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Working Paper 93-1

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A Dynamic Model of Organizational Learning and Action: Intergovernmental Planning for Hazardous Materials

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The Dilemma of Learning vs. Action in Dynamic Environments

Organizations operating in a dynamic environment confront a serious dilemma in which the continuous flow of demands, threats and opportunities from the environment may either trigger spontaneous new organizational learning, leading to creative problem solving or overload existing organizational capacity, paralyzing action. This dilemma requires organizations to confront the issue of substantive change in their internal problem solving capacity in order to function effectively in a dynamic external environment.

Initiating change in its performance is one of the most difficult, problematic tasks that any organization can undertake. To do so requires the organization to re-examine its basic assumptions and modes of operation (Argyris, 1982), which will necessarily slow down or halt performance. Not to do so in an environment that requires fresh approaches and improved performance risks continuing entropy (Bardach, 1977; Gleick, 1987:257-258,260-261) that ultimately leads to atrophy and collapse of the organization. The record of successful efforts to initiate organizational change is brief indeed (Haveman, 1992). In contrast, the literature on failed attempts at organizational change is long and rich (Argyris, 1990; Wildavsky, 1979; March and Olsen, 1976, 1979; Hargrove, 1975; Bardach, 1977; Benveniste, 1989; Williams, 1980; Ingram and Mann, 1982; Comfort, 1982). Improving performance on a

daily basis while still keeping their primary goals in focus requires organizations to reconceptualize both learning and action in dynamic environments.

Operating conditions in such environments demand that organizations learn while they act (Mackenzie, 1986). That is, if organizations learn, it occurs in real time, while they are striving to meet current obligations, fulfill legal responsibilities, and are being held accountable for the performance of tasks that affect lives and property in a community. Information from the environment produces both energy for continuing organizational performance and entropy that causes the organization to lose its focus and efficiency.

Continuing ambiguity about organizational performance or a cumulative burden of unsolved external problems erodes the legitimacy of organizations as viable mechanisms for social action. For most organizations, learning is not yet perceived as action, an essential phase in the maintenance and self-renewal of organizations operating in complex, dynamic environments. Rather, it is often perceived as an obstacle to action, an admission of weakness or lack of competence, a loss of time in performance which the organization may never regain. In order to retain legitimacy and effectiveness in complex environments, organizations need to redefine action to include learning.

The tension between learning and action becomes most acute when organizational responsibilities cross jurisdictional levels or disciplinary domains in complex policy arenas. Different jurisdic-

tions may require different rates of learning, different types of technical competence, and different degrees of skill in order to address a shared problem. These initial differences may, in turn, produce unexpected variations in system performance (Gleick, 1987) and possible conflicts or paralysis in subsequent action. At issue is the critical relationship of micro level action to macro level design, turning, like a mobius loop, to a reconsideration of micro level design and its effect on macro level action. This paper examines the sources, mechanisms, and consequences of this dynamic tension between learning and action as part of the larger process of initiating change.

Theoretical Bases of the Problem.

Four lines of inquiry in the literature inform this effort to reformulate the problem of learning vs. action in complex policy arenas. First is the identification of different types of organizational learning in the studies of reasoning, learning and action led by Chris Argryis and Donald Schon (Argyris and Schon; 1974, 1978; Aryris, 1982; 1990; Comfort, 1985; Freeman, 1990). Argyris and Schon laid the groundwork for two decades of research, discussion, and challenge by illustrating that individuals process the same information differently under different conditions of organizational structure and norms, resulting in significantly different outcomes in organizational performance. The now-familiar concepts of Model 1 and Model 2 learning in organizations (Argyris and Schon, 1974, 1978) have become synonymous with organizations that seek to improve performance by increasing skills but suppress-

ing conflict over basic assumptions (Model 1) or by re-examining and reformulating basic assumptions in order to renew skills and commitment to improved performance (Model 2).

Argyris (1986, 1990) has elucidated the full force of organizational reprisal against efforts to change, which in turn hastens the ultimate inability of the organization to adapt to the changing needs of its external constituency in a dynamic environment. While fundamentally reshaping our thinking about whether and how organizations learn, this approach is nonetheless limited by its conception of alternating organizational processes, as if organizations can take only one form or the other at a time. Freeman (1990) extends the taxonomy of organizational learning models in relation to different types of service populations, but still focuses on the question of organizational growth or decline in response to external change. Rather, reflection is needed on the design of organizations that can interact effectively with their changing environments to address basic social problems. This body of literature emphasizes the importance of organizational goals in generating action, and the need for reclarification of those goals under conditions of rapid environmental change.

A second body of research has examined evolving states of organizational performance in response to environmental problems (Holland, 1975, 1992; Holland et al., 1986; Axelrod, 1984; Piaget, 1980; Nelson and Winter, 1982; Staw and Cummings, 1990; Comfort, 1991.) The processes of evolution, adaptation, escalation, and decline in problem solving efforts in complex environments (Staw

and Ross, 1990; Cummings, 1990; Perrow, 1984; Axelrod, 1984; Holland, 1975; Comfort and Dai, 1991) are acknowledged as dynamic states in organizational learning. The determinants of these processes are still largely perceived to be external, with the organization's responses operating primarily in a single direction at a time, creating a momentum in assumptions and actions that becomes difficult, if not impossible, to redirect by managerial design.

In their book, Holland et al. (1986:79-82) propose a model of an organizational knowledge system that uses the interaction of competing "rules" for discriminating among the various types of environmental demands that vie for the organization's attention and action. They acknowledge that new rules are generated largely through recombining old ones. They also note the systemic effect of "old rules" in distorting new information to conform to existing norms (Holland et al., 1986:204). Consequently, the organizational knowledge system is biased toward the status quo, inhibiting the process of accurate perception and evaluation of changing environmental conditions. Their theory essentially confirms and elaborates the Model I theory of Argyris and Schon. In his recent article, Holland (1992:24-25) notes that organizations "anticipate" the future, basing present actions on expected outcomes. Yet, in his view, organizations function essentially as rule-based knowledge systems with varying degrees of flexibility and constraint.

