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NEVER LATE, NEVER LOST, NEVER UNPREPARED

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Introduction

In this chapter we examine innovation as a dynamic system of forces that constantly and necessarily redefine the boundaries between science, technology and the normative sphere of liberal democracy. We consider innovation as a phenomenon which is on a path-dependent trajectory, with origins in the scientific revolution and the emergence of the modern state in the 16th and 17th centuries. We give an overview of its evolution through the lens of the 'demarcation problem': that is, we consider innovation with respect to the boundaries that demarcate scientific research from other human activities. More specifically, we look at *how* those boundaries have been drawn over time, *by whom*, and *to what ends*. In this exploration, we identify three main modes of demarcation that function as principles and drivers of innovation, defining the structure of the space in which it evolves: we call these 'separation', 'hybridization' and 'substitution'.

'Separation' refers to the ideal division between the facts of science and the values of governance and to the

corresponding 'dual system of legitimacy' that regulates the 'modern' relation between knowledge and power. In this framework, uncertainty and complexity are ideally externalized from the realm of scientific knowledge and activity. 'Hybridization' corresponds to the transition from curiosity-motivated 'little' science to big, industrialized science, in which science and technology, discovery and invention, and facts and values are blended (hybridized) in 'technoscientific' endeavours. In this framework, uncertainty and complexity cannot be effectively banished; however, they can be reduced and ideally controlled through quantitative risk assessment and management. 'Substitution' involves the replacement of natural resources with technoscientific artefacts, of decision making with data management and of understanding with making. Ultimately, substitution leads to the replacement of science itself by technology in a process that defines and legitimizes (*i.e.* demarcates) innovation. Values are substituted by facts, in the sense that normative issues are reduced to technical matters that can supposedly be resolved by technoscientific means. In this framework, uncertainty and complexity are acknowledged, managed and ideally eliminated.

These modes of demarcation have emerged consecutively and are presented here in an historical perspective, but, as we will see in our study of the narrative of innovation, they also co-exist to various degrees[1]. As the story unfolds, we will introduce a frame of reference for the narrative of innovation, providing examples of how various technoscientific innovations in the fields of nanotechnology, space exploration and emergent information and communication technology (ICT) have been represented

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[1] Indeed, different historical accounts are possible, emphasising continuity and parallel developments rather than distinct phases in the style of scientific research and application. See, for example, Crombie (1994).

to consumers, investors and governments in such a way as to affirm their epistemic, normative and economic legitimacy. Considered collectively, these examples illustrate how innovation is constituted by appealing to the ideals of separation, hybridization and substitution and how the main proponents of innovation — scientists, administrators and entrepreneurs — draw the boundaries of their territories in order to ensure their survival and expansion (or, in modern terms, competitiveness and growth). These examples shed some light on the current complex and contentious relationships between science, technology and governance.

In the final section of this chapter we will perform a thought experiment: we will assume that all doubts regarding the impact of technoscience have been laid to rest, that the risks associated with it have been mitigated and that its promises have been fulfilled. This assumption will allow us to imagine what kind of world is implied, based on what values and with what implications for whom. This exercise will make plain some of the main contradictions inherent in the prevailing narrative of innovation and will point to possibilities for developing alternative narratives.

Separation: science as representation of the true and good

Narratives of progress can be construed as demarcating strategies — that is, rhetorical repertoires that legitimize certain worldviews and systems of knowledge and power. As such, all narratives imply a specific set of relationships between science, technology and the normative sphere of liberal democracy.

In the early stages of the scientific revolution and the modern state in the mid-17th century, we find the emergence of a dual legitimacy system, ideally separating the

objective world of facts—the realm of science—from the subjective world of human affairs and values, regulated by emerging institutions of governance. The banishment of uncertainty and complexity from the jurisdiction of scientific endeavour was essential for this dual system to function: the object of scientific investigation had to be protected from the inner world of the experimenter (ruled by subjective sensations, emotions and passions) and from the world outside the laboratory (governed by social and political values)[2].

In this framework, science had to be dissociated not only from ideology (meaning metaphysics, religion and politics), but also from *technology*. Justification, discovery and knowing were deliberately distinguished from application, invention, and making, in an effort by scientists to compete with engineers and religious authorities for epistemic legitimacy and material resources.

