

# **Large Technical Systems and the Discourse of Complexity**

**in Lars Ingelstam (ed.), *Complex Technical Systems*, Swedish Council for Planning and Coordination of Research, Stockholm: Affärs Litteratur 1996, 55-72**

**Bernward Joerges**

## **Introduction**

The Sigtuna conference and this volume are based on a double assumption: complex technical systems are of great significance to society, and they provide promising topics for trans-disciplinary research. The present chapter introduces and examines a particular research perspective in the broad area of social studies of technology: historical and sociological studies of Large Technical Systems, or short LTS.

For a long time, social science technology researchers were not unduly concerned with the technical ensembles identified here as LTS. This is because technology research is not part of the sociological canon and because the (continental) social sciences outside the history of technology did not begin to engage in technology research on a broad scale until the early 1980's. At that point Renate Mayntz, sociologist at the Max-Planck-Institute in Cologne, and Thomas P. Hughes, historian of technology at the University of Pennsylvania – opened up a new research field, "the modern transportation, communication and supply systems, which one might subsume under the heading infrastructural systems, since their primary function consists in *enabling* a multitude of specific activities to take place ...." (Mayntz, 1988: 233) – An international research network was developed and cultivated, a series of conferences took place, a number of conference proceedings appeared (Mayntz/Hughes 1988, LaPorte 1991, Summerton 1994, Braun/Joerges 1995). Empirical and comparative research gathered momentum in various places; something like a research community, with its characteristic "discourses," evolved.

What is the significance of this body of research in the present context? In order to place the LTS debate in the context of a more general concern with the complexity of technical systems, I will do three things in the following. First, I will recapitulate some of the basic distinctions and suppositions introduced early on in the LTS debate. Secondly, I will deal at greater length with the issue of complexity, as it appears in LTS re-

## *Complex Technical Systems*

search up to 1995.<sup>1</sup> Finally, I will draw some lessons from this "discourse of complexity" in social studies of technology.

### **I. Early Distinctions and Queries**

In their introduction to the first volume of LTS studies (Mayntz/Hughes 1988), the editors wrote:

"Social science research on technology has long focused on the development, diffusion, and especially the consequences of specific isolated technologies or technical artifacts: the steam engine, the automobile, the telephone, the computer, etc. More recently, it has been recognized that an important characteristic of modern technology is the existence of *complex and large* technical systems – spatially extended and functionally integrated socio-technical networks such as electrical power, railroad, and telephone systems. These systems have played a focal role in the process of industrialization and economic development, and they have contributed to a significant change in life style. Aside from undoubtedly beneficial effects such systems are also creating problems – negative externalities, the risks of failure and disaster, management, control, and coordination problems. Thus a new field of research is emerging where historians and social scientists have started to cooperate in the analysis of the development and functioning of large technical systems."

The first task in this undertaking was to achieve a measure of consensus about the types of technical systems under discussion. Here, Thomas Hughes work proved fruitful beyond the historical description, and interpretation against broad societal change, of energy generation and distribution systems. In fact Hughes had put forward systematic concepts generalizable to other systems of similar scale and provided a rationale for delineating *technological* systems from other social systems, small or large.

This has set the scene for an examination of basic terms and explanatory issues. Talking across various social science disciplines, with their widely varying conceptualizations of technology, it quickly became clear that the basic terms "systems", "technical" and "large technical" were used differently by participants to the debate. This applied and continues to apply in the first place to the term "system". Since most of the time this word is used in a general, non-technical way, representing notions of complexity and complicatedness, it seems entirely unproblematic. One merit of the system metaphor in social studies of technology is of course its endless interpretative latitude "out there": It makes sense to engineers and to disenchanted laypeople, to theoretical biologists and to grand theoreticians of society.

*Large Technical Systems and the Discourse of Complexity*

The systems term poses problems, however, when it is used more analytically. Can one specify the relationship of the systems under discussion with their environments? Are LTS responding, in their build-up, to demands and requirements "outside" themselves, for example science-push, market forces, international competition, political and regulative state exigencies, even deep cultural forces? Or do LTS define scientific problems, create their markets, destroy their competitors, enlist state agencies, and shape cultural meanings? What accounts for the apparent self-propelling and potentially destructive quality, what for the counter-image of LTS as collective creations and tokens of a sustained vitality of industrial societies?

Such "locus of control" and "technological determination" issues hinge on a systems logic requiring the meaningful identification of system boundaries and substantial descriptions of system environments (or envioning systems with their boundaries). The notorious ambiguity, or even emptiness, of the concepts "technical" and "technological" (systems) in sociological conceptualizations do not facilitate this. This is why some technology researchers reject the systems concept in favor of what he calls "techno-structure" to indicate the essential interrelatedness of linked technical objects with ecological and other social structures. Even Hughes's suggestive metaphor of the "seamless web" somehow seems to counter the systems metaphor by evoking some characteristic of never-ending generative process.