A third body of relevant literature has explored the processes of communication and information in social problem solving and

policy decision processes (Deutsch, 1963; Churchman, 1971; Simon, 1969, 1981; Luhman, 1986, 1989; Habermas, 1985; Kursunoglu, Mintz and Perlmutter, 1985; Linstone, 1984; Haas, 1990, Graber, 1991). In this perspective, communication of information is considered the medium through which social action occurs. Communicative acts are viewed as the 'building blocks' of social interaction (Luhman, 1986, 1989). The appropriate design of these acts (Simon, 1969, 1981), in technology, direction, timing and content, serves as a major vehicle for improving organizational problem solving. This body of literature recognizes organizations as open systems with information feedback loops and regards their interaction with the environment as a crucial function in shaping performance.

Luhmann (1986, 1989:15-21) acknowledges the importance of securing support for organizational action through the generation of "resonance," or common understanding and commitment to action, with critical groups in the wider environment. Without establishing a sufficient degree of resonance with its target population, the organization is unlikely to elicit the resources or support necessary to achieve its goals. Luhman further identifies the powerful, driving force for creative self-expression (autopoeisis) as a sustaining element in organizational performance and extends this concept to serve as a criterion of successful social problem solving efforts. While effective communication and creative expression are necessary to achieve cooperative efforts in social problem solving, they are not sufficient to ensure that coordinated action will follow.

A fourth line of inquiry explores the internal mechanisms of complex, dynamic systems, their transition states over time (Gleick, 1987; Farmer, 1986; Hofstadter, 1985; Crutchfield, 1991; Turvey, 1988; Mosekilde and Mosekilde, 1991; Alonso, 1990; Abraham, Albano, Passamante and Rapp, 1989; Atmanspacher and Scheingraber, 1991) and self-organizing criticality (Liebovitch and Czegledy, 1991:150-152; Babyloyantz, 1991; Bak and Chen, 1992). This provocative body of literature, representing two decades of research in physics, mathematics, and more recently, biology, proposes a fundamentally different approach to understanding the origins, mechanisms, and consequences of dynamics in nonlinear systems (Gleick, 1987).

A primary tenet of this approach is that classical models of scientific analysis, based on linear methods of measurement and classification, do not apply to complex, dynamic systems. Attempts to use linear models and methods in the study of dynamic systems produce invalid findings and limit our understanding of their functioning (Lindblom and Cohen, 1979; Lindblom, 1990).[1] Although the initial research on deterministic chaos was done on phenomena in the physical world and assumes the functioning of closed systems (Ruelle, 1989; Gleick, 1987; Hofstadter, 1985), several researchers have sought to extend the application of these concepts to the social world (Bak and Chen, 1992; W.H. Warren, Jr., 1988; Ayres, 1990). With some modification, key concepts from this body of research appear applicable to open systems. These concepts offer fresh insight into their composition and behavior.

Distilled from this extensive body of literature, a set of basic concepts may be adapted to the study of complex social systems. The concepts, drawn from the work of many researchers[2], include:

1. complex, dynamic systems are nonlinear; linear methods of measurement and analysis prove inapplicable; dynamic systems may be described by their composition and functional behavior; behavior of dynamic systems is characterized by relationships occurring in both space and time and by properties of self-organization (Turvey, 1988:328; Badii, 1989:314-316; Prank et al.:150-151)

2. dynamic, nonlinear systems exhibit a "sensitive dependence to initial conditions" that produces differential rates of change in operation (Ruelle, 1989); system complexity arises out of interaction of simple elements; functional simplicity is distilled from compositional complexity through a process of recurring abstraction or scaling (Gleick, 1987:306-307)

3. interactions between the organization and its environment constitute a distinct system [organization-environment] that has properties and dynamics of its own; the dynamics of this O-E system influence the internal performance of the organization and affect its capacity to achieve its stated goals (Turvey, 1988: 340-341)

4. basic properties of dynamical systems can be described and interpreted in terms of information content, information flow, or information production; chaotic systems carry information continuously from fine to coarse scales; open systems carry information in both directions (Dittrich and Graham, 1991:289-290; Mpitsos, Creech, Cohan & Mendelson, 1988:162; Packard, 1988; Turvey, 1988:338-339)

5. scaling, as a means of reducing complexity, generates different levels of abstraction and specificity within a system; fractal forms cross these different dimensions in complex systems; fractal scaling can be described by a small number of parameters that, due to cooperative behavior, link different organizational processes together; chaos represents the energy of the system attempting to change dimensions within system (Gleick, 1987:260; Farmer, 1986:42)

6. pattern formation in organizational behavior is essentially biological (i.e. the result of natural processes); members of organizations encode information from their experience

in the environment, and decode it into new meanings and new patterns of behavior (Prank et al., 1991: 95; Warren, 1988: 384; Schones and Kelso, 1988:78)

7. time serves as an integrative concept; phase transition represents an increase in order in the system; order in the micro world produces strength in the macro world (Jammer, 1990: 243; Kelso, DeGuzman and Holroyd,1990:42-54; Rau, 1990:262)

8. organizations are perceiving-acting systems; measuring perceptions of the organization's performance is an indirect means of measuring the actual functioning of the system (Turvey, 1988:338-341)

While each of these concepts merits full explication and discussion, it is beyond the scope of this brief paper to do so. Rather, these concepts will be employed in an analysis of an actual complex system, the intergovernmental program designed to implement the Emergency Preparedness and Community Right-to-Know Act of 1986, also know as the Superfund Amendments and Reauthorization Act, Title III (SARA Title III). The meaning of these concepts and the merits of this approach will be illustrated through the analysis.

