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Key ideas from a 25-year collaboration at technological forecasting & social change

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ABSTRACT

Since their first meeting in 1991, the authors have enjoyed a friendly dialog centered around topics of interest to the journal *Technological Forecasting & Social Change*. Now, five years after Phillips succeeded Linstone as Editor-in-Chief of the journal, we recap the driving ideas that have characterized the partnership.
The ideas span areas of systems, complexity, and scientific progress; the nature and measurement of innovation, social change, and technological change; the limits to growth; and multiple perspectives, as these pertain to technology forecasting and assessment. Collectively, the ideas and discussions have shaped our editorial philosophy and have appeared piecemeal in TFSC research papers, perspective pieces, and editorials. We now restate these key ideas in hopes of maximum clarity for researchers, managers, and policy makers.
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For want of a nail, the shoe was lost;
For want of the shoe, the horse was lost;
For want of the horse, the rider was lost;
For want of the rider, the battle was lost;
For want of the battle, the kingdom was lost;
And all for the want of a horseshoe nail.

1. Overview: the systems framework

Since their first meeting in 1991, the authors have enjoyed a long and friendly collaboration centered around the topics of interest to the journal *Technological Forecasting & Social Change*.[1] Now, five years after Phillips succeeded Linstone as Editor-in-Chief of the journal, we look back to recap the driving ideas that have characterized the partnership. This paper remarks on those (i) ideas that emerged from items the two of us discussed, (ii) ideas on which one of us responded to the other's invitation for comments or collaboration, and (iii) ideas of Fred's that Hal, as mentor, expressly endorsed.

Topics and ideas arose alternately from papers others had sent to *TFSC*, from *TFSC* special issues in progress, from current events (including natural disasters, and "unnatural disasters" such as the banking crash or current world politics), from our own prior work, or from striking trends in research elsewhere (e.g., the founding of the Santa Fé Institute). Each idea fit into our common orientation toward system thinking and into Hal's multiple-perspective schema as he had updated it in Linstone (2003). These ideas represent our struggles to find viable ways to deal with the future of technology and society, as we drew on many disciplines, from engineering to sociology and from history to accounting, economics, and political science.

The ideas are set down here in an order, not chronological, that allows clearest flow of exposition. They have to do with: the nature of innovation, and how it manifests in sudden shifts in trend lines; extensions to Hal's "discounting" idea, and to his Multiple Perspectives framework; disaster response and recovery; regionalism and Popperian experiments; "bounded futures"; "big data" and the nature of scientific progress; the duality of forecasting and organizational flexibility; The increasingly combinatorial nature of the innovation–commercialization chain; whether social change or technological change is now faster, and how they continually interact; and, finally, about artificial intelligence and the so-called singularity.

1.1. System theory

We happened to have been influenced by some of the same thinkers and their works: Eigen and Winkler (1983) impressed us with its clarity and profundity; Charles Perrow (1985, 1986), whose work on system

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[1] Linstone became Founding Editor of *Technological Forecasting* (later re-named *Technological Forecasting & Social Change*) in 1969. Phillips' first paper in the journal appeared in 1996, and Linstone invited him to the Board shortly after. Early in the next decade, Phillips was appointed Associate Editor, and (in 2006) Senior Editor. In 2011, Linstone became EIC Emeritus, and Phillips the new Editor-in-Chief.

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Table 1
Techniques suited to different complexity regimes. Scenario methods occupy the top right quadrant.

Organizational Complexity			
	High	Leadership	Dialog/qualitative methods
	Low	Just do it	Statistics & Math
		Low	High
		Technical complexity	

Table 2
Evolution of multiple perspectives for analysis — from TOP to PORTI. (Source: Phillips, 2011b).

Original	Current
T = Technical	P = Personal
O = Organizational	O = (intra-)organizational
P = Personal	R = Religious
	T = Technical
	I = Inter-organizational

failures in organizations was pathbreaking; and Karl Popper (1957), whose "multiple engineering experiments" notion affected our views on decentralization and regionalism.

We were acquainted with Herb Simon, whose ideas influenced the direction of our common interest in system theory. That interest had grown due to the efforts of our respective teachers at university, our involvement (in separate eras) with the International Society for Systems Science ISSS, Hal's experience at RAND and Fred's at the General Motors Research Laboratories (Phillips, 1972; see also Phillips, 2013), plus our later experience with people and ideas at the Santa Fé Institute, and the systems-oriented inclinations of the distinguished Advisory Board of *TFSC*.

A systems thinker is disinclined to consider individual trends in isolation. One wants to foresee interactions among trends, as it is these interactions that shape society. However, the toolkit of technology forecasting includes only two techniques that attempt the latter: cross-impact analysis, and scenario methods (Phillips, 2011a, 2014a). Scenario methods are becoming more scientific (see e.g., Kwakkel et al., 2014), but the analysis of interactions of trends remains mostly art, the domain of futurist practitioners. Nonetheless, as problems of a globalized economy and changing climate become more complex, scenario building becomes our most valuable planning tool,[2] even as (because scenarios are, after all, fiction) it is the one arguably most open to criticism. Variants of Table 1 have appeared in many publications; the Table illustrates the point above.

