Why Are So Many Problems That Involve Scientific and Technological Complexity Not Being Adequately Recognized and Addressed? (Continued)

Approaches to planning and decisionmaking can affect the way that problems involving scientific and technological complexity are addressed. Different approaches to planning and decisionmaking can also reflect different perspectives, values, purposes, long-range goals, and priorities.

Four Approaches to Planning and Decisionmaking

Laissez faire

*Disjointed incrementalism

Goal-Oriented Jointed Incrementalism

Comprehensive Total Planning

*(Charles Lindblom, "The Science of Muddling Through," **Public Administration Review** 19 (1959): 79-88.)

The above typology is based on the work of Henrik Blum. See Allan Blackman and Henrik L. Blum, "Approaches to Social Change and Their Consequences for Planning," in **Notes on Comprehensive Planning for Health**, pp. 2.02 - 2.06. Berkeley, CA: Comprehensive Health Planning Unit, School of Public Health, University of California, 1968.

Henrik Blum's "Goal-Oriented Jointed Incrementalism" is a goal-oriented approach to planning and decisionmaking that can be readily adapted to meet changing needs in a turbulent environment. It is not the typical approach that is taken to planning and decisionmaking. Laissez faire and disjointed incremental approaches are far more typically found in a highly turbulent environment. Comprehensive total planning approaches are rarer and can be fraught with problems especially in a highly turbulent environment. This may occur because there may be no ready way to adapt a "total plan" to rapidly changing circumstances. Use of a comprehensive total planning approach can also make it difficult to revise or broaden the problem definition. It can also make it difficult to incorporate lessons learned and make mid-course corrections.

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7) An Example of an Unmet Challenge: Using a Legacy from Y2K to Enhance the Nation's Homeland Security Efforts

The Information Collection and Reporting System (ICRS) was a software program developed and used by the President's Council on Year 2000 Conversion to monitor incidents before and after the Y2K rollover. The system was used in the Y2K Information Coordination Center (ICC). The overall cost of standing up and operating the ICC was around $45 million. The cost of developing the software alone was several million dollars. The software could be redeployed today. It could be refined and adapted to meet current needs for homeland security and emergency management operation centers. It could be used to address national security as well as homeland security needs. It could be used to enhance situational awareness in man-made as well as natural disasters and catastrophic events.

Why wasn't the ICRS software program revived after 9/11 when the need for such a system became obvious? Why isn't it in place today to help meet current needs? The revival of the system depends in part on there being one or more individuals in positions of sufficient authority who recognize the merits of reviving the system. They would also need to have some sense of how the system might be refined and adapted to meet needs of the post-9/11 world. In addition, they would need to consider integrating this system with other systems that are already in place such as the National Emergency Management Information System (NEMIS).

The implementation of a system that integrated ICRS and NEMIS would require understanding of the needs that such a system would help meet. It would require sustained interest and attention. It would require expertise and resources. The process could be slowed considerably if those individuals with the requisite expertise are not available or interested. The individuals with the knowledge and the expertise may well need to join together to make a case for the feasibility of integrating and deploying the systems. This can be particularly challenging if there are numerous other projects and challenges competing for attention.

Success might well depend on the ability of those who understand the merits of the project to convince others of those merits, others who may have little or no technical background. The importance of the fact that the software has already been proven successful may also elude individuals who are involved in the decisionmaking process if they had little or no knowledge of the past use of the system for the ICC. While a system exists that could help address current needs, arriving at a decision to adapt and use the system may not be a simple matter.

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8) A Second Example of an Unmet Challenge: Problems Relating to the Anthrax Attacks in the Washington, D.C. Metropolitan Area

~ The response to the anthrax attacks involved institutional, professional, and jurisdictional conflicts, conflicts that are as yet unresolved. Interestingly, few of the decisionmakers involved in the response to the anthrax attacks seem to be aware of the existence of these conflicts, let alone their nature and significance.

~ Efforts need to be made to understand organizational, jurisdictional, and political issues and constraints that marred the effectiveness of response efforts. Actions need to be taken to make sure that such challenges are addressed more effectively in the future should other attacks occur.

~ Of particular note is the fact that there was no declaration of a Federal disaster. As a result, there was great uncertainty concerning who was in charge and what resources should and could be used and how the costs of services rendered would be covered and by whom. To be better prepared in the future, it would be helpful to think through possible alternative scenarios in advance.

~ The response was also complicated owing to an imperfect understanding of scientific and technological issues relating to all aspects of the anthrax attacks. There is a need to take steps to increase state of the science and state of the technology understanding. Steps also need to be taken to help ensure that those who need such understanding are able to acquire it. To this end, improved approaches to knowledge transfer are needed. Individuals in key roles of responsibility who may possess greatly varying levels of expertise, need to be better informed concerning the state of scientific understanding about anthrax, including diagnostic and treatment protocols as well as forensic and remediation protocols. State of the science and consensus development conferences similar to those organized by the National Institutes of Health's Office of Medical Applications of Research (OMAR) could help meet such needs. (For a discussion of the approaches used by OMAR, see "Using E-Technology to Advance Homeland Security Efforts" by Paula Gordon at http://users.rcn.com/pgordon/homeland/ and "Knowledge Transfer: Improving the Process" also at that same URL.)