What analytic models and methods of measurement are appropriate for the study of nonlinear systems? Scholars vary in their views, but a fruitful approach, especially in the early stages of developing an analytical model, is the use of analogy (Holland et al., 1986; Morgan, 1986). Analogy serves a valuable function in "second-order modeling" (Holland et al., 1986). That is, it generates a model from a known problem than can be applied to a novel situation and facilitate more appropriate measurement and analysis. The use of analogy tends to break down as the target problem becomes more completely specified, but the first cut is often productive in transferring basic perspectives across domains

to explore an unknown problem. The next section will develop an analogy to the SARA Title III program as a preliminary step in the development of a dynamic model of this complex system.

Intergovernmental Planning for Hazardous Materials: A Kaleidoscope in Motion

While John Holland and his associates[3] have used analogy to support problem solving across domains, Gareth Morgan (1986) uses metaphor in a less rigorous way to redefine conceptual models of complex systems. More poetry than problem-solving, metaphor serves the function of an imperfect analogy in causing us to re-examine a complex problem in a different conceptual framework. Both analogy and metaphor seek to abstract critical elements from a familiar model and transfer them to explain the performance of a similar system in another domain.

This section serves four purposes: 1) to suggest that a kaleidoscope in motion serves as an apt analogy to the functioning of a complex, dynamic system; 2) to describe briefly the purpose, structure and prescribed processes of SARA Title III, the federally mandated program for emergency planning and management of hazardous materials; 3) to map the corresponding components from a moving kaleidoscope to the intergovernmental hazardous materials planning and management system; and 4) to assess the analogy as a preliminary model for analyzing the intergovernmental hazardous materials risk reduction system.

A Kaleidoscope in Motion

Imagine, if you will, a wonderful kaleidoscope -- not the

ordinary variety available at a local toy store for $7.59, but a grand, brass tube, three inches in diameter, with three sets of rings intermeshing chips in varied sizes, shapes, and colors. Viewed through the long tube, the set of interacting rings whirl, converge, intersect, and reform, creating patterns of amazing complexity. The inner space of the kaleidoscope appears alive, with diamonds turning into hexagons, triangles emerging out of squares, and intersecting circles bursting into stars. The kaleidoscope appears to develop its own rhythm, responding to the outward twist on the lens with an inner resonance that sets large circles in motion slowly, with smaller triangles and squares forming within the circles at faster and faster rates. The moving patterns strain, as if to escape the confines of their gleaming brass tube, but are limited by the structure of the system. The changing forms create a striking image of freedom within structure, creativity emerging from a seemingly endless variation of patterns, colors, shapes, and sizes. The moving kaleidoscope represents a complex, dynamic system operating within a context of constraints.

The Intent and Provisions of SARA Title III[4]

The Emergency Preparedness and Community Right-to-Know Law (SARA Title III)[5] also represents a complex, dynamic system operating within a context of constraints. The law was enacted in 1986, with the intent of setting common standards for community protection from the threat of hazardous materials across the nation. The law initiated a significant change in the planning and management of hazardous materials at federal, state, and local

levels. Implementation of the law required three levels of governmental jurisdiction to design and implement a new mode of intergovernmental problem solving.

This task involved several types of policy and management problems. First, the nationwide program of planning and management for hazardous materials is extraordinarily complex. The fifty states have significantly different levels of exposure to, and experience with, hazardous materials, access to economic resources, professional training, knowledge, expertise, and organization in their efforts to reduce the risk of hazardous materials. Further, within each state, substantial differences exist at the community level on these same conditions. The range and degree of variance within communities and among states creates a very uneven set of initial conditions for participating actors in the intergovernmental hazardous materials management process.

Recognizing that programs of action need to be fitted closely to the needs and capacity of each state, the law allocated responsibility to state executives for the design and direction of its implementation within their respective states. The state executives, in turn, are accountable for the progress of their programs to the federal level. Each state established a State Emergency Response Commission (SERC), which designed the guidelines for the law's implementation within that state. The SERCs, in turn, designated the units of operation for the Local Emergency Planning Committees (LEPCs). The composition of the LEPCs is outlined in general structure by the federal law to include public, private,

and nonprofit organizations from the respective communities. As each state has sought to adapt the requirements of the law to its needs and resources, relationships among participating organizations and jurisdictions have multiplied. In macro design, the three jurisdictional levels of the SARA Title III system create a nested set of organizations directed toward managing hazardous materials, with each set fitting wholly inside the next -- local, state, and federal. Within each set, however, are multiple organizational units interacting with one another in not wholly predictable ways that influence the jurisdiction's relationship to the other levels.

Second, the implementation process for SARA Title III is inherently dynamic. Procedures established by states affected prior policies and practices that were already in place.[6] Establishment of the LEPCs generated different perspectives with respect to hazardous materials in community practice. The design of the law allocates legal responsibility for assessment and monitoring of the presence of hazardous materials to both public and private organizations. The composition of the LEPCs specifies the inclusion of representatives from the major types of organizations in a community that are likely to be affected by a sudden, threatening release of hazardous materials or that are responsible for community protection. Interaction among organizations that previously had primary responsibility for hazardous materials changed, as other organizations, with different perspectives, engaged in the process. New relationships emerge, are tested, fail and are reformed. The process evolves continually.

Third, information processes are designed to drive the SARA Title III program, but they also require increased technical skills, competency, and willingness to learn from the participants. The law seeks to engender voluntary cooperation and coordination among the participating members of the LEPCs to reduce risk from hazardous materials in their respective communities.[7] To encourage this behavior, the law requires all relevant parties to report detailed information about the presence of hazardous materials in the community. The law explicitly identifies the types of information to be reported via a standard form, the Material Safety Data Sheets (MSDS), as well as sets reporting schedules for local and state levels. These requirements generate voluminous amounts of information that, in turn, need to be managed productively.

Fourth, the relationships between the micro and macro levels of performance need to be redefined to reflect the interdependence of the system's design. Breaking down old barriers of distrust and creating a new sense of shared responsibility among the participating organizations and jurisdictions, while crucial to the functioning of the whole system, depends very much on local leadership and communication patterns.

