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TECHNOLOGIES OF HUMILITY: CITIZEN PARTICIPATION IN GOVERNING SCIENCE

ABSTRACT. Building on recent theories of science in society, such as that provided by the 'Mode 2' framework, this paper argues that governments should reconsider existing relations among decision-makers, experts, and citizens in the management of technology. Policy-makers need a set of 'technologies of humility' for systematically assessing the unknown and the uncertain. Appropriate focal points for such modest assessments are framing, vulnerability, distribution, and learning.

THE PERILS OF PREDICTION

Long before the terrorist atrocities of 11 September 2001 in New York, Washington, DC, and Pennsylvania, the anthrax attacks through the US mail, and the US-led wars in Afghanistan and Iraq, signs were mounting that America's ability to create and operate vast technological systems had outrun her capacity for prediction and control. In a prescient book, published in 1984, the sociologist Charles Perrow forecast a series of 'normal accidents', which were strung like dark beads through the latter years of the twentieth century and beyond – most notably, the 1984 chemical plant disaster in Bhopal, India; the 1986 loss of the *Challenger* shuttle and, in the same year, the nuclear plant accident in Chernobyl, USSR; the contamination of blood supplies with the AIDS virus; the prolonged crisis over BSE ('mad cow disease'); the loss of the manned US space shuttle Columbia in 2003; and the US space programme's embarrassing, although not life-threatening, mishaps with the *Hubble* telescope's blurry lens, and several lost and extremely expensive Mars explorers.[1] To these, we may add the discovery of the ozone hole, climate change, and other environmental disasters as further signs of disrepair. Occurring at different times and in vastly-different political environments, these events nonetheless have served collective notice that human pretensions of control over technological systems need serious re-examination.

While American theorists have often chalked up the failings of technology to avoidable error, especially on the part of large organiza-

[1] Charles Perrow, *Normal Accidents: Living with High Risk Technologies* (New York: Basic Books, 1984).

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tions,[2] some European analysts have suggested a more troubling scenario. Passionately set forth by the German sociologist Ulrich Beck, the thesis of 'reflexive modernization' argues that risks are endemic in the way that contemporary societies conduct their technologically-intensive business.[3] Scientific and technical advances bring unquestioned benefits, but they also generate new uncertainties and failures, with the result that doubt continually undermines knowledge, and unforeseen consequences confound faith in progress. Moreover, the risks of modernity often cut across social lines and operate as a great equalizer of classes. Wealth may increase longevity and improve the quality of life, but it offers no assured protection against the ambient harms of technological societies. This observation was tragically borne out when the collapse of the World Trade Center on 11 September 2001 ended the lives of some 3,000 persons, discriminating not at all among corporate executives, stock market analysts, computer programmers, secretaries, firefighters, policemen, janitors, restaurant workers, and others. Defeat in war similarly endangers the powerful along with the disempowered. In many other contexts, however, vulnerability remains closely tied to socio-economic circumstances, so that inequalities persist in the ability of social groups and individuals to defend themselves against risk.

'Risk', on this account, is not a matter of simple probabilities, to be rationally calculated by experts and avoided in accordance with the cold arithmetic of cost-benefit analysis.[4] Rather, it is part of the modern human condition, woven into the very fabric of progress. The problem we urgently face is how to live democratically and at peace with the knowledge that our societies are inevitably 'at risk'. Critically important questions of risk management cannot be addressed by technical experts with conventional tools of prediction. Such questions determine not only whether we will get sick or die, and under what conditions, but also who will be affected and how we should live with uncertainty and ignorance. Is it sufficient, for instance, to assess technology's consequences, or must we also seek to evaluate its aims? How should we act when the values of scientific inquiry appear to conflict with other fundamental social values? Has our

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[2] *Ibid*. See also Diane Vaughan, *The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA* (Chicago: University of Chicago Press, 1996); James F. Short and Lee Clarke (eds.), *Organizations, Uncertainties, and Risk* (Boulder: Westview Press, 1992); and Lee Clarke, *Acceptable Risk? Making Decisions in a Toxic Environment* (Berkeley: University of California Press, 1989).

[3] Ulrich Beck, *Risk Society: Towards a New Modernity* (London: Sage, 1992).

[4] A pre-eminent example of the calculative approach is given in John D. Graham and Jonathan B. Wiener (eds.), *Risk versus Risk: Tradeoffs in Protecting Health and the Environment* (Cambridge, Mass.: Harvard University Press, 1995).

ability to innovate in some areas run unacceptably ahead of our powers of control?[5] Will some of our most revolutionary technologies increase inequality, promote violence, threaten cultures, or harm the environment? And are our institutions, whether national or supranational, up to the task of governing our dizzying technological capabilities?

To answer questions such as these, the task of managing technologies has to go far beyond the model of 'speaking truth to power' that once was thought to link knowledge to political action.[6] According to this template, technical input to policy problems has to be developed independently of political influences; the 'truth' so generated acts as a constraint, perhaps the most important one, on subsequent exercises of political power. The accidents and troubles of the late twentieth century, however, have called into question the validity of this model – either as a descriptively accurate rendition of the ways in which experts relate to policy-makers, or as a normatively acceptable formula for deploying specialized knowledge within democratic political systems.[7] There is growing awareness that even technical policy-making needs to get more political – or, more accurately, to be seen more explicitly in terms of its political foundations. Across a widening range of policy choices, technological cultures must learn to supplement the expert's preoccupation with measuring the costs and benefits of innovation with greater attentiveness to the politics of science and technology.