***Technical Systems, Projects and Networks***

The specification of what we mean by "technical" is more critical. It has become commonplace to say that social and technical phenomena must not be opposed, because the technical is "socially structured", or simply because it *is* social. If technical is always social, technical artifacts are social artifacts, but what kind of social artifacts are they? The legal norms governing traffic systems are social artifacts. Highways, automobiles and traffic lights are considered technical artifacts. What about the technical norms regulating road and automobile construction? Are they to be considered technical or social artifacts, or something in between?

This may sound scholastic, but using such labels without spelling out their relations, or collapsing them as uniformly "social", invites all kinds of technological or social determinisms. The situation is exacerbated by the fact that major perspectives in present day social science theorizing about technical systems tend to ignore the material-operational cores of such systems. Explicitly or implicitly, the concept "technology" is

### *Complex Technical Systems*

meant to refer to phenomena other than machinery, material constructions and regulated physical processes.

Two things would follow. In the first place, the term "social" should, if possible, be used as an umbrella term only. Non-technical social phenomena (organizations, institutions, interactions, etc.) should be specified carefully in social science terms. Otherwise its meaning will always revert to the "merely physical" aspects of technical systems. In the second place, the freestanding material-technical artifacts and what they do by themselves should be taken seriously. This means that their actual operations (not just their design) and the actual, embodied norms (standards) governing these operations should be conceptualized as genuinely social processes of a particular kind. Machineries are "normated natural events" (Norbert Elias), events turned into operations according to complex normative schemes (technical norms), and many recent studies of the constitution of material-technical artifacts have shown and argued that to make natural events behave is no small feat.

It seems obvious to me that any specification of "technical" should be grounded in the concept of formal rationality, i.e. standardized methods of calculation on which routine actions can be based. Modern law consists of such methods, the money economy is based on such methods, and so are technical systems. While the social sciences have spent much effort in understanding legal and economic rationality and its inventions, the specific character of technical rationality has not received systematic attention. In an action theory perspective, the problem consists in establishing the *differentia specifica* of technical transactions, as opposed, for example, to legal and economic transactions.

There has been, in LTS debates, a recurring need to distinguish between types of LTS and major types of subsystems, in order to gain a more secure base for comparisons and generalization across systems. Two variants especially, both prominent in LTS research, need to be distinguished and pose somewhat different problems: large technical networks (LTN) and large technical programs (LTP). The shuttle program, the Aswan or Cabora Bassa dams, the fusion reactor are LTP, the classical example is the Manhattan project. LTP may blend, on the one margin, into large R&D programs such as SDI, Eureca, or Esprit, or on the other into major "missing link" type projects. LTN and LTP are, as a rule, closely connected and resemble each other in so far as both involve multiple state agencies, not only as regulators, and are of transnational scope; they combine, in other words, the difficulties and opportunities of multinational and mixed economy structures. Yet, the problems they pose are somewhat different.

*Large Technical Systems and the Discourse of Complexity*

Analyzing the linkages of participating actors to LTN, problems of coupling various operating and controlling actors on the one hand, and users, organizations-to-be sustained on the other hand are usually distinguished. Control problems typically seem to arise from a-synchronical changes on the part of diverse operating agencies, or diverse users, or *between* operators and users. The latter is of special interest because here highly variable user styles, particularly in informal everyday life settings, tend to clash with highly formalized operating and control styles. Thus, issues of load management run through the history of most LTN. Networks lack market and other regulating mechanisms allowing for efficient and flexible response. As a result, sudden or unexpected a-synchronic changes in their organizational webs "hit them harder" than, for instance, corporate production systems. Thanks mainly to their tight physical coupling, they require high central control capability and central interventions in case of failure.

Another permanent problem of LTN, akin to load problems but located at the interfaces between competing LTN or relatively autonomous subsystems, is – to generalize a term from transport planning and research – "modal split" management: the proportioning of services allocated to different (sub)systems, e.g. individual or public transport, cable or satellite transmission, human or artificial organ transplants, conventional or nuclear defense, manned or robotic space travel, and so on.

LTP, in contrast to networks, can be seen as pre-infrastructure systems oriented towards some quasi-experimental set of technical, economic or political goals. They resemble, on an over-large scale, what industrial sociologists call "stationary production processes", that is productions where design, manufacture and installation of a more or less unique industrial product are inextricably interwoven, for instance in plant construction (*Anlagenbau*). In so far as LTP are often undertaken in a context of radical expansion or transformation of LTS, one may also look at them as "forward salients", if I may expand on Hughes's notion. The rationale underlying LTP seems to relate one way or another to the synergetic effects to be had, or expected, from high organizational "compression". "Getting ahead", "achieving big leaps" into technical futures, often combined with strategies of pushing legal and technical standards for long-term development, are typical justifications for, as a rule, highly controversial, financially and politically risky LTP (LTP Apollo may have been an exception).

The problems of LTP seem to arise largely from a need for synchronous organization and integration of "mature" and "immature" components of the end product, both with respect to hardware and "orgware". Since the products of LTP are always unicates (or

## *Complex Technical Systems*

reach only the prototype stage of a "normal" production cycle), design lines once embarked upon can often not be revised, for economic or, interestingly, for technical, "systems" reasons. LTP generally lack, in other words, the buffers and loops characteristic of long sequential processes in the generation, application and amplification of technical products. In this sense, one might call such programs "hyper-fast" forms of social organizations where specific sequences, from R&D through production to end use are compressed and made parallel in social time.