Fifth, the question of resources underlies the definition of responsibilities among the multiple participants in the process. Different alternatives for action depend upon reallocation of scarce resources at federal, state and local levels. Each alternative generates different patterns of behavior and response. Choices are made, delayed, unmade, and remade. Creating the

financial and organizational support for a new course of action requires engendering the voluntary cooperation and coordination among participating organizations that the law seeks to create. In this ambiguous state, clear alternatives for action are vulnerable to resistance and withdrawal from key participants in the process.

Sixth, as the implementation of the process proceeds, the amounts of information, the interacting patterns of behavior, and the possible strategies for action become cumulatively more complex. Managers at each level need strategies for simplification. The production of information through the submission of MSDS forms becomes overwhelming, swamping the capacity of ordinary organizations to absorb it in any meaningful way without restructuring the process. The complexity of the program increases at seemingly exponential rates.

Finally, the actual outcomes of the implementation process differ considerably from the expected outcomes. Differences in structure, process, and performance in planning and management for hazardous materials occur both within and among the fifty states. These differences could not be explained by the federal law, or its implementation guidelines, which were the same for all fifty states. Clearly, other patterns of behavior are emerging than had been anticipated. The causes of these differences are not obvious, and the outcomes could not have been predicted from the intent and design of the law.

The Analogical Model

In what ways does the analogy of a moving kaleidoscope inform

our inquiry into the intergovernmental planning and management process for hazardous materials? The analogy serves four critical functions in our effort to explain the functioning of SARA Title III. First, the kaleidoscope shifts our focus from the parts of the system to the whole, and in doing so, we recognize the dynamic complexity of the SARA Title III program. Focusing on the whole system, we are able to see each community organization, each LEPC, and each state as interacting components of the intergovernmental system responsible for maintaining national standards of performance and reducing risk from hazardous materials.

Like the rings of a kaleidoscope, the jurisdictions of the hazardous materials management system represent multiple organizations and groups with varying degrees of authority, responsibility and resources. Like chips in different sizes, shapes, and colors in kaleidoscopic patterns, these organizations and groups have different levels of information, resources, communication, and capacity for action within their jurisdictional roles. In interaction, these components create patterns of rich variation and detail in hazardous materials management. The ensuing complexity reflects the intricacy and potential creative power of activating all components simultaneously in the enterprise of the system.

Second, the kaleidoscope demonstrates the critical relationship of micro level performance to macro level capacity, and its inverse, macro level performance to micro level capacity, in this complex set of interactions. In the dynamic motion of the kaleidoscope, small circles spin within larger ones, intermeshing

triangles form hexagons, stars implode to reform as outer boundaries to new circles. In implementing SARA Title III, much of the substantive work of the LEPC is done within sub-committees of three to five people. Their recommendations, in turn, are presented to the whole committee of twenty-five to thirty people. The policy decisions of the whole LEPC become binding on the member organizations, representing in most cases a substantial body of the residents of the community. Sound performance of individual members at the micro level of the sub-committee thus creates the basis for strong action at the macro level of the whole LEPC. In turn, action at the LEPC level informs and strengthens performance at the state and federal levels. Redesign of policy at the federal level, based upon information generated at the local and state levels, facilitates further development at the local level. The interdependence of micro and macro components is illustrated both within the kaleidoscope, where small wheels turn larger circles, and the hazardous materials management system, where the work of sub-committees drives the larger process at local, state, and federal jurisdictional levels.

Third, the kaleidoscope demonstrates the role of structure in defining alternative patterns of movement. Vivid patterns generated by the kaleidoscope, alive with color and movement, are constrained by the elegant brass tube. In important ways, the legal structure of SARA Title III also constrains the activity of planning and management for hazardous materials. The requirements of reporting information on the presence of hazardous materials in local

communities are mandatory. The structure of the LEPCs and the composition of membership of these committees are defined. The limit on resources available from the federal level is set. These constraints provide the context within which the intergovernmental system must operate.

Fourth, the kaleidoscope illustrates the marvelous coordination of a system in which all parts are functioning in synchronized performance of separate activities. Likewise, the component units of the hazardous materials management system demonstrate the potential for coordinated, cooperative action in a smoothly functioning dynamic process. Like the kaleidoscope, creativity in intergovernmental hazardous materials management occurs in its dynamic process, not its static state.

The analogy breaks down in three critical ways. First, the kaleidoscope remains a closed system, while the hazardous materials management system is open to the flow of information, experiences, and energy that comes from continuous interaction with its environment. In actual practice, investment in resources, attention, and energy by different jurisdictional levels engaged in hazardous materials problem-solving may expand or contract in response to external demands or internal dynamics.

Second, although capable of producing rich and varied patterns, the component parts of the kaleidoscope have no capacity for learning. In contrast, the members and organizational units of the intergovernmental system demonstrate the capacity to learn from mistakes, new experiences, good examples, and to transform

that information into changed behavior. The flow of information alone does not necessarily produce learning, but the exchange of information with clear transfer of meanings and possible courses of action does generate behavioral change. Interaction with the environment creates the opportunity for feedback that drives the learning capacity of the intergovernmental system.

Third, the kaleidoscope demonstrates relationships among its components that function in both space and time, but, limited by the structure of the tube and its cycle of planned iterations, they function perfectly forever. The hazardous materials management system, in contrast, exhibits a wide range of relationships among its components that cut across dimensions of both space and time. These relationships provide opportunity for active engagement with its environment at different jurisdictional levels and different geographic locations over different periods of time, as well as the capacity to learn from previous experience and to anticipate the future. As such, they bring to the system both new sources of energy and vulnerability to cumulative entropy.

In summary, a kaleidoscope in motion serves as a useful metaphor for the intergovernmental hazardous materials management system. Unlike the static metaphors of a "layer cake" or a "picket fence" that have previously been used to describe the intergovernmental system, a moving kaleidoscope conveys the complexity and dynamic transitions generated by its interacting parts. This metaphor reminds us that the intricate patterns of relationships produced by the interaction of the components of the SARA Title III

program are central to the functioning of the whole system.