Encouragingly, the need for reform in governing science and technology has been acknowledged by political authority. In the millennial year 2000, for example, the House of Lords Select Committee on Science and Technology in Britain issued a report on science and society that began with the ominous observation that relations between the two had reached a critical phase.[8] The authors foresaw damaging consequences for science and technology if these conditions were allowed to persist. This observation was widely attributed to Britain's particular experience with BSE, but the crisis of confidence *vis-à-vis* the management of science

5 Never far from the minds of philosophers and authors of fiction, these concerns have also been famously articulated in recent times by Bill Joy, co-founder and chief scientist of Sun Microsystems. See Joy, 'Why the Future Doesn't Need Us', *Wired*, http://www.wired.com/wired/archive/8.04/joy.html.

6 The *locus classicus* of this view of the right relations between knowledge and power is Don K. Price, *The Scientific Estate* (Cambridge, Mass.: Harvard University Press, 1965).

7 See, in particular, Sheila Jasanoff, *The Fifth Branch: Science Advisers as Policy-makers* (Cambridge, Mass.: Harvard University Press, 1990).

8 United Kingdom, House of Lords Select Committee on Science and Technology, Third Report, *Science and Society*, http://www.parliament.the-stationery-office.co.uk/pa/ld199900/ldselect/ldsctech/38/3801.htm (2000).

and technology has spread significantly wider. The European Union's 2001 White Paper on Governance drew on the activities of a working group on 'Democratizing Expertise', whose report promised new guidelines 'on the collection and use of expert advice in the Commission to provide for the accountability, plurality and integrity of the expertise used'.[9] The intense worldwide discussion of the risks, benefits, and social consequences of biotechnology that began in the late 1990s can be seen as sharing many of the same concerns.

These initiatives and debates reflect a new-found interest on the part of scientists, governments, and many others in creating greater *accountability* in the production and use of scientific knowledge. The conduct of research has changed in ways that demand increased recognition. As captured by the 'Mode 2' rubric, the pursuit of science is becoming more dispersed, context-dependent, and problem-oriented. Given these shifts, concerns with the assurance of quality and reliability in scientific production, reflecting the dominance of the 'speaking truth to power' model, are now seen as too narrowly focused. The wider public responsibilities of science, as well as changes in modes of knowledge-making, demand new forms of public justification. Accountability can be defined in different ways, depending on the nature and context of scientific activity – for example, in demands for precaution in environmental assessments, or in calls for bioethical guidelines in relation to new genetic technologies. Whatever its specific articulation, however, accountability in one or another form is increasingly seen as an independent criterion for evaluating scientific research and its technological applications, supplementing more traditional concerns with safety, efficacy, and economic efficiency.

But how can ideas of accountability be mapped onto well-entrenched relations between knowledge and power, or expertise and public policy? The time is ripe for seriously re-evaluating existing models and approaches. How have existing institutions conceptualized the roles of technical experts, decision-makers, and citizens with respect to the uses and applications of knowledge? How should these understandings be modified in response to three decades of research on the social dimensions of science? Can we respond to the demonstrated fallibility and incapacity of decision-making institutions, without abandoning hopes for improved health, safety, welfare, and social justice? Can we imagine new institutions, processes, and methods for restoring to the playing field of governance some of the normative questions that were sidelined in cele-

9 Commission of the European Communities, *European Governance: A White Paper*, COM (2001), 428, http://europa.eu.int/eur-lex/en/com/cnc/2001/com2001_0428en01.pdf (Brussels, 27 July 2001), 19.

brating the benefits of technological progress? And are there structured means for deliberating and reflecting on technical matters, much as the expert analysis of risks has been cultivated for many decades?

There is a growing need, I shall argue, for what we may call the 'technologies of humility'. These are methods, or better yet institutionalized habits of thought, that try to come to grips with the ragged fringes of human understanding – the unknown, the uncertain, the ambiguous, and the uncontrollable. Acknowledging the limits of prediction and control, technologies of humility confront 'head-on' the normative implications of our lack of perfect foresight. They call for different expert capabilities and different forms of engagement between experts, decision-makers, and the public than were considered needful in the governance structures of high modernity. They require not only the formal mechanisms of participation but also an intellectual environment in which citizens are encouraged to bring their knowledge and skills to bear on the resolution of common problems. Following a brief historical account, I will offer a framework for developing this approach.

THE POST-WAR SOCIAL CONTRACT

In the US, the need for working relationships between science and the state was famously articulated not by a social theorist or sociologist of knowledge, but by a quintessential technical expert: Vannevar Bush, the distinguished MIT engineer and presidential adviser. Bush foresaw the need for permanent changes following the mobilization of science and technology during the Second World War. In 1945, he produced a report, *Science – The Endless Frontier*,[10] that was later hailed as laying the basis for American policy in science and technology. Science, in Bush's vision, was destined to enjoy government patronage in peacetime as it had during the war. Control over the scientific enterprise, however, would be wrested from the military and lodged with the civilian community. Basic research, uncontaminated by industrial application or government policy, would thrive in the free air of universities. Scientists would establish the substantive aims as well as the intellectual standards of research. Bush believed that bountiful results flowing from their endeavours would translate in due course into beneficial technologies, contributing to the nation's prosperity and progress. Although his design took years to materialize, and even then was only imperfectly attained, the US National Science

[10] Vannevar Bush, *Science – The Endless Frontier* (Washington, DC: US Government Printing Office, 1945).

Foundation (NSF) emerged as a principal sponsor of basic research.[11] The exchange of government funds and autonomy in return for discoveries, technological innovations, and trained personnel came to be known as America's 'social contract for science'.