If more anthrax attacks were to occur in the future, there is little reason to believe that the key spokespersons and experts would be "on the same page" and speak with any more of a unified voice. There is also every reason to believe that institutional, professional, and jurisdictional conflicts similar to those that arose in late 2001 and in 2002 would recur. Of even greater concern is the fact that no institution appears to "own" these problems. Thus far, no one in a high level position in a public health-related or emergency management-related institution has publicly acknowledged or addressed in any kind of a comprehensive way the sets of challenges and conflicts described here.

9) A Third Example of an Unmet Challenge: GPS Vulnerabilities

The following recommendation concerning homeland security was made in a January 7, 2002 Heritage Foundation Report on Homeland Security:

"Designate the Global Positioning System (GPS) frequencies and network as critical national infrastructure. The GPS satellite network is an enabling system for other infrastructure systems, such as telecommunications, that are vital to the nation's security. Disruption by terrorist groups or hostile states could jeopardize America's homeland security, but the GPS has not been designated as a vital national asset. President George W. Bush should immediately add the GPS to the current list of vital national infrastructure and assign responsibility for its security to the U.S. Department of Defense (DOD). Immediate steps should begin to make the GPS network more secure."
http://www.heritage.org/research/homelanddefense/project.cfm.

Is the attention being given to such vulnerabilities anywhere near adequate today?

~ There is skepticism on the part of high ranking officials concerning the existence of GPS vulnerabilities. Such individuals may have insufficient technical expertise to make such an assessment themselves and may be relying solely on the assessments of others whom they assume possess the necessary expertise;

~ The technical experts upon whom key policymakers or decisionmakers may be relying for assessments of technological vulnerabilities, may have many areas of responsibility. GPS vulnerabilities may not have a high priority;

~ The technical experts with responsibilities relating to GPS may not have the multi-disciplinary expertise needed to develop a comprehensive understanding and definition of the problem. For instance, a comprehensive approach to assessing and addressing GPS concerns and vulnerabilities would include understanding the nature of GPS-related concerns found in a wide range of agencies and departments, including the Federal Communication Commission, the Departments of Defense, Commerce, Homeland Security, and Treasury; the National Aeronautics and Space Agency; and the National Oceanic and Atmospheric Administration. Understanding would need to encompass concerns relating to the military, commerce, transportation, communications, space technology, finance, and the nation's economy. Those concerned with GPS tend to focus on one or a few of these, but rarely if ever on all.

~ Disinterest or insufficient interest, denial, wishful thinking, and/or the absence of knowledge and expertise may also get in the way when it comes to recognizing and addressing a problem.

There is no evidence that GPS-related vulnerabilities are being addressed in the kind of comprehensive manner that is needed. The problem has no owner.

10) What Changes are Needed in Order to Improve Efforts to Address Problems of Scientific and Technological Complexity

~ Lessons from past efforts need to inform efforts to address current challenges. Building on legacies from the past when possible can save time and resources.

~ A new mind set is needed that gives adequate attention to broad rationality and generalist approaches. A fuller more comprehensive approach to defining and understanding problems is needed. A reorientation of educational and inservice training institutions can help foster broad rationality and generalist approaches.

~ Generalist/specialists are needed who can connect knowledge and understanding to prescriptive analysis and action. Generalists with sufficient subject matter interest and knowledge are needed who can help decisionmakers and policymakers understand complex problems and issues and the actions needed to address them. Indeed, in the Eisenhower administration, Harold Seidman served in just such a role with the title of "generalist/specialist".

~ Public interest-oriented, action-oriented, thinktank-type efforts are needed to fill the vacuum that exists, particularly in the public sector. Such efforts need to address the many problems that are now being overlooked, particularly those problems that require the application of expertise from many different disciplines.

~ There needs to be a fuller understanding of the principles of knowledge transfer, innovation diffusion, research utilization, and technology transfer. There needs to be a wide spread use of model approaches to innovation diffusion and knowledge transfer such as those developed and used by the Office of Medical Applications of Research (OMAR) at the National Institutes of Health (NIH).

~ The Research Applied to National Needs Program (RANN) of the National Science Foundation and the Congressional Office of Technology Assessment (OTA) need to be brought back to life. The General Accounting Office and the Office of Science and Technology, RANN, and OTA need to have the capacity to identify and address the many complex problems that are now being overlooked.

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Paula Gordon's doctoral dissertation, **Public Administration in the Public Interest**, includes a chapter on complex problem solving and some impediments to applying knowledge to the problem solving process. The dissertation is available to authorized users of academic libraries through the ProQuest Digital Dissertations (PQDD) service and the "Current Research@" service.

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