LEPC Perceptions of the Hazardous Materials Planning System

Accepting the intergovernmental hazardous materials management system as a complex, dynamic system, what methods of measurement are appropriate and available to evaluate the system's performance? Nonlinear, dynamic systems require methods of measurement and analysis that capture both the entropy and the energy that characterize their operations. The familiar methods of social science research -- direct observation, surveys, content analysis of documents, qualitative interviews -- provide some measures, albeit imperfect. They need to be presented and interpreted with caution in reference to dynamic systems.

A set of indirect measures of the hazardous materials management system's performance is provided by a key group of participants, members of Local Emergency Planning Committees. Data are presented from a telephone survey of 122 members of Local Emergency Planning Committees from five selected states conducted during July-August, 1990. The sample design was carefully constructed to ensure independence of respondents.[8] Out of 125 selected respondents, 122 interviews were completed for a response rate of 97.6%.[9] These perceptions provide an indirect measure of the design, performance, and direction of SARA Title III by informed members that are actively engaged in reducing risk from hazardous materials in their communities.

Their observations are reported on a set of six characteristics that portray the functioning of the SARA Title III program as

a complex, dynamic system. These characteristics are: 1) sensitive dependence upon initial conditions; 2) differential rates of change in system behavior; 3) information processes within the system; 4) mechanisms for managing complexity; 5) the organization-environment system; and 6) the system's resonance with its environment. Each characteristic will be discussed briefly in light of findings from the survey.

Sensitive Dependence Upon Initial Conditions

SARA Title III assumes that the law applies to all states equally, and further, to all communities within each state equally. It also assumes that there would be no significant differences among the states in the implementation of the law. While no significant differences emerged among LEPC members from the five selected states on perceptions of threat from hazardous materials or on the state of emergency planning prior to SARA Title III, Table 1 shows that the perceived effects of SARA Title III on community planning varied significantly by state.

[Table I about here]

This finding suggests that the law may be interacting differently with local conditions in the five selected states, and that the effects of the law may vary with these initial conditions. This finding is consistent with dynamic behavior in physical and biological systems (Gleick, 1987).

Differential Rates of Change in System Behavior

Why should SARA Title III be perceived to have different

effects in different states? When asked specifically about tasks that all states would perform under the implementation of SARA Title III, differences emerged not so much by state as by the degree of planning that had been done prior to the implementation of SARA Title III. Table 2 shows the perceived changes in performance on emergency planning tasks after the implementation of SARA Title III by degree of prior planning.

[Table 2 about here]

The findings presented in Table 2 demonstrate that the prior state of emergency planning is significantly related to the perceived performance of emergency planning tasks under SARA Title III. These findings suggest that the implementation of SARA Title III is sensitive to the initial conditions of planning in the communities in which it is introduced. That is, the less developed emergency planning was <u>prior</u> to SARA Title III, the more LEPC members perceived their communities to be positively engaged in specific emergency planning tasks <u>after</u> SARA Title III. The rate of change in emergency planning behavior under SARA Title III appears to depend upon the initial conditions of planning in the community.

If states had already been engaged in hazardous materials planning before SARA Title III was implemented, the LEPC members were asked whether the law had changed the procedures for better or worse. The large majority of respondents in four states reported that SARA Title III had resulted in changes for the better. The exception was California, which had already adopted a state program

of emergency planning for hazardous materials prior to the passage of SARA Title III. In California, a majority of the 16 LEPC members who reported that planning procedures were already underway observed that the implementation of SARA Title III had made specific procedures worse. Interestingly, this finding acknowledges the sensitive dependence of the SARA Title III to initial conditions, but in a negative direction for the functioning hazardous materials management system. It suggests serious problems of integration both within the prior emergency planning organization and the SARA Title III program in California.

Information Processes within the System

Since the intent of SARA Title III is to encourage the cooperation and coordination of community organizations in planning and preparedness to reduce risk from hazardous materials, information processes were designed to serve as the driving energy of the system. How these information processes function is critical to the performance of the system, and to the perceived degree of cooperation and coordination it is able to engender.

In setting up their LEPCs, members were asked which sources of information provided the most useful guidance. Table 3 reports significant differences among the five states.

[Table 3 about here]

Key information processes also appear to be related to the degree of planning established prior to the enactment of SARA Title III. In terms of local planning for hazardous materials management, most

respondents reported obtaining information from local public agencies and non-profit organizations with no relation to degree of prior planning. However, Table 4 shows a significant relationship between degree of prior planning and primary source of information for the LEPCs.

[Table 4 about here]

That is, as the degree of prior emergency planning increased, more respondents reported obtaining information from national, state, local sources and from private companies. Although the number of cases is small, it is interesting that the majority of respondents from extremely well developed LEPCs considered their primary source of information to be private companies. This finding indicates a high degree of cooperation in the community regarding planning for hazardous materials.

Table 5 shows a similar relationship between degree of planning and willingness to provide information to state and federal agencies.

[Table 5 about here]

Interpreting these findings as indicators of cooperation across jurisdictional and organizational boundaries, cooperation in both getting and giving information regarding the implementation of SARA Title III appears to be significantly related to the degree of prior planning.

The technology of information processing also appears to be related to the degree of prior planning. Table 6 shows that as the

degree of planning increases, more respondents report that their LEPCs access the data generated by SARA Title III requirements by computer.

This set of findings indicates a pattern of differential development among LEPCs that is related to the initial condition of emergency planning prior to the enactment of SARA Title III. Communities more advanced in their emergency planning processes were more likely to get information and guidance from state agencies and private companies, two sources that are important in the hazardous materials planning process. LEPCs with wider access to information were more likely to develop their planning processes more rapidly, engaging in cooperative efforts with state and federal agencies and developing their information technology to include computers and trained operators. Such a pattern is similar to rates of exponential growth stemming from different initial conditions that is observed in physical and biological systems (Ruelle, 1989).