The Bush report said little about how basic research would lead to advances in applied science or technology. That silence itself is telling. It was long assumed that the diffusion of fundamental knowledge into application was linear and unproblematic. The physical system that gripped the policy-maker's imagination was the pipeline. With technological innovation commanding huge rewards in the marketplace, market considerations were deemed sufficient to drive science through the pipeline of research and development into commercialization. State efforts to promote science could then be reasonably restricted to support for basic or 'curiosity-driven' research. Simplistic in its understanding of the links between science and technology, this scheme, we may note, provided no conceptual space for the growing volume of scientific activity required to support and legitimate the multiple undertakings of modern states in the late twentieth century. In a host of areas, ranging from the environmental policy to mapping and sequencing the human genome, governmental funds have been spent on research that defies any possible demarcation between basic and applied. Yet, for many years after the war, the basic-applied distinction remained the touchstone for distinguishing work done in universities from that done in industries, agricultural experiment stations, national laboratories, and other sites concerned primarily with the uses of knowledge.

As long as the 'social contract' held sway, no-one questioned whether safeguarding the autonomy of scientists was the best way to secure the quality and productivity of basic research. Peer review was the instrument that scientists used for self-regulation as well as quality control. This ensured that state-sponsored research would be consistent with a discipline's priorities, theories, and methods. Peer review was responsible, with varying success, for ensuring the credibility of reported results, as well as their originality and interest.

So strong was the faith in peer review that policy-makers, especially in the US, often spoke of this as the best means of validating scientific knowledge, even when it was produced and used in other contexts – for example, for the purpose of supporting regulatory policy. In practice, a

[11] The creation of the National Institutes of Health (NIH) to sponsor biomedical research, divided US science policy in a way not contemplated by Bush's original design. In the recent politics of science, NIH budgets have proved consistently easier to justify than appropriations for other branches of science.

more complex, tripartite approach to quality control developed in most industrial democracies – peer review by disciplinary colleagues in basic science; the development of good laboratory practices, under applicable research protocols, such as products-testing or clinical trials in applied research; and risk assessment for evaluating the health or environmental consequences of polluting emissions and industrial products. But as the importance of testing, clinical research, and risk assessment grew, so, too, did calls for ensuring their scientific reliability. Once again, peer review – or its functional analogue, independent expert advice – were the mechanisms that governments most frequently used for legitimation.

Signs of wear and tear in the 'social contract' began appearing in the 1980s. A spate of highly-publicized cases of alleged fraud in science challenged the reliability of peer review and, with it, the underlying assumptions concerning the autonomy of science. The idea of science as a unitary practice also began to break down as it became clear that research varies from one context to another, not only across disciplines, but – even more important from a policy standpoint – across institutional settings. It was recognized, in particular, that regulatory science, produced to support governmental efforts to guard against risk, was fundamentally different from research driven by scientists' collective curiosity. At the same time, observers began questioning whether the established categories of basic and applied research held much meaning in a world where the production and uses of science were densely connected to each other, as well as to larger social and political consequences.[12] The resulting effort to reconceptualize the framework of science-society interactions forms an important backdrop to present attempts to evaluate the accountability of scientific research.

SCIENCE IN SOCIETY – NEW ASSESSMENTS

Rethinking the relations of science has generated three major streams of analysis. The first stream takes the 'social contract' for granted, but points to its failure to work as its proponents had foreseen. Many have criticized science, especially university-based science, for deviating from idealized, Mertonian norms of purity and disinterestedness. Despite (or maybe because of) its conceptual simplicity, this critique has seriously threatened the credibility of researchers and their claim to autonomy.

[12] For reviews of the extensive relevant literatures, see Sheila Jasanoff, Gerald E. Markle, James C. Petersen, and Trevor Pinch (eds.), *Handbook of Science and Technology Studies* (Thousand Oaks, CA: Sage, 1995).

Other observers have tried to replace the dichotomous division of *basic* and *applied* science with a more differentiated pattern, calling attention to the particularities of science in different settings and in relation to different objectives. Still others have made ambitious efforts to re-specify how scientific knowledge is actually produced. This last line of analysis seeks not so much to correct or refine Vannevar Bush's vision of science, as to replace it with a more complex account of how knowledge-making fits into the wider functioning of society. Let us look at each of these three critiques.

Deviant science. Scientific fraud and misconduct became an issue on the US policy agenda in the 1980s. Political interest reached a climax with the notorious case of alleged misconduct in an MIT laboratory headed by Nobel laureate biologist David Baltimore. He and his colleagues were exonerated, but only after years of inquiry, which included investigations by Congress and the FBI.[13] This and other episodes left residues in the form of greatly-increased Federal powers for the supervision of research, and a heightened tendency for policy-makers and the public to suspect that all was not in order in the citadels of basic science. Some saw the so-called 'Baltimore affair' as a powerful sign that legislators were no longer content with the old social contract's simple *quid pro quo* of money and autonomy in exchange for technological benefits.[14] Others, like the seasoned science journalist Daniel Greenberg, accused scientists of profiting immoderately from their alliance with the state, while failing to exercise moral authority or meaningful influence on policy.[15] American science has since been asked to justify more explicitly the public money spent on it. A token of the new relationship came with the reform of NSF's peer review criteria in the 1990s. The Foundation now requires reviewers to assess proposals not only on grounds of technical merit, but also with respect to wider social implications – thus according greater prominence to social utility. In effect, the very public fraud investigations of the previous decade opened up taken-for-granted aspects of scientific autonomy, and forced scientists to account for their objectives, as well as to defend their honesty.

To these perturbations may be added a steady stream of challenges to the supposed disinterestedness of academic science. From studies in

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[13] Daniel J. Kevles, *The Baltimore Case: A Trial of Politics, Science, and Character* (New York: Norton, 1998).

