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Systemrationalität und Partialinteresse

Festschrift für Renate Mayntz

Nomos Verlagsgesellschaft
Baden-Baden

Die Deutsche Bibliothek – CIP-Einheitsaufnahme

Systemrationalität und Partialinteresse: Festschrift für Renate Mayntz / Hans-Ulrich Derlien … (Hrsg.). – 1. Aufl. – Baden-Baden: Nomos Verl.-Ges., 1994
ISBN 3-7890-3342-1
NE: Derlien, Hans-Ulrich [Hrsg.]; Mayntz, Renate: Festschrift

1. Auflage 1994

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RGE TECHNICAL SYSTEMS, INSTITUTIONAL SURPRISE AND CHALLENGES TO POLITICAL LEGITIMACY[1]

Todd R. La Porte

sk of losing political legitimacy is a mounting problem for many institutions in rial democracies. It is a matter of growing and unfamiliar urgency for techno-lly oriented agencies and industries -- large technical systems (LTSs), the objects erest here. We see rising opposition to technical programs, the deployment of ad-d technologies, and, recently, a decline in public enthusiasm for supporting large science and technology developments in general.[2] While large technical systems en as fountains of remarkable benefits by most, they also are objects of consider-larm. In 1986, a study group of historians and social scientists gathered to clarify nprove our understanding of LTS evolution and dynamics.[3] Their chartering pro-framed the challenge as follows:

number, scale, complexity and range of large technical systems (LTSs) has in-d steadily over the past one hundred years. Their importance for social develop-and public policy matters is unquestioned. The most significant institutional ties of such systems are their growing organizational and economic scale, in-ngly intensive knowledge requirements, tightening patterns of functional interde-nce within major production or service segments, and expanding networks of co-ion and control. Yet these phenomena are not well understood. And governments technological policy with little help from historical experience or systematic or economic theory.

s situation would be mainly a matter of academic interest and "politics as usual" - benefits of large technological systems were modest, and the consequences of ailures limited. But for a growing number, benefits are not piecemeal, nor break-mainly instructive. Rather, benefits are large scale, dispersed and generous. And cant failures (or even their prospects) evoke wide spread concern, sometimes ear. Indeed, for an increasing number of LTSs, benefits are conditioned on con-sly reliable operations, and, in some cases such as nuclear power, nearly fail-e operations. These requirements pose an extraordinary situation; they exert very

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A revision of a discussion paper for the Rathenau Summer Academy Seminar on "Ordering the uman-Built World", July 1993, Berlin, Germany.

n the U.S., witness the difficulties of the space program and the Superconducting Supercollider SC) development of the early 1990s.

enate Mayntz has encouraged these efforts in her work and her leadership of the Max Planck stitute by supporting the Study Group on Large Technical Systems. She together with Thomas ughes, University of Pennsylvania, and Todd R. LaPorte formed an informal steering group at fostered and in part supported a series of international gatherings. The first was supported by d held at the Max Planck Institute, November 1987. See Mayntz and Hughes, eds. (1988), Porte, ed. (1991), Salisbury, ed.(forthcoming), and Summerton, ed. (forthcoming) that sum-arize much of this discussion.

strong demands for remarkable performance at a time when there is scant understanding of the systems relevant to such operations. Yet we are becoming increasingly dependent on systems with just such characteristics" (La Porte 1991, 1f.).

The intellectual and policy challenges persist, the stakes seem even higher than a decade ago.

This essay reviews a way of conceiving of LTSs that allows for a clearer understanding of their social manifestations, and then turns to several unsettling consequences of key organizational or social properties of LTSs. I shall argue that, grand as the benefits of large technical systems have been, they harbor "surprises of success" that threaten more than environmental purity; they risk the political and social legitimacy of those most committed to them.[4] The U.S. experience with managing radioactive wastes will be a brief case in point.

I. LARGE TECHNICAL SYSTEMS AS ORGANIZATIONAL SYSTEMS

Large technical systems (LTSs) may be viewed in a number of ways: as amalgams of hardware, engineered products and architectural achievements, as masses of people and large networks distributing manufactured goods across wide areas, or as huge economic entities drawing support from and influencing governments and states.[5] Each view signals different questions, each contains its own body of causal explanations and expectations. Often LTSs are discussed with all these things in mind, though with little attempt to distinguish one facet from another.

The view taken here emphasizes the institutional or social nature of LTSs with less emphasis on the economic, physical or hardware aspects. These latter views have been over-emphasized; they mask the intrinsically human or social nature of LTSs and leave an impression of "technology" as a reified, distant, disembodied and impersonal actor beyond the reach of citizen response. For purposes of social understanding and public policy, discussing LTSs mainly in terms of imposed, engineered order on physical matter tacitly discounts the individual and organizationally motivated drive toward economic and social development and political advantage, and leaves us partially blind.

4 The tone of this essay may suggest that I do not appreciate the extraordinary benefits accruing from swift and thorough-going technical development. It is precisely because I do, and because I can also appreciate the enthusiasms of policy makers who wish to be associated with furthering these benefits, that I take a cautionary tone here. But I do not mirror the substantial "technology and society" literature arguing that "technology is a political problem", or that "technology" somehow is an "autonomous force that propels society" toward repellant "structures". Rather, I hope to contribute to a more detailed view of "technologies" as compelling means to achieve economic and social ends and the source of political surprise. As such they should be better understood and shaped in part on the basis of social and historical analysis.