Mechanisms for Managing Complexity

Most complex, dynamic systems evolve mechanisms for simplifying their operations in ways that allow order to emerge from the continual flux of operations. Using investment in information technology as a possible mechanism for coping with the complexity of an escalating information flow, a majority of LEPC respondents reported substantial expenditures to purchase computer equipment, maintain databanks and files, and analyze data. While these expenditures tend to increase with the degree of prior planning,

the relationship was not statistically significant.

Mechanisms of coping with complexity may well be a weak point in the SARA Title III management system. Without adequate integration or scaling for critical levels of information, the continuing flux of events, incidents, and unorganized demands for resources and attention lead to entropy, or distraction from the system's main goal. SARA Title III is still a relatively recent entity. The law was passed in 1986, and the first organizational plans were due on October 15, 1987. The system has been in operation barely five years. Whether the system can develop the appropriate forms of integrating new energies, demands and information in order to offset the continuing pull of entropy at its multiple levels of operation will prove a major challenge to its sustainability.

The Organization-Environment System

The SARA Title III program seeks to achieve its objectives through interaction with a wider environment. These interactions, in turn, form a distinct system that includes the SARA Title III program as one component with other organizations and groups. How effectively the organization (SARA Title III) is able to function in conjunction with its relevant supporters and opponents is also a measure of the organization's capacity and strength.

Table 7 shows that the integration of hazardous materials planning into planning for other emergencies varies significantly by state. Interestingly, while California has the most advanced

emergency planning for hazardous materials, it also has the largest proportion of respondents reporting that hazardous materials planning is not well integrated into an overall emergency plan. This is further evidence of the "sensitive dependence upon initial conditions" in the performance of SARA Title III.

Table 8 shows that citizen participation in hazardous materials planning also varies significantly by state. Again, California has the highest proportion of respondents who report that citizens have not been active in the planning for hazardous materials. To the extent that involving citizens in the process of protecting their own communities is related to creating viable responsibilities for them in risk reduction, these findings indicate that more work needs to be done, especially in California.

Other measures indicate positive interaction between the LEPCs and their respective environments. Virtually all LEPC members report that their organizations hold regularly scheduled meetings. Others report increased interaction with community members outside the LEPC meetings, indicating an increase in trust and common interest, both essential in building a community commitment to reduce risk from hazardous materials. These differences do not appear to be significantly related to prior planning, but rather the result of interaction once it has begun.

Resonance

The final measure is resonance, or the degree to which the organization, SARA Title III, is able to elicit understanding, support, resources, and well-trained members from its environment.

Table 9 reports that those LEPCs with more developed emergency plans prior to the passage of SARA Title III were more likely to apply for, and receive, funding for their programs from the Environmental Protection Agency (EPA).

[Table 9 about here]

In summary, the findings on these six characteristics of the SARA Title III program are consistent with characteristics of complex, dynamic systems observed in the physical and biological worlds. These systems behave differently than the classic linear models that have been portrayed in traditional analyses of bureaucracy. They also offer valuable insight into understanding and explaining the performance of complex, dynamic systems in the social world.

Conclusions

What do these findings mean in terms of explaining the functioning of the SARA Title III system? They offer fresh perspective in our understanding of this complex, evolving system and its performance in hazardous materials planning. These findings are summarized briefly below:

1. As in dynamic physical and biological systems, the characteristic of "sensitive dependence upon initial conditions" explains variations in performance within the intergovernmental hazardous materials system

2. This condition leads to different rates of learning, development and performance among different units within the system. That is, different units apparently function on different time schedules in their efforts to achieve the goal of reducing risk from hazardous materials. These differences, however, affect the degrees of cooperation and coordination that are essential for the effective functioning of the entire system. It suggests that time phases may be used as a means of integrating disparate groups into an

overall schedule of development for the program, acknowledging the different levels of need and allocating time, resources, and attention accordingly.

3. Information processes demonstrate their intended key role as the driving force of the system. However, the infrastructure for facilitating these information processes is not fully in place. This condition affects adversely the prompt feedback to multiple participants in the process that drives the operation of the system. Until the technology of information processing, analysis and dissemination is advanced to provide the needed support for cooperative decision making and coordinated action, the SARA Title III system is not likely to achieve its intended goals to the degree and rate of its expected performance.

4. Mechanisms of coping with complexity and integrating new information into the system's operating knowledge base and actions are not well developed for SARA Title III. Given the complexity of the system and its multiple components and arenas for action, the risks of entropy are serious. Entropy or diversion of the system's energy from its primary goal results from inadequate integration of information from the environment into system performance. Mechanisms of scaling or abstraction that cut across jurisdictional and disciplinary boundaries to simplify the complexity of the problems are especially needed to clarify and maintain the basis for action.

5. New measures are needed to investigate complex, dynamic systems in the social world. Especially needed are better measures for assessing the degree of integration and the degree of entropy that indicate how well the organization is assimilating information to adjust its performance to its continually changing environment. It is crucial to map the context of the system's operation in order to anticipate the next stage in the evolution of the organization's dynamic process. These models are likely to rely upon nonlinear adaptations of Bayesian statistics, fuzzy logic and Lyapunov exponents.

NOTES

1. C.E. Lindblom cogently criticizes the inappropriateness of current methods of inquiry for the study of public policy problems in his book, Inquiry and Change (New Haven: Yale University Press, 1990). These methods have largely been based upon standard models of linear analysis. The ineffectiveness of these methods may, in fact, be due to their attempted application to complex, dynamic,

social systems which are fundamentally nonlinear.

2. The primary authors are identified for each concept, although the concepts developed through the discussion and interaction of researchers in the field. An important contribution to the development of this field were the NATO ASI conferences which brought together researchers from many countries and disciplines. In this fertile intellectual ground, the concepts were developed, shaped, and refined through the exchange of ideas and research findings. The papers presented at these conferences were then published and served as the basis for a new round of inquiry, discussion, and debate in the exciting development of this new approach to understanding complex, dynamic systems. The sources are many, and are cited in full in the list of references for this paper.

