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Post-Normal Science and the complexity of transitions towards sustainability☆

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ABSTRACT

The theory of Post-Normal Science is now approaching obsolescence; it needs to be renewed and enriched. In historical perspective, PNS evolved from a criticism of Probabilistic Risk Analysis, and put the essentially political idea of Extended Peer Community at its core. Establishing the legitimacy of the EPC requires a review of the methodology of science in the policy process. The time is not ripe for a modification of PNS, and so the best move forward is to raise the issue of Sustainability. For that I sketch a theory of complex systems, with special attention to pathologies and failures. That provides the foundation for a use of 'contradiction' as a problem incapable of resolution in its own terms, and also of 'characteristic contradiction' that drives a system to a crisis. With those materials it is possible to state the characteristic contradiction of our modern industrial civilisation, and provide a diagram with heuristic power.

1. Introduction

The roots of our problem can be traced to a philosopher who wrote these lines while a resident in the city of Utrecht:

> "...it is possible to reach a kind of knowledge which will be of the utmost use to men, and that in place of that speculative philosophy which is taught in the Schools, we can achieve a practical one by means of which, by ascertaining the forces and action of fire, water, the air, the heavenly bodies, and the skies, of all the physical things that surround us, as distinctly as we know the various trades of our artisans, we can apply them in the same way to all the uses for which they are fit, and thereby make ourselves the lords and possessors of nature (Descartes, 1638)".

Descartes' dream was to realise the power of the magicians and alchemists, but to exercise it over a disenchanted nature that is tame and safe. In this vision there is no longer need for awe of the world and its supposed Maker, nor a need for awareness of our ignorance. Such hubris was certain to bring about its nemesis. Our awareness of this historic drama of our civilisation started with the Bomb, and it now continues to grow through the environmental crises of this century.

With that perspective, we must ask, to what degree is our inherited science part of the problem, and how must it be modified if it is to become part of the solution, understood here as the transitions to sustainability.

In this essay I will deal with a natural sequence of themes. The first is Post-Normal Science (Funtowicz and Ravetz, 1992, 1993, 1994a; Ravetz, 1999a, 1999b, 2001, 2005). I will review recent developments in the theory, which serve to improve its scope and effectiveness. But I must recognise that the theory is approaching obsolescence, and I face the problem of how to manage a transition to a new basic insight. This will be based on my qualitative version of complex systems theory, which (exceptionally for that field) focuses on imperfection and

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failure. Within systems theory we can understand a special version of the concept of 'contradiction'. I extend that to speak of the 'characteristic contradiction' of a system. With those conceptual tools, I can analyse the problematique we face, with the twofold contradiction of affluence (expropriation of the poor and of the environment), now challenged by the desire of the poor to have 'development' and thereby make their own contribution to the ecological crisis. I produce a diagram which describes this compounded characteristic contradiction; and in conclusion I have a diagram describing the parallel technical fixes, among the rich and the poor. Finally, I ask whether there are other approaches, following the spirit of Gandhi, that might be effective.

2. New understandings of Post-Normal Science

In the quarter-century since PNS was first conceived by Silvio Funtowicz and myself, the politics of uncertainty has been transformed. Since PNS has always had strong political aspects, we should consider whether and in what ways its content should now also be modified.

The principal policy context of the original insight of PNS was probabilistic risk assessment. This scientific field, created mainly in the service of civil nuclear power, attempted to apply standard mathematical methods to problems where the uncertainties were actually overwhelming. The 'probabilistic risk assessments' enjoyed an initial plausibility because they were presented as Science, that is objective and certain, free from bias and doubt. The policy agenda was clear: a risk of one-in-a-million is acceptable, hence an installation with such a risk is scientifically proved to be safe. In many of the national debates, those who criticised those exercises were branded as subversives or sectarians, motivated by political or even psychological agendas in their opposition to the authoritative judgements of the established scientific communities. Only with the Three Mile Island disaster, when a reactor with a one-in-a-million chance of a serious accident exploded within a few months of start-up, did the façade of scientific complacency and arrogance begin to crack. The risk analysts had to admit a category of 'zero-infinity' risks, strictly speaking with negligible probability but unacceptable harm. The product is indeterminate, and so quantitative risk analysis found its limits.

The task for the philosophical critic then was to show that not all problems with a scientific appearance are capable of solution in orthodox scientific terms. The way had already been opened by Alvin Weinberg, with his concept of 'trans-science' (Weinberg, 1972). For him the distinction was one of degree rather than kind; and he was pleased when a crucial trans-scientific problem could, through advances in technique, be tamed. We had to show that the difference is of kind; that there exist some problems which are in principle not reducible to 'puzzle-solving' normal science in Kuhn's term (Kuhn, 1962). Further, we wanted to use this philosophical argument to justify the extension of participation in scientific debate beyond the closed circle of accredited expertise. For this we had a few examples in mind, all relating to risks. One was of Dan Ford of the Union of Concerned Scientists, a lawyer who mastered enough of the relevant nuclear physics to demolish an industry spokesman before a Congressional committee. Even more significant was that of Sheldon Krimsky, who showed that ordinary citizens of Cambridge, Massachusetts were quite as competent as anyone else in assessing the safety standards of a proposed lab for recombinant DNA research at Harvard. And there was Phil Brown, whose story of Woburn, Massachusetts showed how entrenched experts could react when citizens tried to do something about their own health and safety issues (Brown, 1990). Between them, they provided the initial empirical foundation for the what we called the 'extended peer community'.