5 See Joerges (1988) for a detailed explication of the constituent concepts.

Technologies and LTSs thus should be seen in a sociological, as well as an engineering, perspective.[6] The central premises of the social view are: (La Porte 1984)

- Technological systems can be viewed as webs of social and organizational relationships which, in a sociological sense, express the technology. In addition to being an intricate meshing of ideas, processes, and methods based on scientific and engineering work, "technology" is intrinsically a human process. Technologies are not only "socially constructed" vis-a-vis their origins,[7] they are "socially enacted".[8] Without sustained enactment, technologies have little social force. People, working together, are absolutely necessary for the possibilities of new or improved technologies becoming available in a society. Unless numbers of people cooperate often quite closely in carrying out the activities necessary to realize the technical potential, its capacity will not be available to modify the physical environment, to enhance public health, and to provide assistance for everyday labor.
- A technology's social and organizational properties will vary systematically as a function of its design and operational characteristics, the particular strategies employed to deploy it, and the scale it ultimately attains. As these properties vary, so does the character and magnitude of social and political change.[9]
- The activities, people, financial and other resources necessary to implement a technology, especially as it approaches large scale, are primary stimuli for changes in social and economic effects felt by the people and community/regional organizations or institutions that come "in contact" with "it."
- Only when a new technology promises to attain significant scale and industrial maturity does it become a matter of serious public policy concern. In a social or political sense, if a technology remains only scantily developed, it falls beneath the threshold of analytical interest. Therefore, analysis must include a technology's properties both at early stages of development and, importantly, as it becomes widely dispersed through large-scale organizations, i.e., becomes a large technical system -- the "it" or "technology" to which technical communities (and I) refer.
- It should also be remembered that the communities, institutions and regions "in contact" with the technology -- the LTS -- have social properties that vary as a function of their demographic, economic, and political characteristics, and the particular na-

6 The "system" in LTS may also have different referents. In the engineering sense, it refers to the "technical rational" design imposed on physical matter, i.e., hardware, that animates the engineering/economics view. This is contrasted to the self-organized, instinctual view biologists have of living systems. I take an intermediate view of social groups semi-self-organizing and exhibiting intentional social and organizational behavior. Again, see Joerges (1988) for a detailed explication; cf. Scott (1991).

7 See Bjiker and Hughes (1987) for an example of this emphasis.

8 See Weick (1979) for an especially insightful, whimsical, and sometimes puzzling perspective.

9 Advanced technologies, due to their intrinsic dependence upon very sophisticated conceptual and organizational requirements, are less likely to exhibit a variety of allowable production modes. Therefore, they will be resistant to modifications prompted by variations in local or national culture. Hence, differences in local or regional effects of a particular advanced technology are more a function of the variations in local or regional conditions than of the design of the technology.

tional and state legal constraints within which these communities and institutions operate.

mproved understanding of particular technologies and their social dynamics requires, hen, analyses of the various effects different types of technologies have upon communities, institutions and regions, themselves possessing variable social characteristics. And it is crucial to understand the interactions between the *organizations* that help to ealize the potential of a technology-as-concept, the *communities* which are directly in contact with the technology-as-organization, and the *societal institutions* -- legal, political, economic, and social -- within which both the communities and the technical organizations function.[10]

Drawing on this perspective, I shall consider several properties of LTSs that disquiet and confound analysis and operations, and in the end pose a threat to the legitimacy of hose who deploy technical systems and oversee them.

II. CHALLENGES FOR PUBLIC ORGANIZATIONS AND POLICY

The promise and benefits of LTSs are evident through increased economic and military apabilities, enhanced agriculture and public health, and in our time, the global reach of echnical and production institutions. The processes of deployment are reasonably well nderstood (even if precisely calculating their long term costs is not). Each generation evelops its versions of rail, air, and motor transport, power networks, water developments, agricultural systems, and regional and global communication; these are paralleled by spreading financial and management coordination schemes. And each generaton has had confidence that the benefits accruing to it from the past will be sufficient to meliorate or reverse the damages done to it by their forbears as they rushed to stamp heir technological mark on the world. By extension, each generation has tacitly beeved that it is bequeathing sufficient benefits in knowledge and capital to their progny so they in turn can repair damages done to them. Now, however, we are less confident of this, and there is a ground swell of public anxiety, in part expressed by the teady drum beat of "technological dissenters".[11] It is enough to say that the continual nactment of LTSs is a constant effort filled with hope, uncertainty, and increasingly iewed with apprehension by their leaders, participants and citizens-in-contact.

The challenges to cope with the promise and effects of LTSs issue certainly from the emands of skillfully assembling the technical and economic resources needed for redible development, gaining the approval of an increasingly wary public, and then

10 Cf. Winner (1977), esp. 2-11. The analytical implications, if taken seriously, are rather more demanding than has been advanced in the past, and few studies of LTSs and their effects have brought together this array of information. It is a daunting task. Hughes (1983) is one of the few attempts to do so descriptively.

11 See Winner (1977; 1986); Murphy, Mickunas, and Pilotta (1986); and Willoughby (1990) for reviews of this literature.

operating the systems satisfactorily through their useful lifetimes. But challenges also issue from the unintended, unaccounted, and surprising effects of fully deployed and "successful" LTS operation.

When large technical systems "succeed", i.e., when they mature, overcome their technical fragility, and pass through stages of early operational and commercial uncertainties, they have become economically and politically viable. Operators, investors and citizens can expect them to become aspects of everyday life -- usually for some time to come. This stability is associated with significant social and political power. It is also productive of four significant effects that surprise and confound; effects that are inherent in an increasing number of LTSs. Together these surprises sow the seeds of suspicion and public distrust; and they erode the political legitimacy of the sponsoring and operating institutions. These effects are:

1. The unavoidable increase in the technical/social *differentiation* of the operation systems. The more complex the technologies' knowledge bases, the more technically and socially differentiated the "technical system", with many experts and specialized working groups. While technical differentiation has, in a sense, been expected, we are usually taken unaware by the degree to which this has been paralleled by the social differentiation needed to "enact them" (Demchak 1992).

2. The increasingly widespread *dispersion* of public and industrial systems. Contemporary use of communication and transport technologies allows the very widespread geographical dispersion of functionally related units and agencies. This has occurred rapidly both within and across national boundaries, beyond the capacities of governments (and system managers themselves) to calibrate its speed, extent and dynamism.[12]

3. The increasing *scale of operations* needed to realize the technical and distributive potentials involved. This familiar characteristic is prompted straight forwardly by the properties of differentiation and dispersion. Scale refers to the combination, first, of the people (and capital) needed to carry out or enact the technical operations -- whether they are integrated within a major agency or firm or scattered among a number of smaller, but closely dependent, organizations in a network technology, a *technoplex* so to say, without strong central administration (see Joerges 1988 for elaborations); and, second, to the people (and capital) needed to deliver the system's formal benefits (and hazards) to the full range of its expected market (La Porte 1988).