3. Holland et al. (1986:292) identify four basic steps in the development of a productive analogy. These steps include:

1) constructing mental representations of the source and target;
2) selecting the source as a potentially relevant analog to the target;
3) mapping the components of the source and the target, (that is, identifying components that play corresponding roles in the two situations); and
4) extending the mapping to generate rules that can be applied to the target in order to achieve a solution.

4. This section of the paper draws upon a presentation of the requirements, functions and provisions of SARA Title III presented in a paper by L. Comfort and H. Dai, "Policy Design in Complex Arenas: The Impact of SARA Title III on the Community Management of Hazardous Materials." Berkeley, CA: Institute of Governmental Studies Working Paper 91-4.

5.Emergency Preparedness and Community Right-to-Know Act of 1986, also known as Superfund Amendments and Reauthorization Act of 1986, Title III. Public Law 99-499, 100 Stat. 1613 (1986), 42 U.S.C. Section 11001-11050, ELR. Stat. EPCRA 001.

6. The most striking example of this negative effect of the law was in California, which had established a comprehensive state program for the reduction of hazardous materials in 1985. Chapter 6.95. Hazardous Materials Release Response Plans and Inventory. Division 20: Health and Safety Code, Sections 25500-25521. State of California, Statutes of 1985:3931-3942.

7. Subtitle B: Reporting Requirements, EPCRA, Public Law 99-499, 100 Stat. 1613 (1986).

8. Out of 50 states, five (5) were selected for inclusion in the sample to ensure representation by geographic location, degree of exposure to hazardous materials and level of economic performance. Within each state, five (5) LEPCs were selected using the same criteria (5 x 5 = 25 LEPCs). Within each LEPC, five (5) members were selected to represent the designated organizations and positions specified in SARA Title III for community representation (5 x 5 x 5 = 125 cases). This sampling strategy allows a small sample of carefully selected respondents to represent the larger universe of members of the Local Emergency Planning Committees engaged in the implementation of SARA Title III in their respective communities. L.K. Comfort. 1990. "Managing Risk: The Design and Implementation of the Emergency Preparedness and Community Right-to-Know Act of 1986. Phase I: State and Local Jurisdictions." Professional Report Submitted to the Environmental Protection Agency, December 12, 1990.

9. The survey was conducted through the Survey Research Center of the University of California, Berkeley. The authors acknowledge the professional skills of Karen Garrett and Selma Monsky, who ably guided the research process, and Percy Tannenbaum, director.

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Table 1

Effects of SARA Title III on Community Planning by State

Q. "How much difference, if any, do you feel that SARA Title III has made in the development of emergency planning for hazardous materials in your community. Would you say that it's helped a lot, helped a little, made no difference, or made things worse than they were before?

	State											
Effects	Calif. N	%	Kansas N	%	Louisiana N	%	Penna N	%	So. Car N	%	Row N Column %	
No Help	1	24.0	1	4.0			1	4.2	1	4.3	4	3.4
Helped a Little	15	60.0	8	32.0	5	20.0	6	25.0	8	34.8	42	35.9
Helped a Lot	4	16.0	16	64.0	20	80.0	17	70.8	14	60.9	71	60.7
Missing	5	–	0	–	0	–	0	–	5	–		
Column Total: Column N Row Percentage	25	20.5	25	20.5	25	20.5	24	19.7	23	18.9	122	100.0
Chi Square Pearson	Value 29.66265				DF 8		Significance .00024					

Missing Cases = 5
Valid Cases = 117

Table 2

Effects of SARA Title III on Planning Procedures by Extent of Prior Planning

Q. Now let's compare your current Local Emergency Response Plan with earlier plans for managing hazardous materials in your community. As I read each of the following, please tell me whether it's something that your local community is not doing now, whether it's something you started doing after SARA Title III, or whether it's something your community was already doing before SARA.

1) Laying out clear procedures for what public, private, and non-profit organizations should do in emergencies involving hazardous materials

Degree of Prior Planning

Status	Thinking About		Plan not too developed		Fairly well Developed		Extremely well developed		Row N Column %	
	N	%	N	%	N	%	N	%	N	%
Still not doing			3	9.4					3	3.0
Doing after SARA	10	83.3	23	71.9	19	36.5	1	14.3	53	51.4
Was doing before	2	16.7	6	18.8	33	63.5	6	85.7	47	45.6
Total: Column N Row Percentage	12	11.7	32	31.1	52	50.5	7	6.8	103	100.0
Chi Square Pearson	Value 29.10855		DF 6		Significance .00006					

2) Local organizations cooperating in managing hazardous materials

Degree of Prior Planning

Status	Thinking About		Plan not too developed		Fairly well Developed		Extremely well developed		Row N Column %	
	N	%	N	%	N	%	N	%	N	%
Still not doing							1	14.3	1	1.0
Doing after SARA	7	58.3	20	62.5	16	30.8			43	41.7
Was doing before	5	41.7	12	37.5	36	69.2	6	85.7	59	57.3
Total: Column N Row Percentage	12	11.7	32	31.1	52	50.5	7	6.8	103	100.0
Chi Square Pearson	Value 27.21057		DF 6		Significance .00013					

Table 3

Most Useful Information Sources to LEPCs by State

Q. We're also trying to learn about sources of information or other help your community may have received when you were setting up your local emergency planning process to comply with SARA Title III.

Which of the sources that provided information would you say provided the most useful information or guidance in setting up your LEPC?