Our solution to the philosophical problem is by now well-known; we achieved the necessary distinction by means of a standard gambit, that of demonstrating an undeniable intermediate case. For us it was 'professional consultancy' (a label that took some time to achieve). Here we have a very distinct occupational role, actually one that typically has more prestige and remuneration than mere research. It uses science; but its problems, and hence its solutions and its methods, are radically different. The key difference is that both 'systems uncertainties' and 'decision stakes' are significantly higher. The professional must cope with greater challenges of uncertainty, and more is dependent on his success or failure; hence s/he justifiably gets greater rewards than the researcher. In the UK, professionals are organised in 'Institutions', while scientific specialties only have 'Institutes'. With that intermediate case firmly established, we could argue that Post-Normal Science is qualitatively different practice from 'normal' or 'applied' science (Fig. 1).

Now, 25 years on, 'uncertainty' has become respectable. We even find 'unknown unknowns' in popular discourse, with the most surprising pedigree. An awareness of the new state of science, stressing mission-orientated problem-solving, has been articulated under the name of 'mode 2' (Gibbons et al., 1994). On the PNS scheme, this would approximate to our 'professional consultancy', but as enlisted on industrial projects rather than serving individual clients as in the past. That study was (I believe) intended to protect the research

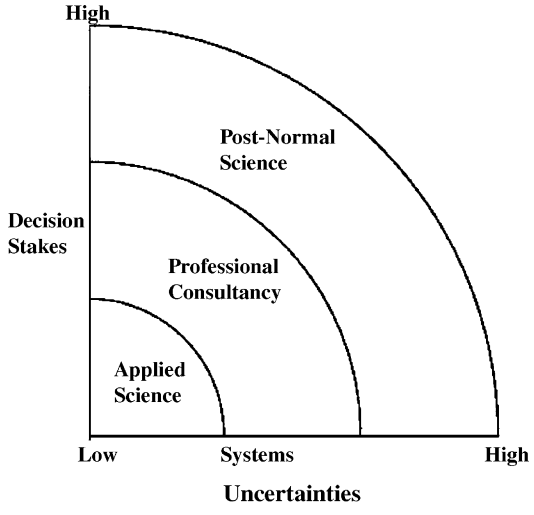

Fig. 1 – The Post-Normal Science diagram.

community, to the extent that that is possible, under the new social relations of the production of knowledge, which I elsewhere describe as 'mega-science' (Ravetz, 2006a). But 'Mode 2' differs profoundly from PNS in that in it, there is no discussion of quality, no hint of a social critique, and no mention of an extended peer community.

Given its deep political commitments, PNS should have been making a contribution to this process, offering its insights about the way science will need to be done in the cause of justice and sustainability. But for a long time, there was no perceptible 'movement' to which to relate; and even now there is no clear focus on science among the new movements for social reform. Those of us who are involved in PNS can help to shape a new 'science of, by and for the people' when the time is ripe. This new social practice is still embryonic, but eventually the autonomous movements for social reform will start to focus on scientific issues, and the Internet and Wiki will provide the technology of democratised knowledge.

3. How the extended peer community makes its contribution

In these new circumstances, what we have called the extended peer community will have a great contribution to make. As PNS has matured, we have gained a better understanding of what is involved in this concept. It is appropriate, therefore, to go through the arguments about the EPC, so as to give this new form of practice better self-understanding and hence greater strength. The work needs to be done carefully, for it may not yet be completely clear, how the extended peer community might make a real scientific contribution. After all, science is a highly technical enterprise, and laypersons remain just that in spite of all their familiarity with a particular issue. This issue has been on my mind ever since I wrote about 'critical science' in *Scientific Knowledge...* (Ravetz, 1971).

In retrospect, I believe that I had been misled by my own scientific experience, that of research in pure mathematics. This subject is truly arcane; in less popular fields, there might be fewer than a dozen people who are fully competent to assess the quality of each others' work. And for that, the most abstruse considerations might be critical in the assessment of quality. As I had learned to my cost when a PhD student, quite subtle gaps in a mathematical argument might vitiate a whole proof! There is no possibility that an untrained person would have anything to contribute to such a process of research and assessment.

In my recent reflections, I recalled one of the first significant examples of Post-Normal Science, that group of citizens convened by Sheldon Krimsky to evaluate the hazards of a proposed facility for conducting experiments on recombinant DNA at Harvard University in Cambridge, Massachusetts. By common agreement, they did a very good job. It was soon realised that what they needed was a modicum of technical knowledge, and a good dose of common sense. There was an issue that the building intended for the research had an infestation of ants, that could not be eliminated without shutting down and cleaning out all the labs. One did not need to be an entomologist to appreciate that such ants represented a biohazard. And like any jury, they could observe 'the demeanour of witnesses': who seemed to be telling a straight story, and who was probably prevaricating.