1.2. Complexity

There is much literature on "managing complexity." The present authors agree that we do not want to manage complexity. The theory of chaotic bifurcations suggests that managing complexity is somewhere between very difficult and impossible. Linstone cites Casti's (2012) many examples of unanticipated catastrophes that occur when our systems become overly complex and increasingly vulnerable.

As Hal suggested in Linstone (2003), the management task falls mainly to preventing harmful disruptions of a system that has become unavoidably complex. He cites the ease of committing terrorist acts that disrupt an interconnected society. Wisdom is called for in distinguishing these harmful disruptions from the beneficial disruptions (e.g., Christensen's disruptive technologies) that ultimately move us forward.

It is sometimes possible, however, to forestall complexity. By smart organizational design, by centralizing or decentralizing, or via regulation of industry, we may prevent problems from attaining the dangerous category of complexity that Perrow called "Type D," involving "intricate interactions and tight coupling" (Linstone and Phillips, 2013).[3]

The political process aiming at nuclear non-proliferation illustrates an effort to simplify an overly complex system (Linstone, 2014). "We must not drift unaware toward Type D situations, but rather see the advance signals of tight coupling and intricate interactions, and take counter-measures — and do so without falling prey to false simplifications" that stem from pathological denial or avoidance of complexity (Linstone and Phillips, 2013).

Eigen and Winkler's (1983) work made it clear that system theory had progressed beyond the old definition of a system as a fixed set of entities (nodes) and connections (arcs). We now know that the system is the set of generative rules that govern the birth and death of nodes and the evolution of their interactions.[4] From the journal's perspective, this insight clarified the link between cellular automata and innovation diffusion models, especially spatial diffusion models,[5] and tied system theory more closely to ideas of technological evolution. The latter consideration led to a special issue of TFSC on evolutionary technology strategy (Phillips and Su, 2009) and a later paper (Hu and Phillips, 2011) on technological evolution in biofuels.

A paper of Gordon and Greenspan (1986) was the first in *Technological Forecasting* & *Social Change* dealing with the "new science of complexity." It sparked Linstone's interest in the link between complex systems and technology forecasting. Phillips and Kim (1996) authored the journal's second such article.[6] It was followed by a special issue on navigating complexity in organizations (Phillips and Drake, 2000).

In that same year, Gladwell (2000) popularized the phrase "tipping point" as it applies to social change. Curious about how tipping points could exist in innovation diffusion processes, given that Modis (2006) had pointed out that the single-parameter logistic function commonly used to model diffusion is scale-free (i.e., evinces nothing that can be called a tipping point), Phillips (2007) applied a systems view to a 3-parameter diffusion process which considers active organizational resistance to change. With 2 + parameters, s-curves evince "intricate structure" (Modis' term) yielding possibly multiple tipping points of diverse kinds. The greater data requirement for fitting multi-parameter curves presents a trade-off, in practice. Yet the tipping points are useful flags for managers.

1.3. Limits to growth?

In 1972 The Club of Rome had just published *The Limits to Growth* (Meadows, 1972), and the head of General Motors Research Laboratories' math department nervously asked Phillips to replicate the model. (What was then the US' biggest company couldn't afford to believe there were limits to growth!) The project was traditional system dynamics, to the extent that the era's computers could crunch it. It is worth mentioning here only because of the subsequent forty years of debate between the "limits to growth" advocates and the "no limits"

[2] Even the Saudis are conducting an "end of oil" foresight exercise. (Nick Cunningham, Saudi Arabia Planning For Transition To Renewables. 22 May 2015, http://oilprice.com/Alternative-Energy/Renewable-Energy/Saudi-Arabia-Planning-For Transition-To-Renewables.html)

[3] The Google search http://tinyurl.com/obyv626 yields book titles such as *Managing Organizational Complexity*; *Embracing Complexity*; and *Harnessing Complexity*, but none on "preventing complexity." The lurid title *Organizational Complexity*: *The Hidden Killer* hints that complexity is best avoided.

[4] Phillips (1997) presented Eigen's idea to managers and planners at the World Future Society, to their evident interest. Both present authors emphasized it again on a panel at a later PICMET conference in Portland, when it appeared that the idea was not widely grasped. The idea implies that theory plays an important role in the analysis of large data sets (Phillips 1985–6). Curiously, the work of Van Duijn et al. (2003) is one of the few we've seen that observes this rule. As the age of big data gains momentum, most published analyses are statistically empirical or merely ad hoc.

[5] The future unfolds over both time and space. Our s-curves over-emphasize the time dimension and under-emphasize spatial diffusion. (In fact we suspect our epidemiologist colleagues are more sophisticated in diffusion modeling than technology management scholars are.) The future is already happening somewhere. Travel, and look for it.

[6] Phillips is grateful for Linstone's decision to publish it, and for Gordon's concurrence.

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