In a compelling account of science in Victorian England, sociologist Thomas Gieryn reconstructed the demarcating strategies of John Tyndall, successor to Michael Faraday as Professor and then Superintendent at the Royal Institution in London, in charge of delivering lectures demonstrating the relevance and the progress of scientific knowledge to both lay and scientific audiences (Gieryn, 1983, 1989). In Tyndall's view, science could compete with religion on the grounds of being practically useful, empirically sound, sceptical with respect to any authority other than the facts of nature, and free from subjective emotions. Confronted with the practical successes of Victorian engineering and mechanics, he described science as a fount of knowledge on which technological progress depended. It thus had to be represented as theoretical and

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[2] Galileo Galilei performed this separation in the realm of science by distinguishing between primary and secondary qualities of objects in *The Assayer* (1623).

systematic in the search for causal principles and laws, and as perfectly disinterested. Furthermore, science was to be understood as a means to culture. The genuine ambivalence of Tyndall's boundary work between scientific and social institutions was a product of the inherent tensions between basic and applied research and between the empirical and the theoretical aspects of inquiry in the 19th century.

In Tyndall's wake, the demarcation of science as an analytical problem preoccupied and even dominated the endeavours of philosophers of science, driven by different ideological commitments but all searching for essential properties that could demarcate science as a unique and privileged source of knowledge (Ravetz, 1991). In the tradition of the Vienna Circle of the 1930s, in their struggle against the dogma and metaphysics of clerical forces, science was the unique path to human truth and improvement, and the inductive method, based on repeated observations and experiments, was considered to be the only foundation for making general statements about nature.

Cognizant of the limits of empirical induction as a method for scientific investigation, Karl Popper invoked the moral quality of "daring to be shown wrong" and made it the core of a new approach based on the principle of "falsifiability". If a theory could not in principle be refuted (*i.e.* 'falsified') by empirical data, it was not scientific (Popper, 1935). In Popper's view, refutation could immunize science against all sorts of pseudo-scientific activities (such as socialism and psychoanalysis) emerging from the collapse of authority in central Europe after World War I.

In the early 1940s, in opposition to "local contagions of anti-intellectualism which could become endemic" (*i.e.* the rise of various forms of fascist and nationalist movements), the American sociologist Robert Merton expressed a need for a new "self-appraisal" of scientific practice and

knowledge, noting that the faith of Western culture in science was, in Veblen's words, no longer "unbounded, unquestioned and unrivalled". In his essay "The normative structure of science", Merton attributed to modern science a unique ability to provide "certified" knowledge, thanks to the institutionalization of distinctive social norms in the scientific community, in the form of a specific ethos that drove progress (Merton, 1973/1942). The ethical and epistemic value of science ensured by the Mertonian norms of communalism, universalism, disinterestedness and organized scepticism helped to delimit a "republic of science"—an autonomous community of peers, self-governed though shared knowledge and under no form of authority other than knowledge itself (Polanyi, 1962; Merton, 1968).

The ideal of separation between facts and values; the suppression of complexity in favour of certainty and objectivity; the identification of moral virtue with epistemic value and meaning; and the uniquely privileged position of scientific knowledge: these are the elements of a foundational narrative of scientific knowledge and investigation that defines the inherited approach to science for policy, in which science should "speak truth to power", providing neutral and objective evidence to support rational decisions in the form of logical deductions (Wildavsky, 1979). As we will see, this mode of demarcation of science is still invoked today in various ways, despite the radically different conditions in which it is applied and the growing conflict over the dual legitimacy system. A paradigmatic illustration of the persistence of this demarcation model was given when Professor Anne Glover, at the time Chief Scientific Adviser to the President of the European Commission, recommended that the incoming Commission find "better ways of separating evidence-gathering processes from the political imperative" (Wilsdon, 2014), as discussed elsewhere in the present volume (Chapter 2).

Hybridization: technoscience for growth, power and prosperity

Advancing along the narrative of innovation to the American post-World War II context, we find a different set of boundaries and balance of forces in play, provoking a shift in the modern ideal of science and the emergence of new demarcating principles. In his 1945 report "Science, the Endless Frontier", the first American presidential science adviser Vannevar Bush affirmed the primacy of basic scientific research as the engine of economic growth:

> *To create more jobs we must make new and better and cheaper products. We want plenty of new, vigorous enterprises. But new products and processes are not born full-grown. They are founded on new principles and new conceptions, which in turn result from basic scientific research. Basic scientific research is scientific capital. Moreover, we cannot any longer depend upon Europe as a major source of this scientific capital. Clearly, more and better scientific research is one essential to the achievement of our goal of full employment. (Bush, 1945)*

Bush's thesis is that the work of individual scientists as they pursue truth in their laboratories ultimately contributes to the common good by feeding into the technological development that stimulates economic growth. Bush evokes Tyndall's definition and legitimation of science as a source of knowledge for technological development. However, crucially, in this view science and technology no longer compete with each other for epistemic authority and material resources; rather, they become intimately related and jointly instrumental to the common goals of the production of goods and the creation of jobs. It was the early stage of a new type of modernity, based on the hybridization of science and technology in the name of technoscientific progress and its promise of unlimited wealth and prosperity.