I eventually came to appreciate fully, that when science is involved in the policy process, it is usually not the deep theoretical obscurities that are at stake, but its relation to a real-world situation. Indeed, when we consider the life-cycle of a PNS problem, its distinctiveness becomes apparent. For in ordinary research or R&D, the initial problem is a positive one, and conducted within some establishment. There is a possibility of a new discovery or a new invention (roughly speaking), and resources are devoted to the exploration. With PNS, the initial problem is negative: there is a suspicion (usually among some non-established person) that something is wrong somewhere. Usually, the established institutions do not want to know about it, and may not want anyone else to know about it either. So the real world is built into the PNS cycle at the outset, with all its variability, uncertainty, complexity and influences of politics, power and privilege. The focus will be on those phenomena and issues that are easily comprehended, and indeed which might even be less visible to those experts who have been ensconced in some protective institution. That is why an extended peer community is at the heart of PNS, and not some afterthought provided by the benevolence of the authorities.

The history of medicine is replete with famous examples of the suppression, doubtless with the most sincere of motives, of innovations that challenge the ruling paradigm and its entrenched interests. The case of Ignaz Semmelweis and puerperal fever is the classic; we also have Dr. Joseph Goldberger and his struggle against the most bitter opposition to show that pellagra (then endemic in the U.S. Southern States) is not a microbial infection but a syndrome of dietary deficiency. Within living memory there was Sister Elizabeth Kenny, who treated acute polio as a temporary spasm to be managed, and who was traduced by the medical establishments of Australia and the U.S.A. until the triumph of the vaccines rendered her endeavour (temporarily) redundant. For more examples in the Health, Safety and Environment fields, there is the pathbreaking study published by the European Environment Agency, Late lessons from early warnings: the precautionary principle 1896–2000 (Harremoës and Gee, 2001). It would appear that the history of such episodes can best be understood in terms of PNS. We frequently find situations where the uncertainties (or complexities) are low (when the critics are finally being heard) but the value commitments are high (in the loss of prestige, power or profit), and so the issue is beyond expertise or consultancy, but definitely post-normal.

We can enhance our appreciation of the role of the extended peer community by articulating the different sorts of questions that are salient in the different types of inquiry. For physical science it is 'what/how?', for design studies (biology and technology) it is 'how/why?', and for PNS it is 'what-about/what-if?' (Ravetz, 1997). Of course it is not all a matter of 'organised common sense'. For a significant example, the use of statistics in court cases, as with DNA profiles, regularly involves the 'the prosecutor's fallacy', which surpasses the understanding of juries and jurists alike. But in general, the real world has so much variability and uncertainty, that it will be the more coarse, rough-and-ready aspects of the scientific evidence that are relevant.

Mayumi and Giampietro (2006) have provided the philosophical basis of the necessity for the extended peer community, as they argue that there will always be 'non-equivalent descriptive domains and non-reducible models', indeterminacy, multiple causation, and an open and expanding information space. These factors can explain the numerous 'failures' that the experts failed to predict. They conclude that the task of science for sustainability should be mutual learning rather than making blueprints. Their analysis shows that we are all an 'extended peer community', not least the researchers and experts themselves. Their argument firmly establishes the principle of the relevant scientific competence of the members of the extended peer community; for its operations we must consider another issue.

The issue of quality assurance in PNS needs to be properly addressed. It is now a commonplace that the maintenance of quality in science is quite a contingent phenomenon. In most areas outside of what I call Max-Weber-land, science languishes and is corrupted by all sorts of external pressures. Its survival even in its heartland depends on quite subtle and probably uncontrollable shifts in sensibility and morality among its publics and recruits. In *Scientific Knowledge...* I had argued that the maintenance of quality in research science requires an enlightened ethical commitment among the leaders of the community. What could be an effective replacement for this, in the agonistic conditions of PNS? (Markowski, 1975, *personal communication*).

To solve this problem, we must make one crucial methodological point. This is, that the scientific material that is introduced in such dialogues is not presented as hard facts, but as evidence. It is admitted to be uncertain to some significant degree; its relevance to the case might be contested; and it is also subject to various legitimate interpretations. (Each side may present its materials as if they are hard facts, but the subsequent discussions will presuppose the looser interpretation that I have outlined here.) Given all the complexities and value commitments in the situation, the 'science' cannot realistically or reasonably expected to be trivially conclusive for the 'policy'. And in any event the discussion is not about the science, but about the policy. Hence the dialogue is not so much one of scientific demonstration, but rather of negotiation, where the science is one element among several.

On that basis, we can invoke the technical term 'negotiation in good faith' to characterise the essence of a dialogue in PNS. To my knowledge, this term was first used in American labor law during the New Deal, when the Wagner Act required employers to do just that with unions that had won an election among the workers in a bargaining unit. Since then it has become standard in many fields. Whatever the variations in its meaning, it is sufficiently well defined in practice so that parties can be legally called to account for failing to observe it. Therefore, ' negotiation in good faith' would seem to be a good criterion for distinguishing a real PNS process from a sham. It would correspond to the 'ladder of participation' articulated in the 1960s by the American scholar-activist Sherry Arnstein (Arnstein, 1969).

But that is not entirely sufficient. Any negotiation is still something prudential; it is a matter of skill, perhaps even cunning, for a good mediator to produce a 'win-win' situation, where each side offers up something that means more to the others than to themselves. Can there be some equivalent, within the policy process, to that personal commitment to truth that I still believe to be at the heart of the quality assurance of research science? There is a variety of methods, ranging from gaming and scenario techniques, all the way over to experiences based on the philosophy of non-violence. They all depend on transforming the attitudes of the participants to each other, to developing trust so that the 'good faith' in the negotiations is genuine, based on an 'I-thou' relationship. This seems to bringing us a long way from science and a longer way from politics. But I would argue that this sort of experiential commitment is at the core of both when they are properly done.