These conditions pose serious, continual challenges to managers and operators. Increasing technical complexity means a rise of relative ignorance in executive (and regulatory) circles. Increased social complexity involved in enacting greater technical complexity also adds to executive uncertainties about the dynamics of the systems they oversee. When LTS operations are spread over large geographical areas, further uncertainties spring from the heterogeneities of regional and ethnic cultures. Concatenating

12 See especially Rochlin; Salsbury; and Genschel and Werle in Salsbury (forthcoming) from LTS conference, Sydney, 1991.

uncertainties reduce the effectiveness of planning and regulatory efforts and threaten stability.

This is a familiar litany of alerts about the pressing demands of managing modern agencies or firms. If they are not effectively met -- and it seems to become more difficult day-by-day -- these conditions lead to an erosion of hierarchical authority, growing bureaucratic *apraxia*,[13] and the rapid increases in the costs of organizational, economic and social integration. Managerial and analytical demands escalate, costs of coordination mount, small errors seem more likely to trigger substantial loss.[14] Often these are paralleled by aggressive external criticism of operating bureaucracies, dissembled executive communications with public leaders and the media, and timid, guarded advocacy of sound management positions in the face of strong politically based opposition. All this is especially worrisome when LTSs are characterized by the fourth surprise.[15]

4. The dependence on physical processes that, while they may be very beneficial, are *intrinsically hazardous*.[16] That is, some LTSs depend on the manipulation of physical processes that if botched could result in considerable damage to the health and physical safety of operators or citizens, and/or the economic and environmental security of significant regions and nations. Examples proliferate: nuclear power plants, air and rail traffic control, high power electric energy and natural gas services, and high speed transmission of sensitive financial data. As LTSs come to employ more intrinsically hazardous technologies, one might say that large technical systems become hazard systems as well, HLTS, so to say.

In addition to the demands and uncertainties derived from the other characteristics of LTSs, as the apparent potential for harm (as well as benefit) grows, there is an increasing awareness that high levels of reliability and safety are necessary in operating such LTSs. Benefits are seen to be substantial, but production and safe operations are more demanding and costly -- and risks are high with much narrower margins for error. We see a general increase in organizational hope (sometimes confidence) as well as in public anxiety. These qualities provide a rich nutrient for feeding suspicions and, in the end, threaten the operators' political legitimacy.

13 I adopt Winner's (1977, 186) use of this term: "used in medicine to describe the inability to perform coordinated movements. In large scale technical networks composed of artificial components with complex interconnections and interdependencies, apraxia is a constant danger."

14 This argument resonates with an earlier one made, on different grounds, by J.K. Galbraith (1967). Cf. Winner (1977).

15 The dynamics of these effects we know to be associated with swift scale-up in most large organizations. They happen every time, and every time those who encounter them are "surprised". These "surprises" then should not be surprising.

16 The term "hazard," as used here, is distinguished from "risk" or "risky" technologies. These two terms are often applied loosely to mean hazardous. When "risk" is used here it is in the engineering sense, i.e., the product of the damage and harm intrinsic to the systems, i.e., hazard, and the probability that damaging consequences would be experienced by operators and/or citizens.

III. LTSs AND THE BASES FOR INSTITUTIONAL DISTRUST

But how could such interesting and fruitful creatures as these modern manifestations of technical virtuosity nurture institutional distrust or contribute to the erosion of their own political legitimacy? The argument is as follows.

As the incidence and distribution of technical/social *differentiation*, *dispersion* and *scale* increases, and *hazards* grow within LTS, there is a steep increase in public anxiety.[17] Subsequently, demands intensify for

- organizational leaders to assure the harmonious and predictable operation of the systems -- for it seems both more difficult to achieve and more is at stake if "system failures" occur; and for
- governmental leaders to assure that operating these systems results in safe and environmentally benign conditions over large geographic areas and, in a growing number of cases, for very long times into the future -- for it seems unwise to rely on the market as the major means of reducing risk.[18]

If these demands are taken seriously by firms and government agencies, and there is ample evidence to suggest they are, they result in significant changes within operating agencies and firms, and a growth of public and private regulatory functions. There are now some technical systems whose capacities are so beneficial, yet so highly hazardous in their operation, that the relevant firms and agencies orient significant portions of their total efforts toward attaining very high levels of operating reliability. (Nuclear power generation of electricity is an extraordinary example). In effect, such operators seek a kind of sustained perfection in daily operations, however impossible this actually is to achieve (Perrow 1984).

If these LTSs do, in fact, perform up to expectations, they produce great benefits with little harm to humans or to the environment. And there are some systems that seem nearly always to do so -- however, large, complex, distributed, and hazardous they may be. They include not only the already noted nuclear power plants, but also air and railway traffic control, densely distributed electric and natural gas service over very large areas, and high speed transmission of sensitive financial data. In effect, these are high hazard, low risk technical systems.

17 Increased public anxiety about the difficulties and consequences of managing hazardous LTSs - and increased opposition to their deployment - has stimulated a counter emphasis via "risk perception" and "risk communication" studies, and more purely analytical emphasis on "risk assessment". See Dietz and Rycroft (1986), and Short and Lee (1992) for summaries of these emphases. Studies attempting to quantify the levels of perceived "risk" among various groups in the public lead to considerations of how best to "educate" the public to the actual levels of "risk" to which they are exposed. It is often expected that if members of the public "really understood the risks", i.e., how low they are and how "beneficial" technical programs that are the source of both, opposition to their development would subside.

18 An extreme case is the management of radioactive wastes. Due the very long half-lives of some very toxic radionuclides, the period of hazard may extend into the future for over 100,000 years. While not as subject to public controversy, it is sobering to realize that many toxic chemicals have no half lives at all. Their "times of hazard", so to say, stretches for all intents and purposes into the infinite social future.