[14] David H. Guston, *Between Politics and Science: Assuring the Integrity and Productivity of Research* (Cambridge: Cambridge University Press, 2001).

[15] Daniel S. Greenberg, *Science, Money, and Politics: Political Triumph and Ethical Erosion* (Chicago: University of Chicago Press, 2001).

climate change to biotechnology, critics have accused researchers of having sacrificed objectivity in exchange for grant money or, worse, equity interests in lucrative start-up companies.[16] These allegations have been especially damaging to biotechnology, which benefits significantly from the rapid transfer of skills and knowledge. Since most Western governments are committed to promoting such transfers, biotechnology is caught on the horns of a very particular dilemma: how to justify its promises of innovation and progress credibly when the interests of most scientists are unacceptably aligned with those of industry, government, or – occasionally – 'public interest' advocates.

Predictably, pro-industry bias has attracted the most criticism, but academic investigators have also come under scrutiny for alleged pro-environment and anti-technology biases. In several cases involving biotechnology – in particular, that of the monarch butterfly study conducted by Cornell University scientist John Losey in the US,[17] and Arpad Pusztai's controversial rat-feeding study in the UK[18] – industry critics have questioned the quality of university-based research, and have implied that political orientations may have prompted premature release or the over-interpretation of results. In April 2002, another controversy of this sort erupted over an article in *Nature* by a University of California scientist, Ignacio Chapela, who concluded that DNA from genetically modified corn had contaminated native species in Mexico. Philip Campbell, the journal's respected editor, did not retract the paper, but stated that 'the evidence available is not sufficient to justify the publication of the original paper', and that readers should 'judge the science for themselves'.[19] As in the Losey and Pusztai cases, critics charged that Chapela's science had been marred by non-scientific considerations. Environmentalists, however, have viewed all these episodes as pointing to wholesale deficits in knowledge about the long-term and systemic effects of genetic modification in crop plants.

[16] See, for example, Sonja Boehmer-Christiansen, 'Global Climate Protection Policy: The Limits of Scientific Advice, Parts 1 and 2', *Global Environmental Change*, 4 (2), (1994), 140–159; 4 (3), (1994), 185–200.

[17] John E. Losey, L.S. Rayor, and M.E. Carter, 'Transgenic Pollen Harms Monarch Larvae', *Nature*, 399 (1999), 214.

[18] Stanley W.B. Ewen and Arpad Pusztai, 'Effect of diets containing genetically modified potatoes expressing *Galanthus nivalis lectin* on rat small intestine', *Lancet*, 354 (1999), 1353–1354.

[19] '*Nature* Regrets Publication of Corn Study', *The Washington Times*, http://www.washingtontimes.com/national/20020405-9384015.htm, 5 April 2002.

Context-specific science. The second line of attack on the science-society relationship focuses on the 'basic-applied' distinction. One attempt to break out of the simplistic dualism was proposed by the late Donald Stokes, whose quadrant framework, using Louis Pasteur as the prototype, suggested that 'basic' science can be done within highly 'applied' contexts.[20] Historians and sociologists of science and technology have long observed that foundational work can be done in connection with applied problems, just as applied problem-solving is often required for resolving theoretical issues (for example, in the design of new scientific instruments). To date, formulations based on such findings have been slow to take root in policy cultures. The interest of Stokes' work lay not so much in the novelty of his insights as in his attempt to bring historical facts to bear on the categories of science policy analysis.

Like Vannevar Bush, Stokes was more interested in the promotion of innovation than in its control. How to increase the democratic supervision of science was not his primary concern. Not surprisingly, the accountability of science has emerged as a stronger theme in studies of risk and regulation, the arena in which governments seek actively to manage the potentially harmful aspects of technological progress. Here, too, one finds attempts to characterize science as something more than 'basic' or 'applied'.

From their background in the philosophy of science, Funtowicz and Ravetz proposed to divide the world of policy-relevant science into three nested circles, each with its own system of quality control: (1) 'normal science' (borrowing the well-known term of Thomas Kuhn), for ordinary scientific research; (2) 'consultancy science', for the application of available knowledge to well-characterized problems; and (3) 'post-normal science', for the highly-uncertain, highly-contested knowledge needed for many health, safety, and environmental decisions.[21] These authors noted that, while traditional peer review may be effective within 'normal' and even 'consultancy' science, the quality of 'post-normal' science cannot be assured by standard review processes alone. Instead, they proposed that work of this nature be subjected to *extended peer review*, involving not only scientists but also the stakeholders affected by the use of science. Put

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[20] Donald E. Stokes, *Pasteur's Quadrant: Basic Science and Technological Innovation* (Washington, DC: Brookings Institution, 1997).

[21] Silvio O. Funtowicz and Jerome R. Ravetz, 'Three Types of Risk Assessment and the Emergence of Post Normal Science', in Sheldon Krimsky and D. Golding (eds.), *Social Theories of Risk* (New York: Praeger, 1992), 251–273.

differently, they saw accountability, rather than mere quality control, as the desired objective when science becomes 'post-normal'.[22]

Jasanoff's 1990 study of expert advisory committees in the US noted that policy-relevant science (also referred to as 'regulatory science') – such as science done for purposes of risk assessment – is often subjected to what policy-makers call 'peer review'.[23] On inspection, this exercise differs fundamentally from the review of science in conventional research settings. Regulatory science is reviewed by multidisciplinary committees rather than by individually selected specialists. The role of such bodies is not only to validate the methods by which risks are identified and investigated, but also to confirm the reliability of the agency's interpretation of the evidence. Frequently, regulatory science confronts the need to set standards for objects or concepts whose very existence has not previously been an issue for either science or public policy: 'fine particulate matter' in air pollution control; the 'maximum tolerated dose' (MTD) in bioassays; the 'maximally-exposed person' in relation to airborne toxics; or the 'best available technology' in many programmes of environmental regulation. In specifying how such terms should be defined or characterized, advisory committees have to address issues that are technical as well as social, scientific as well as normative, regulatory as well as metaphysical. What *kind* of entity, after all, is a 'fine' particulate or a 'maximally-exposed' person, and by what markers can we recognize them? Studies of regulatory science have shown that the power of advisory bodies definitively to address such issues depends on their probity, representativeness, transparency, and accountability to higher authority – such as courts and the public. In other words, the credibility of regulatory science ultimately rests upon factors that have more to do with accountability in terms of democratic politics, than with the quality of science as assessed by scientific peers.