But what is to replace the ethic of truth, as the living experiential basis for this new existential commitment? It would seem to be some sort of ethic of service, achieving The Good through science. But thanks to the Bomb and all the problems and scandals of contemporary science-based technology, that is not straightforward either. It seems less likely that mainstream research science will provide the foundation for this new ethic of science. Of course I favour 'sustainability' as an inspirational cause, but that is still a rather abstract concept. And my heart warms to 'nonviolence', but I suspect that this will be a minority taste for some time to come. Perhaps in a matured practice of Post-Normal Science a new ethic will arise as a foundation for quality assurance. This might happen if what I have called the maturing of the structural contradictions of modern European science has a creative rather than a destructive outcome (Ravetz, 2006).

4. Post-Normal Science—the next phase

This mention of 'structural contradictions' provides the bridge from the phase of growth of PNS to that of its maturity. The salient policy questions in which PNS are deployed are no longer those of technological risks, but those of sustainability and survival. The politics of uncertainty has, as we have seen, been transformed. In some respects the quadrant-rainbow of PNS may be obsolescent. In these new debates, the extended peer community is not so much concerned with extreme systems uncertainty, as with extreme systems complexity. What should be done with the theory and its core symbol?

I recently discussed this issue with Silvio Funtowicz and several other close colleagues. We found ourselves engaged in 'applied iconology'. I had to learn to distinguish between the trajectory of my own thinking, and that of the PNS doctrine and symbol. Even if I have moved on, the world of scientists out there is still working their way through the issues that made PNS necessary in the first place. I need to keep in mind that in the absence of a tradition of skill in managing uncertainty, when scientists encounter it in forms that lie outside their unselfconscious craft practice, they become concerned and also confused. Each will work out his or her own understanding of the issues, lacking a community of support for reassurance and guidance. The more that narrowly trained researchers engage in post-normal situations, the greater will be their distress.

Over the past quarter century, that rainbow-quadrant has functioned as a sort of icon, like a 'gu-ru', taking a person from the darkness of confusion to the light of understanding. Grasping the meaning of that outer band, scientists can say, ''It's not my fault!'' And when they further learn that high uncertainty does not entail low quality, they are further liberated to do intelligent management of uncertainty. As it diffuses, that symbol becomes charged with energy of an almost spiritual sort. We have met a goodly number of dedicated scientists whose work has been transformed by that understanding, and we know that there are many more.

In those discussions I was convinced of the wisdom of leaving the quadrant-rainbow alone. If I introduce variations on it, then anyone else can. There will be no one PNS, but many; and then there will be sure to arise arguments of a totally scholastic sort, over which is best. And the core of truth and illumination in that icon will be lost in the thicket of arguments about its versions and their merits. So, at least for the time being, perhaps until such time as the symbol becomes so widely accepted that others start to play with it, I will leave it alone. How then to keep the core insights of PNS alive and fresh, moving with the new problems of this century? My approach is to raise my sights from the methodology of solving the policy-science problems, to an analysis of the new problems themselves.

Looking to the future, the new policy context for PNS can be characterised as 'sustainability'. This concept of course lacks a crisp definition; but it is quite well understood. It does not mean simple physical survival, but social and cultural as well. To my knowledge, the issue was first raised properly by the World Council of Churches, when its annual meeting in 1974 was devoted to a 'Just and Sustainable World'. Since our present world is manifestly both unjust and unsustainable, the linking of the two issues is proper. But that linkage quickly reveals the root contradiction of modern civilisation: even with the high standard of living restricted to the 'golden billion' we are destroying our habitat; what then about the rest? Either we preach the virtues of poverty to the poor; or we say that we will pull up the ladder; or we think again about what the good life means. Some scholars have already started; the eminent economist Richard Layard has shown that quality of life is not simply proportional to quantity of consumption (Layard, 2005). We have to keep in mind that the task of achieving sustainability is partly about techniques, but even more about changing consciousness. Changing the common conception of 'science' is an integral part of that process. We need to enrich our conception of 'problem' to include 'contradiction'. For that, an understanding of systems is essential. I now take that up.

5. A sketch of a theory of systems and of their failures

Hitherto, the task of Western philosophy has been conceived as a positive one. It would show how secular knowledge could attain truth, or at least some acceptable approximation to it. Studies of the negative side, of ignorance and error, were kept in the far margins. This was appropriate, for all the centuries that science was advancing and held out the promise of a genuinely human life for all human beings.

But all that has changed now. We cope with failures of all sorts, and our whole civilisation may be heading for a massive and catastrophic failure. The challenge of transition to a sustainable society is by no means assured of success. We need a general scheme of things that will enable us to understand how things go wrong, so that we are better equipped to cope with error and failure when they occur. This is not a fatalistic or even pessimistic philosophy; it is simply a scheme of things that is designed to help us survive in this, the century in which so many things go wrong.

How and why do things go wrong? To answer such a question properly would require a whole philosophy of action and life. Here I can only sketch some preliminary ideas. I am less interested in simple errors of perception, than in the failure of large organised systems. These are the challenge of the present century, since they may well prove to be our undoing as a civilisation, indeed as a species. I have dealt with the topic of global systems failures, including an earlier version of this theory of systems, elsewhere (Ravetz, 2006b). I use my own rather strong adaptation of elements of the theory of complex systems. My discourse starts with brief, dogmatically expressed theses; then I elaborate on various points of current concern.