These and some other LTSs exhibit the conditions discussed thus far. They are very large, internally highly complex both technically and socially, and spread across wide ranging areas. They are at once both beneficial in outcome and hazardous in their design. The firms and agencies that manage (and regulate) them are pressed to operate (or regulate) at much higher levels of reliability than we generally attempt in other sectors -- *as a condition of producing benefits*. Many of them have been able to operate at astonishing levels of reliability and safety, even in the face of often substantial, and unexpected operational and management difficulties -- though at great economic costs and high human efforts. And they generate continuous, very demanding operating conditions which strain the capabilities of operators, managers and regulators alike.[19]

At the same time, there is little systematic knowledge about how to establish and maintain the social organization necessary for such sustained operations. Most of our views about what is sensible to expect from large organizations stem from experiences with error tolerant systems where trial and error learning is an accepted and honored mode of discovery. This is not a firm basis for understanding processes in which the utility of trial and error learning may have sharp limits (La Porte and Consolini 1991; Roberts 1989). When "your next error may be your last trial" a great deal is different.

It is notable that as these systems actually become more hazardous -- due mainly to developing "more powerful" technical production and computerized "control" systems -- the fact that they perform at extraordinary levels of predictability rarely prompts us either to seek a deeper appreciation of their dynamics or to relegate them to the mundane of everyday life. They continue to evoke a mixture of muted wonder, nervous denial of their complexities, and chronic apprehension of possible failures. This becomes a major challenge for governmental agencies operating and/or regulating intrinsically hazardous systems -- HLTSs. It often subjects them to severe cross-pressures from those, on one hand, who wish for super safety and environmental harmony, and those, on the other hand, who would have to pay the substantial costs of achieving them. If such agencies or firms flag in meeting external expectations, no matter how demanding, they risk losing the trust and confidence of political leaders and the public.

IV. ON THIN ICE: LTSs AND INSTITUTIONAL TRUSTWORTHINESS

A number of very fruitful LTSs produce extraordinarily demanding operational requirements (including demands for nearly failure free management) and the potential for substantial harm to health and the environment far into the future. Many of these systems have been deployed by governments and their industrial symbionts, generally with the enthusiastic assistance of the technical professionals most closely associated with them. Often these professionals joined with the leaders of the deploying agencies

19 There are, of course, failures in so called high reliability organizations, e.g., the rare mid-air collisions within the U.S. air traffic control systems, or the quite unusual automatic shut downs of nuclear power stations. If these events are tabulated as a ratio of failures to the chances that failures could occur in the systems, the ratios are minuscule (La Porte and Consolini 1991).

and industries to assure the public that attractive benefits would accrue to us all. That is, the operating systems would be managed in a suitably reliable fashion and "externalities" would either be minimized or worth it due to the expected benefits. Cloaked in the mantle of professional impartiality, technical professionals and their institutional leaders have been believed -- trusted.

Indeed, all those "on the outside", whether technical professionals or not, are, in a sense, obliged to trust those who claim to know, and who authenticate each other in these judgments. They (and we) really have no alternative. But it is also clear that the longer term results of some LTS operations have not been such unmixed blessings as we had hoped or allowed ourselves to anticipate. Technical and industrial leaders sometimes engage in zealous technical advocacy, promise too much with too little advance alert to potentially negative consequences. Some of these, it is now understood, may arrive in the form of wide spread, essentially irreversible environmental damage, redistributions of social or political power, and/or unexpected challenges to ethical values.

The upshot is that laymen and citizens -- outsiders -- increasingly come to believe that deception may have been practiced by the political leaders, technical managers, and possibly technical professionals of these programs. Sadly, questions arise about whether one should have trust and confidence, the second time round, in those who were trusted in the first instance, i.e., those who have given social expression to the demand for new technologies, those public bodies that provide legitimating authorization and often resources, and those who are responsible for regulation. Should they be trusted?

In sum, there is a growing public wariness of LTSs and an increasing distrust directed toward government technical agencies, major industrial contractors, government regulators, and technical professionals (Citrin 1993). In extreme cases, as with U.S. nuclear energy and radioactive waste programs, distrust extends to basic scientists as well (DOE 1993; see Slovic, Flynn, and Layman 1991; Flynn and Slovic 1993 for summaries of numerous studies). To the degree this situation obtains, it provides the basis for considerable policy and political mischief.[20]

When significant portions of the public question the veracity and operating acuity of technical deployers, policy initiatives based on technical development signal a mixed message. The economic or social promise may be there, but can the public be assured that it will be realized by those who seem apparently to have violated the public trust? This, along with other tendencies of technical programs under stress, threaten the loss of public trust and confidence. Once lost, it is extraordinarily difficult to regain. This is

20 Some leaders in the science and technical communities argue that this situation has little to do with "science and technology" or policies related to them. A case can be made for this if one constructs the problem only in terms of the stimulation of so called "basic research", i.e., the increase of knowledge and understanding of the world for its our sake. This is a naive, misleading position for those who care about the status and independence of the scientist qua scientist in our society. And in matters of "government, science and technology" the issues are certainly not construed this way now. In so far as scientific and/or technical work (and policy) are tightly connected to economic and environmental improvement, the effects of technological development and operations on political and institutional legitimacy must be addressed. Analytically, this is a very difficult, newly recognized problem. It is an even more puzzling in terms of institutional design and its meaning for technological design.

as true in the public as it is in the private sector. One crucial difference is that public agencies, in democratic cultures, are expected to maintain political legitimacy in the eyes of the public and stakeholders. (See Box for a brief definitional discussion of trust and confidence.)

A DEFINITIONAL SIDE TRIP

In the literature, the terms "trust", "confidence" and "trustworthiness" are used loosely, and the topics of "institutional trustworthiness" and/or "public trust and confidence" have drawn only scant systematic attention. These definitions were developed for (DOE 1993).*

Trust is the belief that those with whom you interact will take your interests into account, even in situations where you are not in a position to recognize, evaluate and/or thwart potentially negative courses of action by "those trusted".**

Confidence exists when the party trusted is seen to be able to empathize with (know of) your interests, is competent to act on that knowledge, and will go to considerable lengths to keep her/his word.