In this process, 'science-based' technology is granted the epistemic and moral legitimacy of science and it becomes the incarnation of the Cartesian dream of power and control over nature. When newly elected American President Dwight D. Eisenhower gave his lecture on "Atoms for Peace" in 1953, the development of nuclear weapons was told as the first technoscientific story of emancipation, in the form of a promise that nuclear power would provide unlimited energy to people and nations (Eisenhower, 1953). The *New York Times* of 17 September 1954 reports this vision in a speech by the Chairman of the U.S. Atomic Energy Commission, Lewis Strauss:

> *Our children will enjoy in their homes electrical energy too cheap to meter […] will travel effortlessly over the seas and under them and through the air with a minimum of danger and at great speeds, and will experience a lifespan far longer than ours, as disease yields and man comes to understand what causes him to age.*

Technology thus became a source of wonders and unlimited possibilities, and science developed into "the art of the soluble" (Medawar, 1967); it became a 'normal', disenchanted, puzzle-solving profession, as described in the widely acknowledged work of Thomas Kuhn (Kuhn, 1962).

Early signs of a general transition from curiosity-oriented science, with its object of creating universal knowledge, to big, industrialized technoscience, with the function of producing corporate know-how, were given in 1961 in Eisenhower's "Farewell Address to the Nation":

> *Today, the solitary inventor, tinkering in his shop, has been overshadowed by task forces of scientists in laboratories and testing fields. In the same fashion, the free university, historically the fountainhead of free ideas and scientific discovery, has experienced a revolution in the conduct of research. Partly because of the huge costs involved, a government contract becomes virtually a substitute for intellectual curiosity.*

For every old blackboard there are now hundreds of new electronic computers.

In the course of this process of hybridization, the relationship between science, technology and society changed. As laboratories became testing grounds and applied science expanded into the real world, the inherently hybrid notion of 'safety' entered the scene, calling into question the values of the psychological, social, political and economic spheres and the facts of science.

The republic of trans-science

In 1962 marine biologist Rachel Carson published a volume about the possible side effects of pesticides. Evoking a distressing scenario in which nature would awake from winter without any bird to celebrate it, Carson's book *Silent Spring* fostered the emergence of the American environmentalist movement, triggering public awareness and concerns about the potentially devastating drawbacks of the chemical heroes of the Green Revolution and the fight against malaria. In his 1967 book *Reflections on Big Science*, American nuclear physicist Alvin Weinberg, administrator of the Oak Ridge National Laboratory during and after the Manhattan Project, cast doubt on the safety of civilian nuclear technology (Weinberg, 1967). A few years later, in an essay for a meeting of the American Nuclear Society, he described the wonders of nuclear energy in terms of a "Faustian bargain" that would demand unprecedented new forms of vigilance and longevity (stability and long-term commitment) in social institutions (Weinberg, 1994). In 1972, while studying the biological effects of exposure to low-level radiation, he took a further step towards recognition of the transformation taking place within science and technological development: in a landmark article in the journal *Minerva*, he proposed a principle of demarcation for a new class of problem that

he called "trans-scientific" and which was emerging as a consequence of big science (Weinberg, 1972):

Many of the issues which arise in the course of the interaction between science or technology and society — e.g., the deleterious side effects of technology, or the attempts to deal with social problems through the procedures of science — hang on the answers to questions which can be asked of science and yet which cannot be answered by science. I propose the term trans-scientific for these questions since, though they are, epistemologically speaking, questions of fact and can be stated in the language of science, they are unanswerable by science; they transcend science. In so far as public policy involves trans-scientific rather than scientific issues, the role of the scientist in contributing to the promulgation of such policy must be different from his role when the issues can be unambiguously answered by science.

Trans-science essentially breaks down the ideal separation between the facts of science and the values affecting policy decisions. The "republic of trans-science", in Weinberg's terms, has elements of both a political republic and a republic of science. The rights of its citizens are succinctly captured by Weinberg in the saying, "He whose shoe pinches can tell something to the shoemaker": this was possibly the first time the concept of 'stake-holder' was applied in this context.

It then became important to know how to demarcate scientific questions, which could be dealt with exclusively within the protected walls of Mertonian science, from trans-scientific ones, which required an opening of the gates. Moreover, the distinction itself was, of course, not a matter of experimental science.