A 'System' is an intellectual construct, designed to improve our understanding of a world that is not simple. I offer a definition, chosen for effectiveness in solving my problems.

A complex system is a structure of sets, connected by ordering relations of super-, sub- and co-, where each sub-system (itself a system) has a plurality of relations of all three sorts with other sub-systems. (This combines the social insight of Durkheim – 'organic solidarity' – with the approach of Cantor to the theory of infinite sets, turning a paradox into a definition.)

As an example of the variety of relations among systems, we may consider an ashram whose inhabitants devote themselves to the experience of the divine. But as a social system it will necessarily interact with external socio-technical systems, such as satisfying government inspectorates on the quality of its arrangements for sanitation.

Systems derive a large part of their identity from such networks of relations. When they are contradictory, the identity will have internal contradictions. Thus the U.S.A. was 'conceived in liberty' but was established on the basis of the genocide of the natives and the enslavement of the Africans. At first these policies were but *latent* contradictions; there was no reason to believe that they could not persist indefinitely. In the latter case, the *maturing* of the contradiction came fairly quickly, in the form of a Civil War.

Some systems have *activities*, which may be either *metabolic* or *functional* (contributing to the welfare of some super-systems). (This is a great insight of Sir Geoffrey Vickers) (Vickers, 1972).

Some systems have a *conatus* in Hobbes' sense, a drive to survive (Hobbes, 1655). This is expressed as self-referring *purposes*, which may conflict with the *functions* assigned to them by super-systems. Such systems are described as having 'emergent complexity'.

Super-systems will need to *control* some sub-systems. The control activity is embodied in a special sort of activity system, involving criteria of *quality*. These control systems exhibit

recursion ('who controls the controllers?'), which proceeds upwards with no termination. Issues of quality are ultimately decided by an external super-system. Thus when in the UK the schools exams (testing students' quality) were revealed to be a shambles, and the quality-assessment system for exams equally so, eventually the Minister herself resigned.

Quality is itself a systems attribute, being pragmatic, moral and recursive in its practical working out. It is nevertheless as real as anything else in the universe of systems. A systems understanding of quality will enable us to avoid the idiocies of the various post-post-theories of society, which fall into the all-or-nothing fallacy.

Because of the inherent mismatch between any formalised system and reality, in any control system there are limits to the downwards specification of any task. Thus Taylorism is a fantasy, along with governance by 'targets' (as in Blairism). Simple controls create injustice and breed resentment; complex controls create opportunities for evasion and corruption. This was the characteristic contradiction of the command-and-control economy of state socialism, leading to the 'spikes-or-tacks' syndrome of production, and the need for a gray economy to keep the official one going.

There is no essentially privileged perspective on a system, as each subsystem has its own characteristics of scale, rate-of-change, and fineness of perception (Mario Giampietro), along with value-determined aspects of perception.

Thus *knowledge* itself is systemic, as it exists within determinate technical–social–cultural–historical frameworks, and is characterised by quality rather than by some absolute standard. (Thus the collapse of the 'foundations of mathematics' programme of a century ago.) We can, without sliding into scepticism, appreciate that any image of reality, being constructed within a particular system, simultaneously reveals, distorts and conceals.

With the systems perspective, we can appreciate that when knowledge is put to use, the unit elements are not so much 'facts', nuggets of (purported) truth, but 'evidence', injected into an argument whose conclusions are more or less robust. Those who present such items of evidence are offering their testimony. In this scheme the epistemological analysis of knowledge-statements can be as rich (and complex) as the ethical analysis of actions.

Similarly, *ethical* judgements are situated within systems. There can be a troubling 'ethical flip' as one goes up through hierarchical levels. The best known case is that of a person who commits a bad act in a good cause ('the end justifies the means') but we should not forget the converse case, as the example of the soldier who fights bravely for a bad cause. This consideration adds to the complexity of ethical judgements.

The co-ordinate relations among systems, sometimes causal in character, explain the *ramification* of effects of any activity, and remind us that there is no such thing as a zero risk. There will always be 'unknown unknowns' whose discovery is painful. This is now recognised as 'the law of unintended consequences' (there always are some) or 'Murphy's Law' ('whatever can go wrong, will'). Systems that are designed in ignorance of this 'flipside' are fantasy, doomed to failure. Unfortunately, our scientific education, scientific research style, and economic orthodoxy all conspire to maintain such ignorance. The resulting failure might well include our whole techno-scientific material culture.

In this context of uncertainty, value-loading and complexity, the practical political issue, 'How safe is safe enough?' is the quality-question *par excellence*. It is totally systemic, possessing no definitive answer. Also, defying any attempt at quantification, it belies the numerological reductionism that characterises our scientistic world view. This conundrum is perhaps the characteristic internal contradiction of our modern intensive-technology civilisation.

When sub-systems have *conatus* they will strive to enhance their own purpose at the expense of their imposed functions. From the perspective of the controlling super-system, this is *corruption*. For it to be prevented or ameliorated, the self-conscious elements of the sub-system must believe in an *ideology* (Plato's 'Noble Lie', or 'Dulce et decorum est, pro patria mori'). These ideologies are knowledge-systems, which exhibit all the behaviour of complex systems, sometimes in extreme form. The ordinary response of sub-elements is evasion ('Good Soldier Schweik'), but this does not challenge the legitimacy of the system.