Trustworthiness, then, would be a combination of trust and confidence.***

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* The "trust" relationship has been discussed in terms of confidence, credibility, legitimacy, authority, and opportunism. But there has been little attempt to sort these notions out and relate them systematically to the concept of "public trust and confidence" (see Thomas 1993a).

** "Trust" is sometimes interpreted to mean a naive, child-like deference, fully acquiescing "trustfulness", turning to another person completely to advise and suggest behavior. This is not what the term means in public policy parlance. Rather "trust and confidence" is more akin to professional or "institutional" trust and confidence.

*** Credibility/legitimacy undergirds trust and trustworthiness, though one can have trusted organizations that are not legitimate, and legitimate organizations that are not trusted. Among students of organizations, there is a readiness to talk of organizational credibility/legitimacy. There is less confidence about notions of organizational trustworthiness.

Indeed, a central feature of democratic society is the willingness of citizens to accord legitimacy and status to government officials, to delegate authority to political leaders, and to contribute resources to government agencies so that they may act in the general interest of the public. In this exchange, one partner, government, by law subordinate to

the citizenry, is delegated, by citizens, the authority and capacity to provide services to citizens, whose individual economic and social well-being and legal authority are relatively vulnerable. Agencies need to trust, count on citizens to legitimate, and to provide resources and social status, and to cooperate readily, or at least with minimum resistance. Without these, there is a long term degradation of an agency's capacity to perform effectively. Citizens need to trust their public agencies to maintain the capacity to provide services, to solve problems, and to fulfill commitments, even to those who will not necessarily be able to evaluate the competence of agency personnel nor the likely consequences of agency plans and proposals. Institutional or citizen trustworthiness becomes a matter of crucial concern when either party flags significantly in their respective contributions to this government/citizen exchange. When this occurs, it is costly in terms of oversight, time delay, enforcement, and loss of status and legitimacy. If this imbalance is sustained, political conflicts and operational stalemate are likely to result. Large technical systems are certainly as subject to this dynamic as other institutions in modern society.[21]

V. REQUIRING TRUST/EVOKING DISTRUST

But are all LTSs equally at risk? Of course not, though the details of variation are obscure. It is not likely that all LTSs possess equally the properties that heighten the need for public trust or make it hard to sustain. I argued at the outset that LTSs have different social and organizational properties just as do the communities and regions into which they are deployed. Some, while widely dispersed, can be operated via very loose authority relations vis-a-vis a central headquarters, e.g., naval flight operations at sea. Others, just as dispersed, require tightly coordinated command relations, e.g., operation of the tracking net monitoring space shuttle flights. LTSs are not equally subject to managerial apraxia nor equal in scale, dispersion or technical complexity.

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21 Thus far an implicit assumption has been that PT&C is a necessary attribute for the effective deployment and maturation of LTSs. But this is not obvious. LTSs do evolve in the face of public distrust; the US nuclear industry is a case in point. This raises both practical and normative questions about the relationship between the public and major governmental or industrial technical programs. Without attempting to address them here, I can briefly list them as follows:

1. How important is PT&C in the conduct and success of technological development and operations? Does a lack of PT&C (public distrust) threaten the development\quality of technological programs?

2. Should PT&C be an important requisite for conducting scientific and technological programs in democratic political systems? Should a lack of PT&C be the basis for altering or terminating such work?

3a. If the answers are "No", or "Maybe not", then: to what degree is the use of political or institutional power justified in promoting technological programs? Does such use seriously threaten the success and/or scientific and operating quality of such programs?

3b. If the answers are "Yes", then: If PT&C is important, what are the conditions that maintain it, result in its loss, and assist in recovering it? What are the consequences for the conduct of scientific or technical work if there is widespread, sustained distrust? [See DOE (1993) for a partial answer.]

But this does not go very far in refining our understanding of those properties that increase the difficulties for the managers and promoters of LTSs in assuring public trust and confidence. We need, first, a better specification of what conditions, if attained, would result in public trust and confidence. Then we can ask if there are key conditions that vary the degree to which LTSs may risk losing their publics' trust and confidence?[22]

I shall claim first that, given the definition of trust and confidence employed here (See Box), PT&C will exist to the extent the following general conditions obtain between parties to exchanges[23]:

Parties have a reasonably *high respect/regard for each other* based on general familiarity and perceived high degree of mutual understanding and integrity (openness and honesty). Understanding and integrity, while important for anticipating a trustworthy relationship, is not identical to it (Luhmann 1979). That is, one can understand another person and have confidence in his/her integrity and still be uncertain about the degree to which he/she will take your interests into account.

Parties possess the *competence to understand the problems others face* and the solutions advanced to address them. In our case, these would be either technical and institutional problems with limited emphasis on personal or work group related difficulties.

Parties have a reasonably *equal part in defining the terms of their relationship.* The less this is the case, the more the necessity for (institutional) opportunities for the weaker party to advance and press grievances -- even those of minor significance.

Parties maintain a *positive history of relationships* during which agreements have been kept, even in the face of apparently very demanding challenges.

Parties are able to *determine unambiguously the effects of their relationship* on each other in a full and timely fashion.

Parties *take seriously the implications of their actions* for sustaining the relationship.

In so far as these conditions obtain, they make it possible to realize the elements of the definitions outlined above. For our purposes, I assume that in situations where there is a high degree of PT&C that members of the public understand -- whether or not they think much about it -- that these conditions are being met.

But it is clear, especially for complex institutional settings that have been viable for some time, that realizing and sustaining these conditions may be difficult.[24] Based on the argument thus far, can we suggest some indicators of incipient loss of public trust and confidence? The following list builds on the perceptions of stakeholders arranged in terms of four major relationships. The more these perceptions characterize the public's view, the more the institutions risk the loss of public trust and confidence; the more serious the loss, the more likely distrust and conflict will deepen. If deep distrust persists, it threatens the political legitimacy of the salient institutions.

Apply these indicators to a LTSs of your choice. To what degree were or are these conditions present? What measures, if any, were or are taken to counter them? It is clear that some LTSs are much more at risk than others. We shall discuss an extreme case in the U.S. experience with managing radioactive waste management.