Recalling these early conceptual and substantive debates reveals that the varied characterizations and analytical schemes offered were informed throughout by one central notion, or metaphor: LTS are complex systems. At the same time, it is clear that this notion, or metaphorical resource, is taken from rather disparate intellectual fields: sometimes from evolutionary thought, sometimes from engineering science, sometimes from the theory of social systems as differentiated, self-organizing systems. Taking a closer look, what does it mean when LTS researchers describe their systems as particularly and peculiarly complex and to what uses do they put this notion?

## **II. The Discourse of Complexity In LTS**

In order to answer this question, I will take a close look at empirical, as rule case study type contributions to four representative volumes this research scene has produced to date: "The Development of Large Technical Systems" (Mayntz/Hughes, 1988), "Social Responses to Large Technical Systems" (LaPorte, 1991), "Changing Large Technical Systems" (Summerton, 1994b) and "Technik ohne Grenzen" (Braun/Joerges, 1994). I will extract from studies published in these books certain formulations and weave them into "intertexts" which will then serve me to demonstrate the varied ways in which the notion of systemic complexity has come to play a crucial role in LTS discourse.<sup>2</sup>

With few exceptions, I will refer only to texts concerned with the spatially and temporally, extensively and expansively interrelated technical artefacts which have now commonly come to be subsumed under the category of LTS: railroads, electricity, telecommunications, transportation, water supply, air and space travel, and the like. In other words, contributions to this discussion which take a conventional view of "high-tech" as undifferentiatedly synonymous with "large-tech" are not subject to the present analysis.

If, invariably, the exceptional complexity of LTS is continuously emphasized throughout<sup>3</sup>, then it is still unclear whether the term is used in an ornamental fashion,

*Large Technical Systems and the Discourse of Complexity*

whether it serves strategic functions whether this generalization bears interesting implications for the specific dynamics of these systems.

***Trivialities***

First of all, one must discount all manner of banal usage of the notion of complexity, much as with the systems notion.

*We do need models to synthesize and analyze the incredibly complex phenomena of LTS developments. - A safe commercial operation requires a set of complex systems to work together. - A complex system has a variety of branching paths and feedback loops. - And many more.<sup>4</sup>*

None of these sentences would lose any meaning if the term complex were skipped.

***Generalities***

Beyond this, it seems to me that the category of complexity serves in the first place as a preliminary summary for a series of ascertained, suspected or simply presumed attributes such as the uncertainty, imperspicuity, uncontrollability of LTS – attributes which one then promises to illuminate, to render more transparent through analysis.

What does this generality achieve? In most cases, one might just as well simply speak of great variety, multiplicity and multitude. And in fact, a marginal usage can be detected again and again that belongs to a different semantic field but is evidently intended to describe similar phenomena: LTS as "messy," "heterogeneous," "hybrid," even the felicitous image of the "seamless web" invented by Thomas Hughes. These are characterizations which emanate from the vocabulary of constructivist sociological research on science and technology, whose proponents have at best played the role of critical outsiders in the LTS research community.<sup>5</sup>

An important function of "complex-speak" may therefore be to capitalize on certain conceptual associations of the term complexity: its implicit reference to a broad range of high theories – of non-linear systems, chaos, autopoiesis and such – helps to secure LTS research a respected place in the evolving canon of technology and organization studies.

Another quality of this particular discourse is metaphorical. The persistent idea of exceptional complexity serves as a heuristic analogy: nothing is defined, nothing established, no terminology prescribed; a problem is pointed out, that is all. In the broader

## *Complex Technical Systems*

metaphoric context of evolutionary notions, for example, the analogy tell us that we are dealing with a species of social and/or technical systems which, in a more or less Spencian sense, are evolving towards a higher level of form. One must then ask whether it is productive to think in terms of an evolutionary scheme, and this will be decided in some pragmatic (scientific, economic and so forth) political context.

### *Complexity Out Of Control*

One particular political context has obviously do with the notion that the complexity of LTS creates serious problems of societal control and steerability.

*Research into LTS is oriented towards ... a ... concern with systemicity and the alleged modern growth of systemicity in technology as highly problematic in view of human control, assuming that increasing systemicity connotes things like growing momentum, rising complexity, increasing global interdependence and a growth of autodynamics in technical change. – The larger the scale and complexity of the system (e.g., the geographical scope, the diversity of task, and the nature and diversity of technology), the more difficult it is to control events. – Safe operation requires a set of complex systems to work together. – Perrow is particularly concerned with tightly-coupled, complexly interactive systems. – Theories of societal control trying to make complex systems function more safely, control systems are required with an increased level of complexity. – The uncertainty-reducing properties of qualitative and quantitative advances in systems is neatly canceled out by the increasing rapidity and complexity of operations. – Once again, one finds allusions to the idea that system complexity has a self-propelling quality. – The practical-political reason for the interest in large-scale technology is the experience with technical systems, and its thematisation in the political public, which are seen as out-of control, highly complex and expansive, and particularly risky... – These systems are complex social configurations displaying functional differentiation at all levels. ... they display complex patterns of institutional integration and modes of governance. ... The co-ordination of these increasingly complex multi-unit enterprises requires specialists and specialized technologies. – The system operators expect that users are willing to take on additional complexity in return for greater control... – In trying to make complex systems function more safely, control systems are required with an increased level of complexity. Attempts to extend control to environmental systems entail exactly the same infinite regress.<sup>6</sup>*

