engineering and nanotechnology both produce ongoing technical agency below the thresholds of human perception and control, it seems unavoidable that both should awaken the same kind of apprehension or fear. And to the extent that this fear serves to set normative standards for the evaluation of specific technologies and for the design of more appropriate ones, it must not be dismissed as irrational.

Günther Anders enjoins us that we learn to imagine what we do since we can only assume responsibility where we can conceive our actions and their effects. Technology naturalized is regressive in that it returns us to a state of ignorance towards our technical interventions that confront, perhaps dwarf us like uncomprehended nature. Anders thus calls upon engineers to reflect the purpose of technology and to counteract its regression.

For example, if one were to engineer a device that can move about, affect things, let alone replicate at the nanoscale, one would also have to learn how to track and monitor, to perceive and control it. For technology naturalized we will need to discover technologies of containment that tie it back in with the scale of human action. Such technologies of containment encompass the design of interfaces, the political determination of design specifications, even conceptual or literary techniques of coming to terms and socializing naturalized technology.[9]

6 Surprise vs. Control

So far, nanotechnology as noumenal or naturalized technology has only been discussed in terms of the incredible tininess of nano, in terms of its absolute smallness just as soon as we try to imagine its size. There is quite another way, however, to critique nanotechnology in its aspect of naturalness. "Bottom up" nanotechnology is said to harness the powers of self-organization. Self organization, of course, is that natural process by which systems spontaneously achieve higher states of order, for example, when polluted ecosystems finally reach their tipping points and suddenly go dead. Jean-Pierre Dupuy puts the point as follows:

> We know today that what makes a complex system, (e.g. a network of molecules connected by chemical reactions or a trophic system) robust is exactly what makes it exceedingly vulnerable if and when certain circumstances are met. […] Beyond certain *tipping points*, they veer over abruptly into something different, in the fashion of phase changes of matter, collapsing completely or else forming other types of systems that can have properties highly undesirable for people. In mathematics, such discontinuities are called *catastrophes*. This sudden loss of resilience gives complex systems a particularity which no engineer could transpose into an artificial system without being immediately fired from his job: the alarm signals go off only when it is too late. (Dupuy, 2004)

Dupuy's point was echoed by the Swiss Reinsurance Company when it remarked about nanotechnology that you cannot very well build on surprising new properties

[9] For a somewhat more detailed account of this notion of "containment" (as in giving shape, purpose, direction, technical as well as societal context) see Nordmann (2005b).

if you want a technology that can be counted on and that therefore offers no surprises (Hett, 2004, 40–44).

One can object against Dupuy, of course, that any successful technical system will have to withstand tests of robustness and resilience, that Dupuy is only pointing out the ultimate untenability of technology naturalized. Yes, he is and so am I, remarking with a bit of incredulity that the most advanced technical visions in computing, genetics, and nanotechnology go to a limit where technology becomes magic and returns us to our place of departure, namely to an enchanted, uncanny state of nature that we already found untenable when we first thought of controlling, calculating, even mastering it. All the more reason, therefore to carefully contain – technically and philosophically – the implementation of these technical visions.

References

Amato, I., 1999, *Nanotechnology – Shaping the World Atom by Atom*, National Science and Technology Council, Interagency Working Group on Nanoscience, Engineering and Technology, Washington.

Anders, G., 1972, *Endzeit und Zeitende: Gedanken über die atomare Situation*, München: Beck.

Bensaude-Vincent, B., and Guchet, X., 2005, What is in a word? Nanomachines and their philosophical implications, Centre d'histoire et de philosophie des sciences, Université Paris (unpublished manuscript).

Clement, A., 1978, If "small is beautiful," is micro marvellous? A look at micro-computing as if people mattered, *ACM SIGPC Notes* **1**(3):14–22.

Dupuy, J.-P., 2004, Complexity and uncertainty, in: *Foresighting the New Technology Expert Group: State of the Art Reviews and Related Papers*, Brussels, pp. 153–167, http://europa.eu.int/comm/research/conferences/2004/ntw/pdf/soa_en.pdf (January 25, 2006).

Hett, A., 2004, *Nanotechnology - Small Matter, Many Unknowns*, Swiss Reinsurance Company, Zurich.

Hooke, R., 1665, *Micrographia, or, Some Physiological Descriptions of Minute Bodies Made by Magnifying Glasses: With Observations and Inquiries Thereupon*, Martyn and Allestry, London.

Jones, R., 2004, *Soft Machines*, Oxford University Press, Oxford.

Joy, B., 2000, Why the future doesn't need us, *Wired* (April 2000).

Nordmann, A., 2004, Nanotechnology's worldview: new space for old cosmologies, *IEEE Technol. Soc. Mag*. **23**(4):48–54.

Nordmann, A., 2005a, *Noumenal* technology: reflections on the incredible tininess of nano, *Techné* **8**(3):3–23.

Nordmann, A., 2005b, Nanotechnology: convergence and integration – containing nanotechnology, in: *9th Japanese-German Symposium: Frontiers of Nanoscience*, Deutsche Gesellschaft der JSPS-Stipendiaten, Bonn, pp. 105–119.

Nordmann, A., 2005c, Wohin die Reise geht: Zeit und Raum der Nanotechnologie, in: *Unbestim mtheitssignaturen der Technik*, Gerhard Gamm and Andreas Hetzel, eds., transcript, Bielefeld, pp. 103–123.

Rossmann, T., and Tropea, C., eds., 2004, *Bionik: Aktuelle Forschungsergebnisse in Natur-, Ingenieur- und Geisteswissenschaften*, Springer, Berlin.

von Gleich, A., 2006, Potenziale und Anwendungsperspektiven der Bionik: Die Nähe zur Natur als Chance und als Risiko, draft study.

Weber, M., 1988, *Gesammelte Aufsätze zur Wissenschaftslehre*, J.C.B. Mohr, Tübingen.