The erosion of the public's trust in large technical systems varies as a function of the degree to which

Benefits and Costs

(1.1) citizens perceive a mismatch in the distribution of benefits and the costs (in financial, social terms to self and/or future generations) associated with realizing the agency's/firm's mission;

(1.2) citizens perceive the risks or hazards associated with significant program failure to be very high and very long lasting;

Accuracy/Speed of Feedback

(2.1) citizens realize that a relatively high level of technical, esoteric knowledge is required to operate the production system and/or evaluate its success, risk and hazards;

(2.2) citizens perceive a long time lag in the discovery of success or failure, especially if the evidence of failure is likely to be ambiguous, equivocal;

Capability of Others to Meet Expectations

(3.1) citizens perceive a decline in the competence of agency/firm members (relative to the demands of the problems/processes central to effective operations);

(3.2) citizens perceive a decline in operating reliability and disclosure of complete information about difficulties and failures;

Motivation of Others to Understand and Keep Bargains

(4.1) citizens perceive an unwillingness of LTS managers or regulators to respect the views of vulnerable parties (as expressed, e.g., by condescending attitudes or deception); and

(4.2) citizens perceive an inability (unwillingness) of LTS leaders to fulfill promises (contracts, agreements) to maintain consistent levels of agency performance, or to maintain promised political support for LTS operations.

In combination, these are demanding, often costly, conditions to counter. Indeed, some may be impossible given the nature of the technical processes central to a LTS's mission and function, others are conditioned largely by the social or political history of the particular system. This makes the application of these notions to specific LTSs, es-

22 This section draws from my contributions to DOE (1993).

23 Cf. Luhmann (1979: ch. 7) for one of the few general theoretical explorations of the function of trust as a means individuals employ to simplify social complexity. He argues that the more technically complex a system, the more individuals need/wish to trust the "system" in order to cope with the increased complexity of individual experience induced by the system. Several conditions of "system trust" similar to those listed below are then proposed. I am grateful to Renate Mayntz for bringing this work to my attention.

24 While I do not dwell on it here, there is a significant difference in situations where the parties at interest wish merely to establish and sustain a satisfactory level of PT&C contrasted to one where there is a need to *recover* PT&C, i.e., when a LTS is experiencing a deficit of PT&C or is substantially distrusted by the public. The latter case requires much more effort and time than to establish and keep PT&C.

pecially in [illegible] es when PT&C has been lost, problematic without rather detailed analyses of the peculiarities of each case. Viewing LTSs vis-a-vis the perspective of technologies-as-social-organizations provides a beginning language to sort these out.

VI. TRUST AND THE U.S. RADIOACTIVE WASTE MANAGEMENT PROGRAM

A vivid example of a LTS that has suffered a steep decline of public trust and confidence is provided by the U.S. Department of Energy's (DOE) experience in managing radioactive wastes. One of the most troubling legacies of the swift development of nuclear power, the safe disposal of radioactive wastes represents a major operational and policy challenge to a) DOE, the agency that has legal responsibility to dispose safely of these materials, b) the U.S. Nuclear Regulatory Commission, the chief regulator in this process, c) the electrical utilities that employ this means of making steam, and d) the associated technical communities.[25] The radioactive wastes, especially "high level", very toxic waste forms that pose the most demanding challenge, come in the U.S. from two rather different sources: the spent fuel used to generate commercial electrical power, the "civilian wastes"; and a wider variety of materials that have been highly contaminated in the process of fabricating nuclear weapons, the so called "defense wastes." With the cessation of nuclear weapons production, these latter programs have recently been reorganized with the mission of environmental clean-up and restoration. There are substantial quantities of wastes from each source, with the spent fuel currently being stored at the power plant sites where they were produced.

Efforts to refine the technologies and to locate sites for final disposal have gone on for several decades with an increasing tempo of public awareness and alarm. This has been most intense in those regions that have found themselves to be potential candidates for these facilities. The history of these matters is tangled, quite complex and too voluminous to even attempt to summarize here.[26] Suffice it to say, that opposition to the Department from the relevant States and communities has become sustained and vehement.

A major dynamic in this situation stems from the agreement some years ago between the nuclear utilities and the DOE that the government would take title to this spent fuel

25 The technoplexes involved are very large, the networks extraordinarily variegated. For present purposes, the argument is limited in two ways. First, I consider only radioactive waste management systems (Radwaste). This LTS is closely related to the "nuclear industry", usually meaning those who produce electrical energy by utilizing nuclear fuel for steam generation. It might be included to form one, very large functionally related LTS. However, in the U.S., the radwaste system is sufficiently distinct institutionally from the nuclear industry to be treated as an analytical unit. This is less the case for European countries where both the nuclear production of energy and the treatment of the resulting wastes are consigned to the utilities. Second, there are, as well, additional regulatory agencies that have responsibilities over aspects of these processes, e.g., the U.S. Environmental Protection Agency, and various state agencies, and a wide variety of interest groups that take a keen interest in this area. They are given much less notice than they would ordinarily receive in policy analytic discussions.

26 For cogent overviews and discussions of the extensive literature covering this area, see Carter (1987) and OTA (1985).

by 1998 for transport off site and final disposal -- most likely in a small number of centralized burial locations. This agreement was used in sizing the amount of on-site storage capacity -- in large water cooled pools -- the utilities would need. These pools are now nearing full capacity with very limited progress in selecting burial locations. The program is subject to continuing controversy with indeterminate prospects for consensus and the opening of a final repository.

Among the many properties that characterize this LTS, two are particularly unsettling: a) "the long lag in the time to the discovery of success or failure, especially since the evidence of failure is likely to be ambiguous, equivocal" and b) "a history of uncertain technical reliability and the withholding of complete information about difficulties and failures" (DOE 1993). The first is a physical aspect of the technology, the second is institutional.

It is intrinsic to managing radioactive wastes that a program's success or failure can only be fully determined so far in the future that all the managers and technical people responsible for its current management will be long gone.[27] Long time lags to the discovery of success or failure mean that our familiar methods of holding officials accountable have little force. We now have no alternatives. When systems are also intrinsically hazardous, as these programs certainly are, the situation is ripe for festering public suspicion, overzealous technical advocacy, and intense political conflict. Adding a history of incomplete disclosure, dissembling, reluctance to be forthcoming with complete information, followed by discovery by outsiders that technical analysis has been flawed, deepened a sense of distrust (DOE 1993).