These excerpts are more vivid than some of the earlier intertexts, they are more immediately recognizable as parts of familiar debates about the social problems technology poses, in other words as related to public discourses rather than specialist research accounts. They do not, as the previous quotes, establish scientific authoritativeness; they establish the social responsibility of research. Part of this complexity/control-discourse is very much the figure of a *growing* complexity and of "complexity breeding complex-

ity". Increasingly complex technical systems induce, so the reasoning here, increasingly complex control systems, a vicious circle results.

### ***Technical Complexity/Non-technical Complexity***

But where, "in the system as a whole", does complexity reside?

*The complexity of present day societies is, among other things, a result of the superimposition of (these) technological systems and their corresponding organizational systems. – ... it will become immediately apparent what complex legitimation requirements this technical system presents and what a broad field of activity it opens up to scientific-technical expertise. – Technology produces a coupling ... not only of consciousness and communication ... ; the growth of technical complexity is perceived as an irritation not only in psychic but also in social systems, and for Luhmann too technology counts among the most important "risk generating factor of modern society" – (T)he global telephone system, with its  $10^{10}$  possible linkages, is almost as complex, in a purely structural view, as the brain which with good reasons we would concede an incomparably larger functional complexity.<sup>7</sup>*

The categorical distinction of technical and social systems, maintained under the strong impression that the two are inextricably interlinked, forces the notion that there are two kinds of complexities, social and technical, to be distinguished but in close functional interdependence. This unhappy analytical situation is aggravated by the fact that technical complexities tend to be interpreted in the light of metaphors of the artificial and explicated in engineering term whereas social complexities more often are framed as organic systems and explained in terms of meaningful social interaction.

### ***A Concern With Conceptual Complexity***

Intermittent reflections on issues of conceptual complexity and requisite theoretic complexity are then not surprising, even in a field where the notion that one can unambiguously distinguish factual and conceptual levels is largely uncontested.

*Some students believe that technology is growing more systemic, connoting increasing interconnectedness, complexity, size, ubiquity, determinacy, autodynamics, and momentum. To clarify such claims, one obviously needs a conceptual device that at least in principle allows us to measure degrees of systemicity. – Only an the abstract birds eye view makes it possible to see more than fragments of the system, to apprehend it as a complex whole. – And yet, concepts like complexity, system, stability have been corrupted into empty word-shells, affecting a precision of conceptualization which may not be achieved for these Systems. – While for technology "per se" system-theoretical concepts such as control ... (or*

## *Complex Technical Systems*

*complexity may be doubtless precisely and meaningfully applicable because here they allow for a quantitative formulation, in sociological usage the ... system-theoretical terminology (à la Luhmann) meets with the utter perplexity of system-theoreticians...<sup>8</sup>*

Where social constructivist approaches to the analysis of LTS are introduced, i.e. where outsider/analyst-epistemology gives way to insider/participant epistemology and the factual/conceptual distinction is blurred, this issue can acquire a peculiar twist: is the complexity of systems a result of the conceptual schemes scientists dream up in order to help creating such systems and what are the ethical implications of this feat?

### ***Paradoxes of Complexification/Simplification***

Meanwhile the lament over conceptual complexities cannot prevent the LTS complexity discourse from slipping badly.

*If today the feeling is prevalent, for instance, that the transition to decentralized energy technologies is a utopia, because this contradicts the modern system trend towards increasing growth and complexity, then this assumption is not necessarily founded on historical fact. New systems frequently gain acceptance because they appear simpler from the user's point of view; the increased technical complexity has been an unwelcome side-effect.<sup>9</sup>*

The inability and/or unwillingness to engage in a thorough self-examination of LTS semantics and of the relationship between outsider/observer language (the LTS researcher) and insider/observed language (LTS system builder, user) results in heroic simplifications, in a remarkable tolerance of ambiguity and unwitting paradox:

*Despite its complexity, traffic could be described as a very smooth system with few problems. Drivers and other road users seem highly skilled and very able to participate in this waltz of vehicles. – I discovered that the most substantial thinkers among the counterculture elite identified large-scale systems as a salient negative aspect of contemporary culture ... Oppressive technological--not political--systems were their major concern ... a counter response to the order and control of large-scale modern systems. counter themes such as messy vitality, and complexity and contradiction.<sup>10</sup>*

There are few attempts to account conceptually for this ambivalence between complexification and simplification.