In modern industrial societies, studies designed to establish the safety or effectiveness of new technologies are frequently delegated to producers. Processes of quality control for product testing within industry include the imposition and enforcement of good laboratory practices, under supervision by regulatory agencies and their scientific advisers. The precise extent of an industry's knowledge-producing burden is often negotiated with the regulatory agencies, and may be affected by economic and political considerations that are not instantly apparent to outsiders

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[22] A problem with this analysis lies in the term 'post-normal science'. When scientific conclusions are so closely intertwined with social and normative considerations as in Funtowicz and Ravetz's outermost circle, one may just as well call the 'product' by another name, such as 'socially-relevant knowledge' or 'socio-technical knowledge'.

[23] Jasanoff, *op. cit.* note 7.

(setting MTDs for bioassays is one well-known example). Resource limitations may curb state audits and inspections of industry labs, leading to problems of quality control, while provisions exempting confidential trade information from disclosure may reduce the transparency of product- or process-specific research conducted by industry. Finally, the limits of the regulator's imagination place significant limitations on an industry's duty to generate information. Only in the wake of environmental disasters involving dioxin, methyl isocyanate, and PCBs, and only after the accidental exposure of populations and ecosystems, were gaps discovered in the information available about the chronic and long-term effects of many hazardous chemicals. Before disaster struck, regulators did not appreciate the need for such information. Occurrences like these have led to demands for greater public accountability in the science that is produced to support regulation.

New modes of knowledge production. Going beyond the quality and context-dependency of science, some have suggested that we need to take a fresh look at the structural characteristics of science in order to make it more socially responsive. Michael Gibbons and his co-authors have concluded that the traditional disciplinary science of Bush's 'endless frontier' has been largely supplanted by a new 'Mode 2' of knowledge production.[24] The salient properties of this new Mode, in their view, include the following:

- Knowledge is increasingly produced in contexts of application (i.e., *all* science is to some extent 'applied' science);
- Science is increasingly transdisciplinary – that is, it draws upon and integrates empirical and theoretical elements from a variety of fields;
- Knowledge is generated in a wider variety of sites than ever before, not just in universities and industry, but also in other sorts of research centres, consultancies, and think-tanks; and
- Participants in science have grown more aware of the social implications of their work (i.e., more 'reflexive'), just as publics have become more conscious of the ways in which science and technology affect their interests and values.

The growth of 'Mode 2' science, as Gibbons *et al*. note, has necessary implications for quality control. Besides old questions about the intellectual merits of their work, scientists are being asked to answer questions

[24] Michael Gibbons, Camille Limoges, Helga Nowotny, Simon Schwartzman, Peter Scott, and Martin Trow, *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies* (London: Sage, 1994).

about marketability, and the capacity of science to promote social harmony and welfare. Accordingly:

> Quality is determined by a wider set of criteria, which reflects the broadening social composition of the review system. This implies that 'good science' is more difficult to determine. Since it is no longer limited to the judgments of disciplinary peers, the fear is that control will be weaker and result in lower quality work. Although the quality control process in Mode 2 is more broadly based, it does not follow . . . that it will necessarily be of lower quality.[25]

One important aspect of this analysis is that, in 'Mode 2' science, quality control has for practical purposes merged with accountability. Gibbons *et al*. view all of science as increasingly more embedded in, and hence more accountable to, society at large. To keep insisting upon a separate space for basic research, with autonomous measures for quality control, appears, within their framework, to be a relic of an earlier era.

In a more recent work, Helga Nowotny, Peter Scott, and Michael Gibbons have grappled with the implications of these changes for the production of knowledge in public domains.[26] Unlike the 'pipeline model', in which science generated by independent research institutions eventually reaches industry and government, Nowotny *et al*. propose the concept of 'socially robust knowledge' as the solution to problems of conflict and uncertainty. Contextualization, in their view, is the key to producing science for public ends. Science that draws strength from its socially-detached position is too frail to meet the pressures placed upon it by contemporary societies. Instead, they imagine forms of knowledge that would gain robustness from their very embeddedness in society. The problem, of course, is how to institutionalize polycentric, interactive, and multipartite processes of knowledge-making within institutions that have worked for decades at keeping expert knowledge away from the vagaries of populism and politics. The question confronting the governance of science is how to bring knowledgeable publics into the front-end of scientific and technological production – a place from which they have historically been strictly excluded.

THE PARTICIPATORY TURN

Changing modes of scientific research and development provide at least a partial explanation for the current interest in improving public access to

25 *Ibid*., 8.

26 Helga Nowotny, Peter Scott, and Michael Gibbons, *Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty* (Cambridge: Polity, 2001), 166–178.

expert decision-making. In thinking about research today, policy-makers and the public inevitably focus on the accountability of science. As the relations of science have become more pervasive, dynamic, and heterogeneous, concerns about the integrity of peer review have transmuted into demands for greater public involvement in assessing the costs and benefits, as well as the risks and uncertainties, of new technologies. Such demands have arisen with particular urgency in the case of biotechnology, but they are by no means limited to that field.