In a largely self-contained system, where external controls are ineffective, corruption can become endemic, and quality is abandoned. In government the extreme state of this is 'kleptocracy'; in civil society it may be called 'meretricracy', where everything has its price and so nothing has any value (Ravetz, 2000). Advanced corruption now appears in socio-technical systems of great sophistication. Thus we have the corruption of 'electronic voting' systems in the U.S.A.; in the U.K. it manifests as large-scale IT projects, where public-sector purchasers and private-sector providers collaborate on ever more costly botched mega-projects (Craig and Brooks, 2006).

In extraordinary situations where the system is suddenly exposed as fraudulent and immoral, there can be deep disillusion in the official ideology, and a consequent schism or collapse. Such a moral outrage triggered the original Reformation in 16th-century Europe, and on a smaller scale, the current revolt within the Roman Catholic Church over the hierarchy's protection of paedophile priests. This is a reminder that on occasion, when the systemic conditions are ripe, morality has great political power.

Leaders of super-systems may also be victims of ideology. They may have invested themselves and their society in a belief-system which has little relation to their real tasks (as Marxism for the Soviet Union). Then there is a sequence: fantasy needs mendacity for its perpetuation, which breeds corruption, and that in turn creates incompetence of all degrees. The implementation of the 'Project for a New American Century' could be an instructive contemporary example of this cycle of ideology-driven degeneration of a political-military system.

To the extent that leaders of a political system can enforce conformity, criticisms of the official belief-system are suppressed. This requires a 'totalitarian' regime, which becomes particularly corrupt and incompetent. Such systems are especially brittle. We have seen the decay and dissolution of Stalinist Russia and Maoist China. In the democracies, the label 'conspiracy theory' serves to stigmatise critical voices, but its effectiveness becomes reduced as official credibility erodes.

6. A new look at 'contradiction'

The problematic philosophical concept *contradiction* may find a new meaning and use in terms of this version of systems theory. I understand it as a set of problems or tasks that cannot be resolved within the terms of reference (or 'paradigm') in which they are conceived. Their resolution may be either destructive (as in a civil war or revolution) or creative (as when consciousness is transformed). Examples of the former are the American Civil War, and the revolutions in France and Russia. Examples of the latter are the successes of non-violence, as in Northern Ireland and South Africa.

An important dynamic theory of eco-systems, that of C.S. Holling, can be interpreted in terms of contradictions. At the beginning we have 'pioneer' species, whose success produces the conditions for their displacement, as they stabilise and enrich their micro-environments. There the contradiction is patent: these aggressive species cannot produce an environment that both nurtures and protects them. Then as the ecosystem matures, it approaches an apparently very stable 'climax'. In design terms, this maximises throughput but at the expense of resilience. When some 'accident' happens, usually fire, there is rapid destruction, and the cycle starts all over again. The 'climax' system turns out to have had the same sort of contradiction as the 'pioneer', but in this case its realisation is long delayed and then sudden. Whether the destruction is destructive or creative depends on the systems perspective. In some cases, as Sequoia trees, the seeds need fire in order to germinate! (Gunderson and Holling, 2002). This sequence might be understood as a 'characteristic contradiction ' of such ecosystems, in the sense that I mentioned above.

Another example of a characteristic contradiction can be seen in the classic short story by E.M. Forster, *The Machine Stops* (Forster, 1909). There, in a high-tech civilisation, the overriding value was stability (a nice contrast to the 'throughput' in Hollings' ecosystem). This required the stifling of criticism. The first sign of degeneration came with a falling-off of quality in the various domestic support systems. People had complained, and the repair crews had come around, but nothing got better and after a while people stopped complaining and eventually forgot that it had once been better! Attempts by the young hero to find out what was really going on were successful, because the containment system had itself degenerated. But then, thanks to the progressive decay, there was what we would now call a sudden total systems failure, and with no creativity in that destruction.

Systems with other sorts of imbalance of objectives can have their own characteristic contradictions, sometimes realised as corruption. Thus in a social system based on selfishness, the 'hidden hand' of Adam Smith may not get a chance to manifest. For when Each finds a palpable advantage (as in minor cheating) which causes no perceptible harm to All the others, then the aggregated economic Utility of the community is increased! In the absence of a universal principle of good behaviour, then All become cheats, and the values of the system are neglected and its ideology betrayed. In political terms, this is most clearly revealed in times of emergencies, when it is discovered that the community did not have a corrupt government, but instead a corrupt non-government. This was the lesson of the earthquake in Nicaragua, and recently in hurricane Katrina; in the former case the discovery triggered a revolution.

A maturing contradiction can manifest in what Silvio Funtowicz and I have called the 'ancien régime syndrome', equivalent to 'hyper-complexity'. In this, the various subsystems are out of control, and so each can prevent any solution of the system's structural problems. Even if the problems are perceived by some, they are denied by most. For they cannot be solved without some sacrifice by each subsystem, and so they are perceived as an existential threat by all. The degenerative process then proceeds through to 'autolysis', first manifested as the soldiers refusing to shoot demonstrators, and ultimately in the abdication or replacement of the authorities (Funtowicz and Ravetz, 1994b).