*One might consider "complexity" as another term to label overall systemicity. If used as a common language notion for units with increasingly differentiated elements and increasingly differentiated internal relations, then rising systemicity*

*Large Technical Systems and the Discourse of Complexity*

*goes hand-in-hand with rising complexity. If complexity is used in the sense of information theory – the number of "bits" required to describe a phenomenon – then rising systemicity typically keeps complexity down. For example, the transition from pre-modern to Newtonian physics was a big leap in the level of systemicity (in the system of physical knowledge) and a giant reduction of complexity in the sense of information theory. Much fewer "bits" are required to describe Newton's world than that of Aristotle. The rise of systemicity – a rise in the degree of organization, one might say – in Western business enterprise over the past 150 years is not in itself a measure of rising complexity but rather a simplifying response to the increasing complexity of business environments. So while some authors think that modern technology is both becoming more complex and more systemic, this is an ambiguous and possibly misleading proposition.<sup>11</sup>*

But the theme is persistent, in LTS narratives, with their ad hocish conceptual schemes, as much as in high church social theory. Listen again to Radkau, who has a running story about the superiority of systemic simplicity over technical complexity uncertainty, risk and dependency on complex expert knowledge *require simplification*:

*Growth in fuel consumption makes timber supply systems so complicated that the transition to coal, despite the technical effort involved, was in some respects a step towards simplicity, when viewed from the point of view of the system. In actual fact, the assumption that progress only proceeds in the direction of increased system complexity is an absurdity. – ... Eventually in the early 19th century, the by now rather complex system of salt refining was organized more simply through the firing of coal and the developing of rock salt as a resource. Once again then we have here a step towards decreased system complexity, albeit involving more complicated technology at times. – Nevertheless, there is a principal reason why, both within mining and outside of it, the steam engine was enjoying growing success as a system, even though water power was in many places cheaper and still had not reached its technical limit: compared with water power ... the steam engine enjoyed the advantage of relative simplicity and site-independence when seen from the point of view of planning and organization. While it might be technically rather large and complicated, as a system it signified a step towards smallness and reduced complexity. ... (T)he noticeable trend towards an advancing mechanization of the systems of production and communication in the course of industrialization was able to appear well suited to making the associated social systems and control tasks less complicated. –The telephone had the great advantage of being able to verbalize long-distance communication, and this advantage of simplicity, reciprocity and the saving of time in communication was to prove universally beneficial in the long run, once conflicting cultural habits had become weaker. – The HTR project proved a disaster because ... it was made too complicated: through being linked to the thorium cycle, the single-circuit helium turbine, the utilization of process heat and the gasification of coal. Greater complexity has always signified dubious progress – hence an often unsatisfied desire for simplicity permeates the history of nuclear technology too.<sup>12</sup>*

### *Complex Technical Systems*

The narrative of simplification as exemplified by Radkau corresponds well with a long-standing functionalist streak in social theory, as represented by German scholars such as Freyer, Gehlen and lately Luhmann. They use the concept of *technisation* in the context of social mechanisms of *Entlastung*, the reduction of tedious complexity and the control of overcomplex causal relationships by isolating them from nature (and bottling them in machineries, as it were). *Entlastung* and *technisation* are then corresponding concepts: both reduce complexity and its attendant uncertainty. It is probably safe to say that these social theorists are evolutionist in orientation; they assume that societal development or differentiation entails social complexification. Technology is then seen one of major means by which social systems keep increasing complexity under control.

### **III. RECONSTRUCTING THE DISCOURSE OF COMPLEXITY IN LTS**

What is to be learned from LTS research on the issue of complexity? Initially, the category of "large technical systems" held out the promise of rendering an interesting conceptual status to the extended, and especially complex, technical foundations, called LTS here, without which modern societies would not be able to develop and maintain their interactions over ever increasing distances of social space and time nor to sustain the breadth and depth of their functional differentiations. But the LTS discourse turns out to be remarkably varied. A common "paradigm" of systems research is currently not emerging.

Should one then regard the high variability of the historical/sociological discourse on LTS, and in particular the ambiguities of the discourse on complexity, as indicating a fundamental difficulty to think of LTS as a particular (and particularly complex) type of social system? Should one see it as indicating that the concepts of social systems (both technical and non-technical) that have informed the hybrid discipline of LTS studies do not provide the means for sufficiently sharp distinctions and enough requisite variety (i.e., *conceptual* complexity) to enable consideration of major systemic and historical aspects? Should one see it as another example that engineering science discourse remains both inapplicable (*undercomplex?*) to LTS-based social systems and incompatible with "old-European" (Luhmann) as well as newfangled (*overcomplex?*) autopoietic social systems theories?

*Large Technical Systems and the Discourse of Complexity*

Answers to such questions may very much depend on the particular vantage point in the disciplinary matrix from which a reading is undertaken. At present, I offer the following points for further discussion.

***Beware of Complex-Speak***

It seems quite important to examine the uses of empty talk about (growing) complexity. It is possible, I think, that an inflationary use of the term distracts from the problem and undermines the integrity of social research. A smart rule could be to use the term as little and as specifically as possible under the circumstances. But there is another side to this coin.

***A Synthetic Concept and Its Uses***

The category of systemic complexity, much like the systems category in the first place, is by its very vagueness, ambiguity and variability a medium of intellectual exchange: it holds the promise that similar questions are asked and can be asked across very different intellectual fields and very different subjects. To show that we lack definitions, consistent and compatible analytical approaches and such does not amount to much, after all. The main thing is to keep talking, and for that one needs a basic common vocabulary; the rest are "productive misunderstandings", if one is lucky. Other vocabularies than the system/ complexity ones are available, but this one is like contemporary English: almost everybody has a bit of it. If we need a pidgin for a "technical age", this might be the one to cultivate.