The pressure for accountability manifests itself in many ways, of which the demand for greater transparency and participation is perhaps most prominent. One notable example came with US Federal legislation in 1998, pursuant to the Freedom of Information Act, requiring public access to all scientific research generated by public funds.[27] The provision was hastily introduced and scarcely debated. Its sponsor, Senator Richard Shelby (R-Alabama), tacked it on as a last-minute amendment to an omnibus appropriations bill. His immediate objective was to force disclosure of data by the Harvard School of Public Health from a controversial study of the health effects of human exposure to fine particulates. This so-called 'Six Cities Study' provided key justification for the US Environmental Protection Agency's stringent ambient standard for airborne particulate matter, issued in 1997. Whatever its political motivations, this sweeping enactment showed that Congress was no longer willing to concede unchecked autonomy to the scientific community in the collection and interpretation of data, especially when the results could influence costly regulatory action. Publicly-funded science, Congress determined, should be available at all times to public review.

Participatory traditions are less thoroughly institutionalized in European policy-making, but recent changes in the rules governing expert advice display a growing commitment to involving the public in technically-grounded decisions. In announcing the creation of a new Directorate General for Consumer Protection, the European Commission observed in 1997 that, 'Consumer confidence in the legislative activities of the EU is conditioned by the *quality and transparency* of the scientific advice and its use on the legislative and control process' (emphasis added).[28] A commitment to greater openness is also evident in several

[27] Public Law 105-277 (1998). The Office of Management and Budget in the Clinton administration controversially narrowed the scope of the law to apply not to *all* publicly-funded research, but only to research actually relied upon in policy-making. The issue is not completely resolved as of this writing.

[28] European Commission, *1997 Communication of the European Commission on Consumer Health and Safety*, COM (97), 183 fin. http://europa.eu.int/comm/food/fs/sc/index_en.html.

new UK expert bodies, such as the Food Standards Agency, created to restore confidence in the wake of the BSE crisis. Similarly, two major public inquiries – the Phillips Inquiry on BSE and the Smith Inquiry on the Harold Shipman murder investigation – set high standards for public access to information through the Internet. All across Europe, opposition to genetically-modified foods and crops has prompted experiments with diverse forms of public involvement, such as citizen juries, consensus conferences, and referenda.[29]

Although these efforts are admirable, formal participatory opportunities cannot by themselves ensure the representative and democratic governance of science. There are, to start with, practical problems. People may not possess enough specialized knowledge and material resources to take advantage of formal procedures. Participation may occur too late to identify alternatives to dominant or default options; some processes, such as consensus conferences, may be too *ad hoc* or issue-specific to exercise sustained influence. More problematic is the fact that even timely participation does not necessarily improve decision-making. Empirical research has consistently shown that transparency may exacerbate rather than quell controversy, leading parties to deconstruct each other's positions instead of deliberating effectively. Indeed, the Shelby Amendment reflects one US politician's conviction that compulsory disclosure of data will enable any interested party to challenge researchers' interpretations of their work. Participation, in this sense, becomes an instrument to challenge scientific points on political grounds. By contrast, public participation that is constrained by established formal discourses, such as risk assessment, may not admit novel viewpoints, radical critiques, or considerations lying outside the taken-for-granted framing of the problem.

While national governments are scrambling to create new participatory forms, there are signs that such changes may reach neither far enough nor deeply enough to satisfy the citizens of a globalizing world. Current reforms leave out public involvement in corporate decision-making at the design and product-development phases. The Monsanto Company's experience with the 'Terminator gene' suggests that political activists may seize control of decisions on their own terms, unless governance structures provide for more deliberative participation. In this case, the mere possibility that a powerful multinational corporation might acquire technology to deprive poor farmers of their rights, galvanized an activist organization – Rural Advancement Foundation International (RAFI) – to launch

[29] Simon Joss and John Durant (eds.), *Public Participation in Science: The Role of Consensus Conferences in Europe* (London: Science Museum, 1995).

an effective worldwide campaign against the technology.[30] Through a combination of inspired media tactics (including naming the technology after a popular science-fiction movie) and strategic alliance-building (for example, with the Rockefeller Foundation), RAFI forced Monsanto to back down from this particular product. The episode can be read as a case of popular technology assessment, in a context where official processes failed to deliver the level of accountability desired by the public.

Participation alone, then, does not answer the problem of how to democratize technological societies. Opening the doors to previously closed expert forums is a necessary step – indeed, it should be seen by now as a standard operating procedure. But the formal mechanisms adopted by national governments are not enough to engage the public in the management of global science and technology. What has to change is the *culture* of governance, within nations as well as internationally; and for this we need to address not only the mechanics, but also the substance of participatory politics. The issue, in other words, is no longer *whether* the public should have a say in technical decisions, but *how* to promote more meaningful interaction among policy-makers, scientific experts, corporate producers, and the public.