Marxist political theory spoke of 'leading contradictions', but this seemed to refer to the most salient issues in a complex situation (as when local struggles of classes and communities interact with common struggles against external enemies). We might rather speak of a 'characteristic contradiction' (or, inventing a German word (!), 'Eigenwiderspruch'). This identifies the contradictions that uniquely drive the system towards its destruction or transformation. In the case of modern Western civilisation, there are two that are linked: the moral unsustainability of a lifestyle that most of the planet's people cannot ever enjoy; and the physical unsustainability of that lifestyle even for the (temporarily) fortunate minority. I shall show how these produce a 'compounded characteristic contradiction' that concisely expresses our problematique.

In a companion essay I have discussed the maturing structural contradictions of modern European science (Ravetz, 2006). These start with the contradiction of 'knowledge and power'. The relation was first conceived by Bacon as a 'marriage' for their mutual benefit, but it now more resembles a 'merger' between very unequal partners. The most recent contradiction is that of 'safety', which our present system seems to guarantee and which has become a right. But governments are caught in the contradiction between guaranteeing safety to their citizens and violating it in the cause of economic innovation and growth (Ravetz, 2003).

Under what circumstances can there be a creative outcome of a characteristic contradiction in a social system? This requires the various actors and subsystems each to make some sacrifice for the common good. In a conflict situation (which is characteristic of such a state of affairs) each must recognise the humanity of the enemy whom they may, with good reason, believe to have done inhuman things. Hence the politics and philosophy of non-violence, best understood in the Gandhian term 'satyagraha' (struggling for one's own truth) is no longer just a luxury sentiment of Western middle-class idealists. It may well lie at the heart of the transition to a sustainable civilisation.

7. Contradiction applied to a new theory of the problematique

We are now in a position to attempt to build on the insights of the original theory of PNS, to comprehend the current problematique. We might even consider the present situation

of the theory of PNS as a contradiction of its own, since the problem of an obsolescent icon cannot be solved in its own terms. The task is to find a creative resolution. For this we focus on the characteristic contradiction of modern Western civilisation. The crucial thing in our understanding of it, is that it is a compounded contradiction. We can see its historical roots in what Marx considered to be the characteristic contradiction of modern capitalist society: social production and individual appropriation. He could not believe that sheer benevolence, or even enlightened self-interest (along the lines advocated by Robert Owen) would suffice to resolve this contradiction. His labour theory of value explained how the capitalists must 'expropriate' surplus value from the workers. And his theory of the decline in the rate of profit (consequent on increasing capitalisation) would (he believed) ensure the greater immiseration of the proletariat.

We know that on the second count, Marx was simply wrong. It is easy to see that he missed the great fecundity of capital, when it became applied to large-scale transformations of matter and energy, rather than simply rearranging matter as in a textile mill. But there was more to it than that, in the resolution of Marx's characteristic contradiction. Two other forms of expropriation grew to great strength, enabling the metropolitan poor to escape the prison of grinding poverty. In our terms, they shifted the contradiction elsewhere, thereby staving off rebellion.

We are most familiar with the intensified expropriation of Nature. This could sometimes be watched while it was happening. For example, the cheap grain from the American Great Plains was produced by farming practices that steadily destroyed the great deep bank of rich prairie soil. By the time of the Dust Bowls of the 1930s, the farmers were scraping on plain dirt; the rest had gone downriver or downwind. And now, complementing the mining of resources of all sorts (from oil to fish) we have the pollution of the rest of Nature, worldwide. Since all imposed harms are a form of expropriation of the powerless by the powerful, this present set counts as such.

Now we have discovered that the expropriation of Nature is one element of the characteristic contradiction of our system. We depend on it, and it is optimistic in the extreme to believe that voluntaristic practices (recycling garbage, driving smaller cars) are in themselves anything other than the modern equivalent of Robert Owen's New Lanark or New Harmony. Yet we know that we cannot continue as before; and so I am justified in using the technical term 'contradiction' for this situation.

The other expropriation has been of the poor of what some call the 'majority world'. Even if the processes of forming empires were, historically, confused and not always profitable in strict terms, they did make a big difference. Starting with the rape of 'Latin America' by Columbus and his successors, through the destruction of the Bengali cotton industry to make way for the inferior Lancashire product, and continuing through the rendering of King Leopold's Congo into the world's largest death-camp so that rich-world cyclists could enjoy soft rides on pneumatic rubber tyres, to say nothing of the slave trade, expropriation of the world's vulnerable peoples has been very real and usually profitable.

In spite of all the changes in rhetoric and real power relations, the expropriation has continued up to now. To what extent has our happy half-century of affluence depended on cheap oil, provided by friendly autocrats so that in the U.S.A. gasoline was cheaper than bottled water? In such cases the expropriation of Nature and of the world's poor have gone hand in hand.

But now it is all changing. It is no longer possible to shift the contradictions of domestic poverty out onto the ecosphere and the world's poor. The limits of safe expropriation of the ecosphere have been breached. And the world's poor are reacting to the historical decline of Euro-American empire. For Europe, it is obvious that the turning point was Sarajevo; for America, we might say Bay of Pigs, Saigon, or most definitely Baghdad. So now the poor all want to be rich, just like us.