***Technical and Nontechnical Complexity***

Can one develop an approach to complexity that overcomes the dichotomy of technical versus social systems and complexities respectively? More useful seems the distinction between systemic complexity (akin to technical complexity which can be modeled, simulated, theorized in a strict sense) on the one hand and non-systemic complexity (non-technical, not easily subject to modeling, simulating)? Both are of course to be understood as genuinely social.

## *Complex Technical Systems*

### ***Complicatedness and Complexity - and Where Do They Reside?***

To ask the question whether a system is *complicated* or complex sometimes is understood to mean whether it is "really" complex or "only" so in the eye of the beholder (researcher, user, etc.). But the situation is trickier: how do complexities out there (whether from the outsider's or insider's viewpoint), that is: complexities in practical functioning systems, relate to complexities "up here" (analyst's conceptual apparatus)? And how are the two levels interrelated? But maybe the problem is in this dichotomy. Maybe it is not very useful to boil it down to our models here and the real systems there, at least not in situations where theories are to be brought into the solution of practical problems. Maybe we must in these situations take serious what we all know of course: that there are many different models around and that there are many practical levels to be considered.

### ***"Macros"***

The story of simplification through LTS has a certain plausibility. LTS are too often celebrated as inherently complex, technically, organizationally and in general. But isn't it so that organizations adopt these technical solutions because they are comparatively simple? Isn't the idea to reduce complexity and uncertainty, to put things on a manageable, permanent and secure basis, *to be able to forget them*, for a while at least? LTS as materialized "macros", to borrow a term from computerese. The point seem to be rather, that that adopting *functioning* technical systems often (and certainly on an historical scale) *complicates* things in other, *non-technical* (i.e., non-systemic) domains, where complex systems theory does not offer solutions and turning life into something like a system is the last thing one wants to do.

### ***Three Schools of Thought***

On a high level of abstraction, it seems to me that there are three schools of thought concerning the basic dynamic of complex systems.

(a) Those who see an increasing complexity in social systems, either as a long run historical trend or as a kind of universal evolutionary law. In any case, something irreversible is going on, and societies have to pay for this with various consequences like

*Large Technical Systems and the Discourse of Complexity*

alienation, loss of solidaristic forms of sociability, immediacy of experience and so on. Life will never be simple again.

(b) Those who assume that somehow the amount of complexity in societal systems is constant. This *law of the conservation of complexity* would allow for all kinds of local variations in complexity, but somehow these would be made up for somewhere else, on a different system level. So for example the growing institutional complexity of modern states would correspond to a decreasing complexity at the level of everyday living. Life has always been complex *and* simple.

(c) Those who think in terms of an oscillating movement, either cyclical or random, where complexity increases or decreases for some reason in certain places, or even everywhere – for a time. This then creates problems of over- or under-complexity, but these problems will be overcome. Solutions will be generated and over-complexity, occurring again and again in history, will be answered with the generation of new macros and codes that make things look simple again (for example through LTS). Similarly, under-complexity will induce complexity-enhancing procedures. Life will change its complexities, but after a while nobody will suffer from it.

***A final note***

Personally, I am among those who hold that there is no clear connection between constructions of complexity in the engineering sciences, in social systems theory or in evolutionary biology. The same term covers different ideas and ideologies. In LTS research we find traces of all of them. But a term cannot become common coin in many disciplines without pointing to a great variety of subtle connections. In this sense, the considered use of this notion will help to achieve this rare good in scientific research: communication and cooperation across intellectual cultures.

**REFERENCES**

Andersen, Svein S., 1991, "The External Control of Large Technical Systems: Offshore Oil Production Safety and Health Regulation in Great Britain and Norway", in: T. La-Porte, *Social Responses to Large Technical Systems*, 43-60.

Bertho-Lavenir, Catherine, 1988, "The telephone in France 1879 to 1979: National characteristics and international influences", in: R. Mayntz and Th. P. Hughes, *The Development of Large Technical Systems*, 156-177.

Beckman, Svante, 1994, "On Systemic Technology", in J. Summerton, *Changing Large Technical Systems*, 311-332.

Braun, Ingo, 1989, "Technische Infrastrukturen der Konsumarbeit", in: *Zeitschrift für Umweltpolitik und Umweltrecht*, 12 (4), 353-375.

Braun, Ingo, 1994, "Geflügelte Saurier. Zur intersystemischen Vernetzung großer technischer Systeme", in I. Braun and B. Joerges, *Technik ohne Grenzen*, 445-499.

Caron, François, 1988, "The evolution of the technical system of railroads in France from 1832 to 1937", in: R. Mayntz and Th. P. Hughes, *The Development of Large Technical Systems*, 69-103.