At the same time, as "every old blackboard" was being substituted with "hundreds of new electronic computers", the world of statistical systems analysis was discovered, once again pushing scientific research out of the laboratories, this time into the world of computer simulations.

Harvey Brooks, solid-state physicist and administrator at Harvard, was one of the pioneers of this transition, as a member of the International Institute for Applied Systems Analysis (IIASA) since its foundation in 1972 and later chair of its U.S. Committee for more than a decade. In a letter to *Minerva*, in the same issue in which Weinberg coined the term trans-science, Brooks pointed out that understanding the evolution of complex systems governed by large classes of non-linear equations, which are at the heart of simulation models, was also a trans-scientific challenge, as it could not be addressed by science alone (Brooks, 1972). In the same year, the Club of Rome published the report "The limits to growth" (Meadows *et al.*, 1972). Based on the so-called World3 system dynamics model for computer simulation, the essay explored for the first time the global trans-scientific issue of how exponential demographic and economic growth interact with finite resource supplies. It was the beginning of the sustainable development movement.

In the transition to big science, not only did the boundaries of the republic of science become fuzzy and permeable; its inner structure, supposedly based on objectivity and neutrality, also proved to be questionable. The autobiographical account of the race for the discovery of DNA, published in 1968 by James Watson, exposed the highly intellectual and affective personal dimension to scientific research, revealing that bitter competition and acrimonious dispute were more nearly the rule in science than the exception (Watson, 1968). The influence of neither the inner, subjective world of emotions and passions nor the outer world of social, political and economic values could be ignored in the practice of science, as illustrated by Bruno Latour in *Science in Action* (1987), using this very example.

In 1974 American sociologist Ian Mitroff published the results of an extensive study performed at NASA, the

heart of another U.S. 'big science' project: the space explo-
ration programme in the race for the Moon. Based on a
substantial set of interviews with a selected group of
Apollo moon scientists, Mitroff uncovered the existence of
a deep-seated ambivalence among the researchers with
respect to the putative norms of science. The Mertonian
norms supposedly underpinning the curiosity-motivated
ideal of science were dynamically balanced by corre-
sponding counter-norms such as particularism (versus
universalism), solitariness (versus communism), interest-
edness (versus disinterestedness), and organized dogma-
tism (versus organized scepticism). The balancing of
norms and counter-norms was instrumental to surviving
in large technoscientific enterprises characterized by hier-
archical systems and high economic and political stakes,
and this skill defined a new model of entrepreneurial
technoscientist. A few years later, the Bayh-Dole Act of
1980 institutionalized this model by authorizing private
ownership of inventions financed by federal funding.

Towards the risk society

Uncertainty and complexity cannot be effectively ex-
ternalized from the realm of technoscientific endeavour.
They emerge in the interaction of technoscience with the
real world of social and ecological systems and in the in-
terplay between the individual and organizational dy-
namics of big enterprises. The modern ideal of science
'speaking truth to power' had to be adjusted to control for
this new configuration of forces. If uncertainty and com-
plexity could not be suppressed, they had to be operation-
alized, statistically controlled (by science), and openly
discussed (by parliamentary democratic processes), in
order for the dual system of legitimacy to be preserved.
The notion of 'risk', which could be technically assessed
and managed by scientific experts and exploited to speak
(a probabilistic) truth to power, was an unsuccessful at-
tempt to solve this emerging tension.

The 1979 nuclear disaster of Three Mile Island was the first prominent example of a 'trans-scientific' failure, in which technological breakdown was inextricably entangled with organizational and management malfunction. The event prompted sociologist Charles Perrow to define as "normal accidents" the inevitable, built-in vulnerability to collapse of tightly coupled, highly complex technological systems, such as nuclear plants (Perrow, 1984/1999).

In 1985, during his second term as Administrator of the U.S. Environmental Protection Agency (EPA), William Ruckelshaus admitted that many of the EPA's regulations depended on the answers to questions that could be asked of but not answered by science—that is, the EPA was dealing in the regulation of trans-scientific problems (Ruckelshaus, 1985). It was the beginning of the so-called "risk society", as defined in 1986 by sociologist Ulrich Beck in a work that treated the growing awareness that the goods and bads of technoscientific development were two sides of the same coin and that risks were woven into the very fabric of technoscientific progress (Beck, 1986/1992).

It was not only sociologists and public officials, but also natural scientists, who had to learn to deal with the risks and ambiguities of technoscientific enterprise and the new boundaries being traced along the trajectory of progress. In 1986, on a cold winter morning a few months before the nuclear catastrophe at Chernobyl, the NASA Space Shuttle *Challenger* exploded a few seconds after take-off, live on national television. In the aftermath of the accident, theoretical physicist and Nobel laureate Richard Feynman was called on to examine the causes of the disaster as a member of the Presidential Commission in charge of the investigation (later known as the Rogers Commission).