This new contradiction is a compounded one. First, the world's rich must now accept the poor as genuine people and not as 'savages' or 'natives' (a new consciousness reflecting new realities of power and culture). We cannot deny them the right to a good life, and we cannot conceive a good life on any but materialistic terms. So we must help them 'develop', and hope that somehow they would not become as lethal as ourselves, in the working out of the other arm of the characteristic contradiction. But since our own efforts at reform of technology are so marginal and confused, we do not possesses strong rhetorical or political resources to strengthen our case.

So the two arms of the contradiction, the double expropriation (of the ecosystem and of the poor) by the world's rich, and the lethal 'development' of the world's poor, interact. This is truly a rich characteristic contradiction of a civilisation. For this I have a diagram, which may be simple enough to become iconic, on the example of the quadrant-rainbow of PNS. It does not show a way out of the contradiction, for in all honesty I cannot offer one. But at least it shows why we are where we are; and it graphically provides an image of the depth of our predicament (Fig. 2).

Here we see two arms of the contradiction emerging from The Rich, through the zone of Expropriation. In response, we have a single arm coming up from The Poor, making its contribution to ecological collapse through the zone of Development.

To conclude this analysis, let me indicate two sorts of developments that are intended to solve the problem that I have characterised as a contradiction. I show them below: two parallel developments, one for the rich and the other for the poor. I believe that these cannot resolve the contradiction, for they are each linear, restricted to its own realm (Fig. 3).

Here we see the separate attempts being made by the rich and by the poor. Among the rich, 'green tech' is nearly all

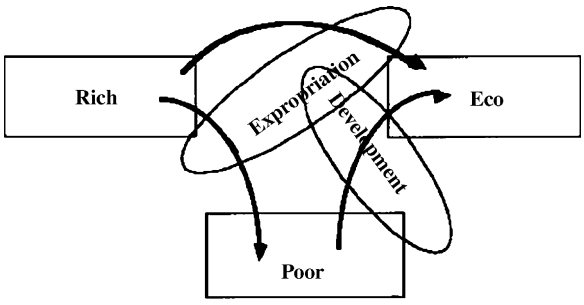

Fig. 2 – The compounded characteristic contradiction.

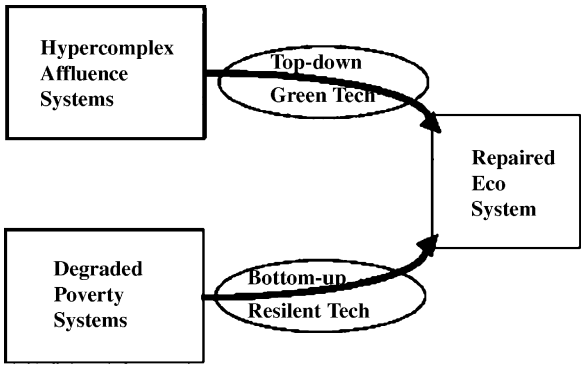

Fig. 3 – Parallel technical fixes.

top-down, with centralised systems for cleaner energy supply of various sorts, and for waste disposal. The individual efforts, like individual energy supply systems, are good for morale, which might become crucial as the contradictions mature further. But they are all encased within the total techno-social system, which I characterise as 'hyper-complex', vulnerable as it is to shocks of any sort. By contrast, the efforts of the poor (a very diverse class, of course) start with low-tech self-help systems, designed for resilience against extremes of their environmental and social context as much as for idealistic motives. And they are working within systems, ecological and social, that are already degraded to some considerable degree. The obvious manifestation of this condition is what we call 'corruption'.

Because of the gross disparity between the two contexts, in both societal and technical dimensions, the two sorts of 'fix' run in parallel. Also, neither directly challenges the second arm of the basic contradiction, the expropriation of the poor. Where oppositional activity occurs, it is mainly in the realm of power-politics. The work of scholar-activists like Vandana Shiva (2005) is an exception; and it could well be that her example, which does unite the two forms of resistance, is an indication of the direction that events must take if there is to be any genuine resolution of the characteristic contradiction of modern civilisation. A complementary path to a resolution would lie in a revolution in consciousness, whereby affluence itself came to be seen as a disease. Would it be utopian to imagine the two wings coming together? This was, after all, the vision of Gandhi, but he was spared the experience of seeing his closest friends and disciples treating it with contempt in their drive to reproduce the life of the rich in India. I have started to explore this theme in a recent essay, 'Towards a non-violent discourse in science' (Ravetz, 2006c).

8. Conclusion

This essay has been written to foster new thinking about PNS with colleagues who are engaged on the new dominant problematique, no longer technological risks but rather the characteristic contradictions of sustainability and survival. This characteristic problematique, although un-calculable, is nonetheless one of central concern for those concerned with the complexity of ecological economic problems. Perhaps even for some working directly with this new problematique, and more for those who will read the papers presented in this special issue, the icon of PNS can still be a liberating insight. Perhaps much like applied science, the concept of Post-Normal Science can remain relevant, for certain situations and with respect to addressing certain types of problems. In the original article drafted for inclusion in this special issue I attempted to adapt that older theory of scientific methodology (PNS) directly to the resolution of the new characteristic contradictions of our civilisation (sustainability and survival). However, it seems that the time for such work is not yet ripe, I will have to wait for some further maturing, of PNS, of our understanding of the new and emerging contradictions, and of my own ideas.

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