Ekardt, Hanns-Peter, 1994, "Unter-Gestell. Die bautechnischen Fundamente großtechnischer Systeme", in I. Braun and B. Joerges, *Technik ohne Grenzen*, Frankfurt: Suhrkamp, 168-213

Galambos, Louis, 1988, "Looking at the boundaries of technological determinism: A brief history of the U.S. telephone system", in: R. Mayntz and Th. P. Hughes (eds), *The Development of Large Technical Systems*, 135-153.

Gras, Alain, 1994, *Grandeur et Dépendance: Sociologie des macro-systèmes techniques*, avec la participation de Sophie L.Poirot-Delpech, Paris: Presses Universitaires de France.

Grundmann, Reiner, 1994, "Über Schienen, Straßen, Sand und Perlen. Große technische Systeme in der Theorie sozialer Systeme", in I. Braun and B. Joerges, *Technik ohne Grenzen*, Frankfurt: Suhrkamp, 500-543.

Heinze, G. Wolfgang und Kill, Heinrich H., 1988, "The development of the German railroad system", in: R. Mayntz and Th. P. Hughes (eds.), *The Development of Large Technical Systems*, 105-134.

Hughes, Thomas P., 1987, "The Evolution of Large Technological Systems", in: W. Bijker, Th. P. Hughes and T. Pinch (eds.), *The Social Construction of Technological Systems: New Directions in the History and Sociology of Technology*, Cambridge/Mass.: MIT Press, 1-82.

*Large Technical Systems and the Discourse of Complexity*

Hughes, Thomas P., 1991, "An Historical Overview", in T. LaPorte, *Social Responses to Large Technical Systems*, 185-188.

Joerges, Bernward, 1996, "Große technische Systeme', oder was ist groß und was ist klein", in Bernward Joerges, *Körper .Technik der Gesellschaft*, Frankfurt: Suhrkamp, 1996, 131-159.

Joerges, Bernward, 1994, "Reden übere grosse Technik", in Hans-Ulrich Derlien, Uta Gerhardt, Fritz Scharpf (eds.), *Systemrationalitaet und Partialinteresse, Festschrift für Renate Mayntz*, Baden-Baden: Nomos, 453-490.

Kornwachs, Klaus, 1994, "Steuerung und Wachstum. Ein systemtheoretischer Blick auf Große Technische Systeme", in I. Braun and B. Joerges, *Technik ohne Grenzen, Entwicklung*. Frankfurt/New York: Campus, 411-433.

Kubicek, Herbert, 1994, "Steuerung in die Nichtsteuerbarkeit", in I. Braun and B. Joerges, *Technik ohne Grenzen, Entwicklung*. Frankfurt/New York: Campus, 107-167.

LaPorte, Todd (ed.), 1991, *Social Responses Large Technical Systems*, Dordrecht etc.: Kluwer.

LaPorte, Todd, 1988, "The United States Air Traffic System: Increasing reliability in the midst of rapid growth", in: R. Mayntz and Th. P. Hughes, *The Development of Large Technical Systems*,, 215-244.

Lévy-Leboyer, Maurice, 1988, "The French Electrical Power System: An Inter-country Comparison", in: R. Mayntz and T.P. Hughes, *The Development of Large Technical Systems*, 245-262.

Mayntz, Renate and Hughes, Thomas P (ed), 1988, *The Development of Large Technical Systems*. Campus Verlag, Frankfurt am Main & Westview Press, Boulder, Colorado

Mayntz, Renate, 1988, "Zur Entwicklung technischer Infrastruktursysteme", in: R. Mayntz, B. Rosewitz, U. Schimank und R. Stichweh (Ed.), *Differenzierung und Verselbständigung: Zur Entwicklung gesellschaftlicher Teilsysteme*. Frankfurt/New York: Campus, 233-259.

Mayntz, Renate, 1991, "A View from the Social Sciences", in: T. LaPorte, *Social Responses to Large Technical Systems*, 181-184.

Mayntz, Renate, 1993, "Große Technische Systeme und ihre gesellschaftstheoretische Bedeutung", in: *Kölner Zeitschrift für Soziologie und Sozialpsychologie* , 45 (1), 97-108. Mayntz, Renate and Hughes, Thomas P. (eds.), 1988, *The Development of Large Technical Systems*, Frankfurt/ New York: Campus/Westview.

Mayntz, Renate und Volker Schneider, 1988, "The Dynamics of System Development in a Comparative Perspective: Interactive Videotext in Germany, France and Britain",

*Complex Technical Systems*

in: R. Mayntz and Th. P. Hughes, *The Development of Large Technical Systems*, 263-298.

Meier, Alexandra von, 1994, "Integrating Supply Technologies into Utility Power Systems: Possibilities for Reconfiguration", In J. Summerton, *Changing Large Technical Systems*, 211-230.

Oster, Clinton V. jr., 1991, "The Aviation Safety Commission: A Task Force Approach to the Evaluation of Large Technical Systems", in: T. LaPorte, *Social Responses to Large Technical Systems*, 127-142.

Perrow, Charles, 1986, *Complex Organizations: A Critical Essay*, second edition, New York: Basic Books.

Pinch, Trevor, 1991, "How Do We Treat Technical Uncertainty in System Failure? The Case of the Space Shuttle *Challenger*", in: T. LaPorte, *Social Responses to Large Technical Systems*, 143-158.