TECHNOLOGIES OF HUMILITY

The analytic ingenuity of modern states has been directed toward refining what we may call the 'technologies of hubris'. To reassure the public, and to keep the wheels of science and industry turning, governments have developed a series of predictive methods (e.g., risk assessment, cost-benefit analysis, climate modelling) that are designed, on the whole, to facilitate management and control, even in areas of high uncertainty.[31] These methods achieve their power through claims of objectivity and a disciplined approach to analysis, but they suffer from three significant limitations. First, they show a kind of peripheral blindness toward

[30] In 1998, a small cotton seed company called Delta and Pine Land (D&PL) patented a technique designed to switch off the reproductive mechanism of agricultural plants, thereby rendering their seed sterile. The company hoped that this technology would help protect the intellectual property rights of agricultural biotechnology firms by taking away from farmers the capacity to re-use seed from a given year's genetically modified crops in the next planting season. While the technology was still years away from the market, rumours arose of a deal by Monsanto to acquire D&PL. This was the scenario that prompted RAFI to act. Robert F. Service, 'Seed-Sterilizing "Terminator Technology" Sows Discord', *Science*, 282 (1998), 850–851.

[31] See, for example, Theodore M. Porter, *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life* (Princeton: Princeton University Press, 1995).

uncertainty and ambiguity. Predictive methods focus on the known at the expense of the unknown, producing overconfidence in the accuracy and completeness of the pictures they produce. Well-defined, short-term risks command more attention than indeterminate, long-term ones, especially in cultures given to technological optimism. At the same time, technical proficiency conveys the false impression that analysis is not only rigorous, but complete – in short, that it has taken account of all possible risks. Predictive methods tend in this way to downplay what falls outside their field of vision, and to overstate whatever falls within.[32]

Second, the technologies of predictive analysis tend to pre-empt political discussion. Expert analytic frameworks create high entry barriers against legitimate positions that cannot express themselves in terms of the dominant discourse.[33] Claims of objectivity hide the exercise of judgment, so that normative presuppositions are not subjected to general debate. The boundary work that demarcates the space of 'objective' policy analysis is carried out by experts, so that the politics of demarcation remains locked away from public review and criticism.[34]

Third, predictive technologies are limited in their capacity to internalize challenges that arise outside their framing assumptions. For example, techniques for assessing chemical toxicity have become ever more refined, but they continue to rest on the demonstrably faulty assumption that people are exposed to one chemical at a time. Synergistic effects, long-term exposures, and multiple exposures are common in normal life, but have tended to be ignored as too messy for analysis – hence, as irrelevant to decision-making. Even in the aftermath of catastrophic failures, modernity's predictive models are often adjusted to take on board only those lessons that are compatible with their initial assumptions. When a US-designed chemical factory in Bhopal released the deadly gas methyl isocyanate, killing thousands, the international chemical industry made many improvements in its internal accounting and risk-communication practices. But no new methods were developed to assess the risks of technology transfer between radically different cultures of industrial production.

To date, the unknown, unspecified, and indeterminate aspects of scientific and technological development remain largely unaccounted for in

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32 Alan Irwin and Brian Wynne (eds.), *Misunderstanding Science? The Public Reconstruction of Science and Technology* (Cambridge: Cambridge University Press, 1996).

33 Langdon Winner, 'On Not Hitting the Tar Baby', in Langdon Winner (ed.), *The Whale and the Reactor: A Search for Limits in an Age of High Technology* (Chicago: University of Chicago Press, 1986), 138–154.

34 Jasanoff, *op. cit*. note 7.

policy-making; treated as beyond reckoning, they escape the discipline of analysis. Yet, what is lacking is not just knowledge to fill the gaps, but also processes and methods to elicit what the public wants, and to use what is already known. To bring these dimensions out of the shadows and into the dynamics of democratic debate, they must first be made concrete and tangible. Scattered and private knowledge has to be amalgamated, perhaps even disciplined, into a dependable civic epistemology. The human and social sciences of previous centuries undertook just such a task of translation. They made visible the social problems of modernity – poverty, unemployment, crime, illness, disease, and lately, technological risk – often as a prelude to rendering them more manageable, using what I have termed the 'technologies of hubris'. Today, there is a need for 'technologies of humility' to complement the predictive approaches: to make apparent the possibility of unforeseen consequences; to make explicit the normative that lurks within the technical; and to acknowledge from the start the need for plural viewpoints and collective learning.

How can these aims be achieved? From the abundant literature on technological disasters and failures, as well as from studies of risk analysis and policy-relevant science, we can abstract four focal points around which to develop the new technologies of humility. They are *framing*, *vulnerability*, *distribution*, and *learning*. Together, they provide a framework for the questions we should ask of almost every human enterprise that intends to alter society: what is the purpose; who will be hurt; who benefits; and how can we know? On all these points, we have good reason to believe that wider public engagement would improve our capacity for analysis and reflection. Participation that pays attention to these four points promises to lead neither to a hardening of positions, nor to endless deconstruction, but instead to richer deliberation on the substance of decision-making.

Framing. It has become an article of faith in the policy literature that the quality of solutions to perceived social problems depends on the way they are framed.[35] If a problem is framed too narrowly, too broadly, or wrongly, the solution will suffer from the same defects. To take a simple example, a chemical-testing policy focused on single chemicals cannot produce knowledge about the environmental health consequences of multiple exposures. The framing of the regulatory issue is more restrictive than the actual distribution of chemical-induced risks, and hence is incapable of delivering optimal management strategies. Similarly, a belief that violence

[35] Donald A. Schon and Martin Rein, *Frame/Reflection: Toward the Resolution of Intractable Policy Controversies* (New York: Basic Books, 1994).

is genetic may discourage the search for controllable social influences on behaviour. A focus on the biology of reproduction may delay or impede effective social policies for curbing population growth. When facts are uncertain, disagreements about the appropriate frame are virtually unavoidable and often remain intractable for long periods. Yet, few policy cultures have adopted systematic methods for revising the initial framing of issues.[36] Frame analysis thus remains a critically important, though neglected, tool of policy-making that would benefit from greater public input.