The impasse has persisted and in the past several years has threatened to erupt in ugly institutional warfare. In 1991, the Secretary of Energy commissioned a task force to examine the Department's programs in terms of the levels the public's trust and confidence, and the dynamics of these relationships and measures for ensuring trust and confidence.[28] An informal, partial summary of some general findings and recommendations of its report, DOE (1993), *Earning Public Trust and Confidence: Requisites for Managing Radioactive Waste*, gives more detail to the meaning of the loss of political legitimacy. Its 20 some findings were overwhelmingly negative, its over 70 recommendations extensive and far reaching. With reference to the two major radioactive waste management programs of the DOE, the Office of Civilian Radioactive Waste Management (OCRWM) and the Division of Environmental Restoration and Waste Management (EM), the task force found:

> There is a widespread lack of public trust and confidence (PT&C) in both major programs. This stems from direct public contacts over many years, and is not generally an example of an irrational NIMBY syndrome.[29] For a number of sectors, this loss has

27 There is a least a 50 year lag in the evaluation of environmental remediation work, often over 1000 to 10,000 years vis-a-vis the possible escape of radioactive materials from permanent repositories.

28 This section draws much from the work and experience of that body, the Task Force on Radioactive Waste Management, Secretary of Energy Advisory Board, which I chaired. The Task Force Director was Daniel Metlay.

29 "Not-In-My-Back-Yard" syndrome.

become so intense as to result in deep distrust. Restoration rather than maintenance of existing PT&C is in order.

The lack of PT&C is resulting in opposition not only to present program activities but to initiatives for programmatic changes as well; it reflects on other non-nuclear activities of the Department, and is sufficiently severe to cause outsiders to discount trust strengthening activities and amplify trust reducing incidents.

Also lacking is an institutional capacity to design, implement and evaluate measures to strengthen PT&C. The agency's wide use of contractors hampers its abilities to improve, and means that contractors' behavior will have to change as well. There is no reason to believe that major re-organization of the radioactive waste management function, as some demand, will of itself improve public trust and confidence (Thomas 1993b).

Restoration will require changed activities over a number of years throughout the Department, its programs, and contractors. These changes may often be efforts which would be unnecessary for an organization enjoying PT&C. This will appear to some among supporters and in the agency as over-compensation, though it will be needed to overcome history.

Finally a wee bit of better news: There has been a modest improvement in the way the Department has been perceived in the past four years. This has brought some benefit to the Environmental Restoration and Waste Management (EM) program where there seems to be an improving capacity to restore PT&C as compared to the Office of Civilian Radioactive Waste Management (OCRWM).

Institutional relationships constraining DOE's programs, especially OCRWM, have resulted in cycles of pressure: attempts to "do it right", i.e., develop technical plans in which everything, including geological analysis, is perfected in advance; subsequent over promising; then posturing by technical managers who, in fact, do not agree that the risks of long term storage are as serious as some public groups believe; and finally, stumbling about apraxically, evading (denying) blame for technical planning failures due in part to politically forced technical compromise (National Research Council 1990). This has led to program delays, failures, and cost overruns. These are then followed by more pressure and another cycle of intense effort, more (now desperate) over promising, followed by yet more disappointment, perhaps exacerbated by managerial or professional dissembling. The result has not been a happy one and nearly all concerned realize that major changes are in order. The exception is a somewhat reluctant OCRWM.

The recommendations that end the Task Force report cover, first, external relationships with stakeholders and communities. Detailed recommendations are derived from a brief set of "design bases" or premises that stress: involvement with community, state and stakeholder groups; keeping commitments unless they are modified through an open process; accessibility of senior agency officials to citizens; and negotiated benefits with the most affected communities. Most of the detailed measures are to be expected save perhaps empowering local "safety review boards (to) temporarily suspend operations at a facility for a pre-established set of reasons".

Second, the task force pays close attention to internal agency and program operations. This emphasis is quite unusual and of most interest here. It arises from the dynamics associated with the long time lag before discovery of the system's failure is possible. In this technical area, there are no timely, credible data on overall system output. Everything is in terms of events that cannot come to fruition for thousands of years -- the escape of radioactive materials into ground water supplies. Surrogates for "production outputs" are needed for skeptical citizens and regulators. Without them, an alternative is for regulators and stakeholders to become familiar with and evaluate the quality of the LTSs internal operations. In a sense, the task force argues that the agency needs to invite those who are skeptical to learn more about internal operations, i.e., for the agency to become quite transparent. "(Stakeholders) should discover internal activities taking place that increase institutional trustworthiness not decrease it. The higher the potential hazard..., the more critical is their proper conduct." In this case, the recovery of trust would result, in part, if the more one knows about the agency, the more confident one is that hazardous processes are and will continue to be done very well. This is the reverse of what most would expect as a consequence of increasing familiarity with large institutions.

The design basis for improvements in internal operations (to which 40 detailed measures are related) emphasize processes of self-assessment permitting the agency to "get ahead of problems ... before they are discovered by outsiders"; "tough internal processes of reviewing and discovering actual operating activity that includes stakeholders"; and high professional and managerial competence and technically realistic schedules. In effect, a new culture of awareness about the rigors of earning PT&C is being called for. A sampling of these measures gives a sense of how grave the task force judged the situation to be and how much effort was needed before substantial change would be likely. Combining these with the thirty detailed measures already noted suggests the high *transaction costs of suspicion.*

To buttress the credibility of technical work, the report recommends stakeholder and external peer review of technical design and experimental work and the auditing of quality assurance programs. The agency is enjoined to straight forwardly address plausible scientific arguments challenging the basis for technical plans that might arise during the project. The highest program officers are to be provided with explicit assessments of the impact on PT&C of policy options and major technical design changes. If the options chosen are likely to weaken PT&C for particular segments of the public, the agency is urged to publish explanations and plans for mitigating these effects. Finally, and perhaps most importantly, "to ensure that organizational dysfunctions are not responsible for operation problems that could lead to decreased institutional trustworthiness", the agency is counselled to delegate greater authority to the units closest to the technical operations, maintain a sufficient staff to assure oversight of PT&C activities within the programs and contractor offices, and to develop and reward processes of overlapping self-regulation and error discovery and correction.