Radkau, Joachim, 1994, "Zum ewigen Wachstum verdammt?", in I. Braun and B. Joerges, *Technik ohne Grenzen*, 50-106.

Rochlin, Gene, 1991, "Iran Air Flight 655 and the USS *Vincennes*: Complex, Large-scale Military Systems and the Failure of Control", in: T. LaPorte, *Social Responses to Large Technical Systems*, 99-126.

Rochlin, Gene J., 1994, "Broken Plowshare: System Failure and the Nuclear Power Industry", in Jane Summerton, *Changing Large Technical Systems*, 231-261.

Salsbury, Stephen, 1988, "The emergence of an early large-scale technical system: The American railroad network", in: R. Mayntz and Th. P. Hughes, *The Development of Large Technical Systems*, 37-68.

Salsbury, Stephen, 1991, "Facing the Collapse of the Washington Power Supply System", in: T. LaPorte, *Social Responses to Large Technical Systems*, 61-98.

Salsbury, Steven, 1994, "The Australian Electric Power Industry and the politics of Radical Reconfiguration", in J. Summerton, *Changing Large Technical Systems*, 141-162).

Schneider, Volker, 1991, "The Governance of Large Technical Systems: The Case of Telecommunications", in: T. LaPorte, *Social Responses to Large Technical Systems*, 19-42.

Schneider, Volker, 1994, "Multinationals in Transition: Global Technical Integration and the Role of Corporate Telecommunication Networks", in J. Summerton, *Changing Large Technical Systems*, 71-92.

*Large Technical Systems and the Discourse of Complexity*

Severin, Ingrid, 1994, "Technische Vernetzungen und ihre Auswirkungen auf zeitgenössische Kunst, Teil I und Teil II", in I. Braun and B. Joerges, *Technik ohne Grenzen*, Frankfurt: Suhrkamp, 215-253, 386-408.

Summerton, Jane, 1994a, "Introductory Essay: The Systems Approach to Technical Change", in J. Summerton, *Changing Large Technical Systems*, 1-24.

Summerton, Jane (ed.), 1994b, *Changing Large Technical Systems*, Boulder/Oxford: Westview.

Thomas, Frank, 1988, "The politics of growth: The German Telephone system", in: R. Mayntz and Th. P. Hughes (eds.), *The Development of Large Technical Systems*, 179-213.

Weingart, Peter, 1989, "'Großtechnische Systeme'- Ein Paradigma der Verknüpfung von Technikentwicklung und sozialem Wandel?" In: P. Weingart (Ed.), *Technik als sozialer Prozeß*, Frankfurt: Suhrkamp, 174-196.

Weingart, Peter, 1991, "Large Technical Systems, Real-life Experiments, and the Legitimation Trap of Technology Assessment: The Contribution of Science and Technology to Constituting Risk Perception", in: T. LaPorte, *Social Responses to Large Technical Systems*, 5-18.

---

For a more extended discussion and introduction into Thomas Hughes' seminal work see Joerges 1988.

<sup>1</sup> For a more extended discussion of LTS discourse in the history and sociology of large technical systems see Joerges 1994.

<sup>2</sup> In the intertexts, all citations can be identified on the basis of the endnotes. Reference is made only to texts concerned with empirical studies; for meta-texts aiming at higher level abstractions and generalizations on the basis of empirical LTS research done elsewhere see especially Mayntz (1988, 1993), Joerges (1996), Braun (1994), Grundmann (1994), Joerges/Braun (1994), Summerton (1994a). Studies like Alain Gras' "Grandeur et Dépendance" (1994) must also be mentioned here.

<sup>3</sup> Note that in all four volumes considered here, with their app.. 40 chapters, the only text where the term complexity is not used conceptually is Robichon (1994). On the other end of the spectrum are the two texts by Severin (1994), on LTS representations in modern art, which share only the concept of complexity with the other texts.

<sup>4</sup> Pinch, 1991: 180; Oster, 1991: 127; Pinch, 1991: 143.

<sup>5</sup> Still more so at the second international LTS conference, which resulted in the LaPorte volume (1991); it is thus all the more surprising that the concept of complexity is used perceptibly more frequently and freely than at the first conference (Mayntz/Hughes, 1988).

<sup>6</sup> Beckman 1994: 1; Rochlin, 1991: 103; Oster, 1991: 127; Pinch, 1991: 143; Weingart, 1991: 13; Rochlin, 1991: 103; Weingart, 1987: 175; Schneider, 1994: 73/75; Abbate, 1994: 9; Weingart, 1991: 14.

<sup>7</sup> Ekardt 1994: 5; Braun, 1994: 19; Grundmann 1994: 12; Kornwachs 1994: 9.

<sup>8</sup> Beckman 1994: 3; Severin, 1994: 5; Kornwachs 1994: 6; Kornwachs 1994: 3.

<sup>9</sup> Radkau 1994: 38.

<sup>10</sup> Juhlin 1994: 1; Hughes, 1987: 187.

<sup>11</sup> Beckman 1994: 6.

<sup>12</sup> Radkau 1994: 4; 11; 12; 14; 30; 36.