	State											
Sources	Calif. N	Calif. %	Kansas N	Kansas %	Louisiana N	Louisiana %	Penna N	Penna %	So. Car N	So. Car %	Row N Column %	
Federal, FEMA, EPA			1	4.0	6	27.3	3	13.6	3	14.3	13	11.7
State, Gov., OES	14	66.7	14	56.0	2	9.1	8	36.4	6	28.6	44	39.6
Local: Pub. Priv.	7	33.3	10	40.0	14	63.6	11	50.0	12	57.1	54	48.7
Total: Column N Row Percentage	21	18.9	25	22.5	22	19.8	22	19.8	21	18.9	111	100.0
Chi Square Pearson	Value 22.64419				DF 8		Significance .00385					

Legend:

FEMA = Federal Emergency Management Agency
EPA = Environmental Protection Agency
OES = Office of Emergency Services

Table 4

Sources of Information for the LEPCs by Degree of Prior Planning

Q. First, tell me where your LEPC gets most of its information regarding planning for hazardous materials management. Do you get any from:

1) State Governmental Agencies:

Degree of Prior Planning												
Sources	No Plan at all		Thinking About it		Plan not too developed		Fairly well developed		Extremely well developed		Row N Column %	
	N	%	N	%	N	%	N	%	N	%		
National Public, Non-profit	1	7.1			3	10.7	9	25.7			13	13.8
State government	7	50.	8	66.7	15	53.6	15	42.9	1	20.0	46	49.0
Local Public Non-profit	6	42.9	3	25.0	6	21.4	7	20.0	1	20.0	23	24.5
Private Companies			1	8.3	4	14.3	4	11.4	3	60.0	12	12.8
Total Column N Row Percentage	14	14.9	12	12.8	28	29.8	35	37.2	5	5.3	94	100.0
Chi Square Pearson	Value 21.76984				DF 12		Significance .04018					

Legend: National Public, Nonprofit = National public and non-governmental agencies
State Government = State governmental agencies
Local Public, Nonprofit = Local governmental authorities or agencies and non-governmental agencies at the community level.
Private Companies = Private profit-making organizations or associations of private organizations.

Table 5

Willingness to Provide Information to State and Federal Agencies by Degree of Prior Planning

Q. When you give information to state or federal agencies, do you give them only required reports, or do you give other kinds of information as well?

	Degree of Prior Planning							
	No Plan Yet		Not too Developed		Plan Developed		Row N Column %	
Types of Information	N	%	N	%	N	%	N	%
Required reports only	13	50.0	14	53.8	10	25.0	37	40.2
Other information as well	13	50.0	12	46.2	30	75.0	55	59.8
Total: Column N Row Percentage	26	28.3	26	28.3	40	43.5	92	100.0
Chi Square Pearson	Value 6.89609				DF 2		Significance .03181	

Table 6

Information Management by Degree of Prior Planning

Q. When it comes to using, managing or retrieving information that's collected for your LEPC district, how is that done – does your LEPC mainly use computers, paper or pencil, or how does your LEPC usually access the data?

	Degree of Prior Planning							
	No Plan Yet		Not too Developed		Plan Developed		Row N Column %	
Type of Access	N	%	N	%	N	%	N	%
Paper and pencil	15	51.7	8	25.0	10	17.9	33	28.2
Can't choose, both	1	3.4	3	9.4	4	7.1	8	6.8
Mainly computers	13	44.8	21	65.6	42	75.0	76	65.0
Total: Column N Row Percentage	29	24.8	32	27.4	56	47.9	117	100.0
Chi Square Pearson	Value 11.40679				DF 4		Significance .02235	

Table 7

Integration of Hazardous Materials Planning into Existing Emergency Plans by State

Q. How well is planning for hazardous materials incidents integrated with planning for other emergencies in your LEPC district -- such as earathquakes, flood or transportation accidents -- would you say it's extremely well integrated, fairly well integrated, not too well integrated, or is there almost no integration with planning for other emergencies?

	State										Row N Column %	
	Calif.		Kansas		Louisiana		Penna		So. Car			
Level of Integration	N	%	N	%	N	%	N	%	N	%	N	%
None, Poor	12	48.0	3	12.0	2	8.0	5	20.8	6	26.1	28	23.0
Fairly well	11	44.0	14	56.0	7	28.0	9	37.5	12	52.2	53	43.4
Extremely well	2	2.0	8	32.0	16	64.0	10	41.7	5	21.7	41	33.6
Total: Column N Row Percentage	25	20.5	25	20.5	25	20.5	24	19.7	23	18.9	122	100.0
Chi Square Pearson	Value 26.79836				DF 8		Significance .00077					

Table 8

Citizen Participation in Hazardous Materials Planning by State

Q. How actively has the general public participated in planning for hazardous materials management in your LEPC district -- would you say that the public has been very active, somewhat active, not too active, or not at all active in participating?

	State											
	Calif.		Kansas		Louisiana		Penna		So. Car		Row N Column %	
Level of Integration	N	%	N	%	N	%	N	%	N	%	N	%
Not active	13	52.0	2	8.0	4	16.0	8	33.3	5	21.7	32	26.2
Not too active	7	28.0	18	72.0	13	52.0	11	45.8	10	43.5	59	48.4
Active	5	20.0	5	20.0	6	32.0	5	20.8	8	34.8	31	25.4
Total: Column N Row Percentage	25	20.5	25	20.5	25	20.0	24	19.7	23	18.9	122	100.0
Chi Square Pearson	Value 18.37476				DF 8		Significance .01859					

Table 9

EPA Funding to LEPC by Degree of Prior Planning

Q. We're also interested in how your LEPC funded the kinds of costs we've been talking about.

Did your LEPC apply for initial training grants from EPA? And did you get the funds you applied for?

Degree of Perior Planning												
Funding Action	No Plan at all		Thinking About it		Plan not too developed		Fairly well developed		Extremely well developed		Row N Column %	
	N	%	N	%	N	%	N	%	N	%	N	%
Did not apply	11	100.0	5	55.6	18	81.8	24	61.5	5	71.4	63	71.6
Applied, but no funds	0	0.0	3	33.3	1	4.5	3	7.7	1	14.3	8	9.1
Applied, got funds	0	0.0	1	11.1	3	13.6	12	30.8	1	14.3	14	19.3
Total Column N Row Percentage	11	12.5	9	10.2	22	25.0	39	44.3	7	8.0	88	100.0
Chi Square Pearson	Value 15.59				DF 8		Significance .04863					

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