This pattern of recommended activities would reach far into the operating organization, stressing public transparency and rigorously applied processes of discovery and self-regulation. They are different from the familiar skills of technical development, coordination and execution -- all carried out far from public view. And they are costly in time and other resources, and call for different managerial skills and attitudes of technical professionals vis-a-vis the public.[30]

The systems that carry on the work of radioactive waste management present the challenges to public trust and confidence perhaps in an extreme form. But other LTSs begin to approximate some of the properties that are at the crux of this challenge. If these effects are not countered, and if the organizations do not deal satisfactorily with the *transaction costs of suspicion*, they risk sliding into the abyss of distrust. In the end, the political legitimacy of the agencies and firms involved is compromised.[31] This outcome is rarely associated with the deployment of LTSs, or even considered possible. To the degree this argument can be sustained, it suggests an additional evaluation criterion (and a good deal of analytical work) when weighing the effects of technology on society, namely, the impacts of particular technical systems (potentially detectable at the design stage) on the political legitimacy of its deployers, its sponsors and, in the end, its public regulators.

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30 They are also likely to be seen as impractical or impossible to institute. Yet there are some organizations that have progressed well down this evolutionary path, e.g. sections of the U.S. air traffic control system and the operational units of several nuclear power utilities. None of these organization think of what they do in the terms used here however.

31 While not in the scope of this paper, two related concerns should be noted. First, there is the matter of designing technologies with an eye to minimizing the properties that put PT&C at risk. This is not done today, though it can be argued that there are a number of technical areas that edge in the direction of distrust evoking systems, i.e., if they were deployed as they are now designed, they would result in LTSs that increase the three properties likely to erode PT&C (see p. 15 above). Could they be designed to produce the physical benefit without the social properties of incipient distrust? Second, there are worrisome secondary "victims" when technical organizations lose the public's trust and confidence: the technical communities involved. Technical professionals are expected, in light of the implicit social contract with society that bestows status, discretion and a certain working freedom upon them, to alert that society to mistakes, sometime misdeeds, taken in the name of technical progress. When LTSs as agglomerations suffer a loss of PT&C, this extends after a time to its the technical professionals as well. A widespread loss of trust and confidence in numerous LTSs may also confront our technical communities with increasing public skepticism and attempts to control.

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REDEN ÜBER GROSSE TECHNIK

Bernward Joerges

So, in der Weite der Front verloren und durch einen großen Abstand von mir getrennt, sah das Geschehen da unten harmlos und zwerghaft aus, und es kam mir seltsam vor, daß dieses Waldstück gestern einen so starken Eindruck auf mich gemacht hatte. Wenn es ein großes Wesen gäbe, das mit einem Blick mühelos die Alpen und das Meer umspannen könnte, so würde ihm dieses Treiben vorkommen wie eine zierliche Ameisenschlacht, wie ein feines Gehämmer an einem einheitlichen Werk. Uns aber, die wir nichts als einen winzigen Ausschnitt sehen, drückt unser kleines Schicksal nieder, und der Tod erscheint uns in furchtbarer Gestalt. Wir können nur ahnen, daß das, was hier geschieht, in eine große Ordnung eingegliedert ist und daß die Fäden, an denen wir scheinbar sinnlos und auseinanderstrebend zappeln, sich irgendwo zu einem Sinn verknüpfen, dessen Einheit uns entgeht.[1]

Diese beachtliche Rede handelt zwar von einer Materialschlacht im ersten Weltkrieg, stimmt aber eine ganze Reihe von Motiven an, die in Theorien sozialer Systeme zentrale Bedeutung gewonnen haben. Das Unüberschaubare bestimmter technischer Systeme, die Frage nach Einheit und Sinn des Systems, die Figur des fernen Beobachters, die Faszination des Gegenstands, die sich auf den Beobachter, der ja immer auch Teil des Systems bleibt, überträgt. Satellitenauge, Nummernwald, große Ordnung, Systemmetaphysik: Themen, über die, wie ich zeigen möchte, in sozialwissenschaftlichen Diskursen über "große technische Systeme" ebenfalls geredet wird, wenn auch in einem anderen Vokabular.

Es soll also um die Art und Weise sozialwissenschaftlichen Redens über "GTS" gehen.[2] Ein fast entschuldigendes Caveat ist vielleicht nicht fehl am Platz. Das Genre des soziologischen Artikels erlaubt allerlei Grenzüberschreitungen ins Kritische, ins Politische, ins Pamphlet sogar, kurz: in jede Art von normativem Diskurs und seine Gleichnisse. Nicht so im Fall "literarischer" Grenzüberschreitungen. Ein Soziologe dürfte den Friedensnobelpreis annehmen, der für Literatur wäre berufsschädigend. Dennoch wähle ich für meine Absichten ein quasi-literarisches Verfahren und pflege jene seltsame Art von Empirie, die sich augenscheinlich nur in Texten bewegt, ohne den Anspruch, etwas über "die Systeme da draußen" sagen zu wollen. Und so, wie wir in der Beschreibung und Interpretation dessen, was wir in der Sozialforschung repräsentieren, aus guten Gründen eine andere Sprache pflegen, als die "im Feld" gesprochene, wähle ich auch hier eine Form, die sich von der soziologischen Form abhebt: es erscheint mir generell nützlich, über Gesprochenes in einem anderen Modus als dem

1 Ernst Jünger, Das Wäldchen 125. Eine Chronik aus den Grabenkämpfen (1918/1925), zitiert nach Heimo Schwilk (1988, 72).

2 Das Kürzel GTS hat sich in der sozialwissenschaftlichen Forschungsszene (wie übrigens auch LTS für "large technical systems" im anglo-amerikanischen Bereich) allgemein eingebürgert; ich sehe darin ein Zeichen dafür, daß ein Forschungsgebiet über den Tag hinaus etabliert ist.