Vulnerability. Risk analysis treats the 'at-risk' human being as a passive agent in the path of potentially-disastrous events. In an effort to produce policy-relevant assessments, human populations are often classified into groups (e.g., most susceptible, maximally exposed, genetically predisposed, children or women) that are thought to be differently affected by the hazard in question. Based on physical and biological indicators, however, these classifications tend to overlook the social foundations of vulnerability, and to subordinate individual experiences of risk to aggregate numerical calculations.[37] Recent efforts to analyse vulnerability have begun to recognize the importance of socio-economic factors, but methods of assessment still take populations rather than individuals as the unit of analysis. These approaches not only disregard differences within groups, but reduce individuals to statistical representations. Such characterizations leave out of the calculus of vulnerability such factors as history, place, and social connectedness, all of which may play crucial roles in determining human resilience. Through participation in the analysis of their vulnerability, ordinary citizens may regain their status as active subjects, rather than remain undifferentiated objects in yet another expert discourse.

Distribution. Controversies over such innovations as genetically modified foods and stem cell research have propelled ethics committees to the top of the policy-making ladder. Frequently, however, these bodies are used as 'end-of-pipe' legitimation devices, reassuring the public that normative issues have not been omitted from governmental deliberation. The term 'ethics', moreover, does not cover the whole range of social and economic realignments that accompany major technological changes,

36 Paul C. Stern and Harvey V. Fineberg (eds.), *Understanding Risk: Informing Decisions in a Democratic Society* (Washington, DC: National Academy of Science Press, 1996).

37 For some examples, see Irwin and Wynne, *op. cit.* note 32.

nor their distributive consequences, particularly as technology unfolds across global societies and markets. Attempts to engage systematically with distributive issues in policy processes have not been altogether successful. In Europe, consideration of the 'fourth hurdle' – the socio-economic impact of biotechnology – was abandoned after a brief debate. In the US, the congressional Office of Technology Assessment, which arguably had the duty to evaluate socio-economic impacts, was dissolved in 1995.[38] President Clinton's 1994 injunction to Federal agencies to develop strategies for achieving environmental justice has produced few dramatic results.[39] At the same time, episodes like the RAFI-led rebellion against Monsanto demonstrate a deficit in the capacity for ethical and political analysis in large corporations, whose technological products can fundamentally alter people's lives. Sustained interactions between decision-makers, experts, and citizens, starting at the upstream end of research and development, could yield significant dividends in exposing the distributive implications of innovation.

Learning. Theorists of social and institutional learning have tended to assume that what is 'to be learned' is never part of the problem. A correct, or at least a better, response exists, and the issue is whether actors are prepared to internalize it. In the social world, learning is complicated by many factors. The capacity to learn is constrained by limiting features of the frame within which institutions must act. Institutions see only what their discourses and practices permit them to see. Experience, moreover, is polysemic, or subject to many interpretations, no less in policy-making than in literary texts. Even when the fact of failure in a given case is more or less unambiguous, its causes may be open to many different readings. Just as historians disagree over what may have caused the rise or fall of particular political regimes, so policy-makers may find it impossible to attribute their failures to specific causes. The origins of a problem may appear one way to those in power, and in quite another way to the marginal or the excluded. Rather than seeking monocausal explanations, it would be fruitful to design avenues through which societies can collectively reflect on the ambiguity of their experiences, and to assess the strengths and weaknesses of alternative explanations. Learning, in this modest sense, is a suitable objective of civic deliberation.

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[38] Bruce Bimber, *The Politics of Expertise in Congress: The Rise and Fall of the Office of Technology Assessment* (Albany: State University of New York Press, 1996).

[39] 'Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations', Executive Order 12298, Washington, DC, 11 February 1994.

CONCLUSION

The enormous growth and success of science and technology during the last century has created contradictions for institutions of governance. As technical activities have become more pervasive and complex, demand has grown for more complete and multivalent evaluations of the costs and benefits of technological progress. It is widely recognized that increased participation and interactive knowledge-making may improve accountability and lead to more credible assessments of science and technology. Such approaches will also be consistent with changes in the modes of knowledge production, which have made science more socially embedded and more closely tied to contexts of application. Yet, modern institutions still operate with conceptual models that seek to separate science from values, and that emphasize prediction and control at the expense of reflection and social learning. Not surprisingly, the real world continually produces reminders of the incompleteness of our predictive capacities through such tragic shocks as Perrow's 'normal accidents'.

A promising development is the renewed attention being paid to participation and transparency. Such participation, I have argued, should be treated as a standard operating procedure of democracy, but its aims must be considered as carefully as its mechanisms. Formally constituted procedures do not necessarily draw in all those whose knowledge and values are essential to making progressive policies. Participation in the absence of normative discussion can lead to intractable conflicts of the kind encountered in the debate on policies for climate change. Nor does the contemporary policy-maker's near-exclusive preoccupation with the management and control of risk, leave much space for tough debates on technological futures, without which we are doomed to repeat past mistakes.

To move public discussion of science and technology in new directions, I have suggested a need for 'technologies of humility', complementing the predictive 'technologies of hubris' on which we have lavished so much of our past attention. These *social* technologies would give combined attention to substance and process, and stress deliberation as well as analysis. Reversing nearly a century of contrary development, these approaches to decision-making would seek to integrate the 'can do' orientation of science and engineering with the 'should do' questions of ethical and political analysis. They would engage the human subject as an active, imaginative agent, as well as a source of knowledge, insight, and memory. The specific focal points I have proposed – framing, vulnerability, distribution, and learning – are pebbles thrown into a pond, with untested force and unforeseeable ripples. These particular concepts may prove insufficient to drive serious institutional change, but they can at least offer starting points for a deeper public debate on the future of science in society.

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