Following his investigation, Feynman famously recounted, again on national television, the physical causes

of the event: the lack of resilience and breakdown at low temperatures of an O-ring seal in one of the rocket boosters, due to faulty design, which caused a fatal leak of pressurized burning gas. However, in his minority report for the Commission (Appendix F to the main report), Feynman examined the causes at a different level[3], questioning the evaluation of safety and the risk assessment procedures within NASA. In his "personal observations on the reliability of the Space Shuttle", Feynman pointed out that the probabilities of failure—the risk of a fatal accident for the *Challenger*—were matters of "opinion" at NASA, ranging from roughly 1 in 100 in the estimate of the working engineers, to 1 in 100,000 in the evaluation of the management. A difference of this magnitude can only be explained in two ways. First, the managers of the project may have deliberately underestimated the risks, effectively lowering the safety standards to ensure the timely execution of the scheduled mission (and consequently the continuous supply of funds). This seems plausible, given that President Ronald Reagan was due to give his State of the Union address to the United States Congress on the day of the launch—a national technoscientific success would have been an outstanding achievement. The second possible explanation was an "almost incredible lack of communication" between NASA officials and engineers, due to the complexity and inefficiency of the Agency's governance structure. In either case, the causes of the *Challenger* disaster were to be traced to the inherent ambiguities and inconsistencies (the interplay between norms and counter-norms, in Mitroff's terms) in the political environment and in the organizational structure of the responsible institution.

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[3] Feynman's move to a higher level of organization in the search for the causes of the accident can be interpreted as a significant attempt to overcome the limits of the reductionist approach, within and outside the boundaries of the physical sciences. For an interesting account of this perspective see Fjelland (2015).

Interestingly, in the conclusion of his Appendix, Feynman refers to the "reality" of natural laws, which "cannot be fooled" by human interests, thus essentially appealing to the possibility and even the necessity of separating the facts of science from the values of decision-making (and giving facts the priority), in the name of technological safety. As an inquisitive, curiosity-motivated commissioner in charge of a public investigation, Feynman recognized the complexities and ambiguities of hybridized technoscience, but still fell back on the option of retreating behind the lines of Mertonian science to ensure that science remained the representation of both the True and the Good[4]. He effectively acted as a bridge between the first phase of modernity, based on the demarcating principle of separation, and another, involving the blending of science, technology and society (hybridization).

The Scanning Tunneling Microscope and the demarcation of nanotechnology: observing and manipulating

In parallel to growing tensions between science, technology and society with respect to safety, a vigorous demarcating effort was being made by the new entrepreneurial scientists to secure the material conditions and epistemic authority of their endeavours and outputs. Technoscientific development was promoted as a source of power and control over natural phenomena. A few months after the *Challenger* disaster, the 1986 Nobel Prize in Physics was awarded to three scientists: Ernst Ruska, Gerd Binnig and Heinrich Rohrer. One half of the Prize went to Ruska "for his fundamental work in electron op-

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[4] In his renowned lecture on "Cargo Cult Science", Feynman argued vigorously for a falsifiable science and for the moral commitment of scientists to do their best to falsify their own work, following a tradition of demarcation from Popper to Merton (Feynman, 1974). See excerpts in this volume (Chapter 2).

tics, and for the design of the first electron microscope" — work which was actually done in the early 1930s.

The other half went jointly to Binnig and Rohrer "for their design of the Scanning Tunneling Microscope" (STM), an evolution of the first electron microscope, capable of imaging individual atoms and bonds with a resolution up to 100 times higher than its predecessor. What is noteworthy is that the three physicists were not honoured for discovering new physical laws or phenomena, but for the invention of new fundamental tools for the visualization of the atomic world, developed for and patented by private companies (Siemens and IBM). In their acceptance speech, Binnig and Rohrer effectively define and legitimize (*i.e.* demarcate) their invention by skilfully navigating the ambiguities of hybridized technoscientific development. While describing the technical aspects of their instrument, they repeatedly emphasized the beauty and the wonder of atomic surfaces, appealing to the modern ideal of the scientist as an explorer of unknown territories, epitomized by figures such as Galileo and Robert Hooke. At the same time, they effectively evoked the technological power and heroism of space exploration, by transforming the arid diagrams of scanned atomic structures into black and white staged photographs of actual physical models, suggesting remote planetary surfaces (Figures 1 and 2)[5].
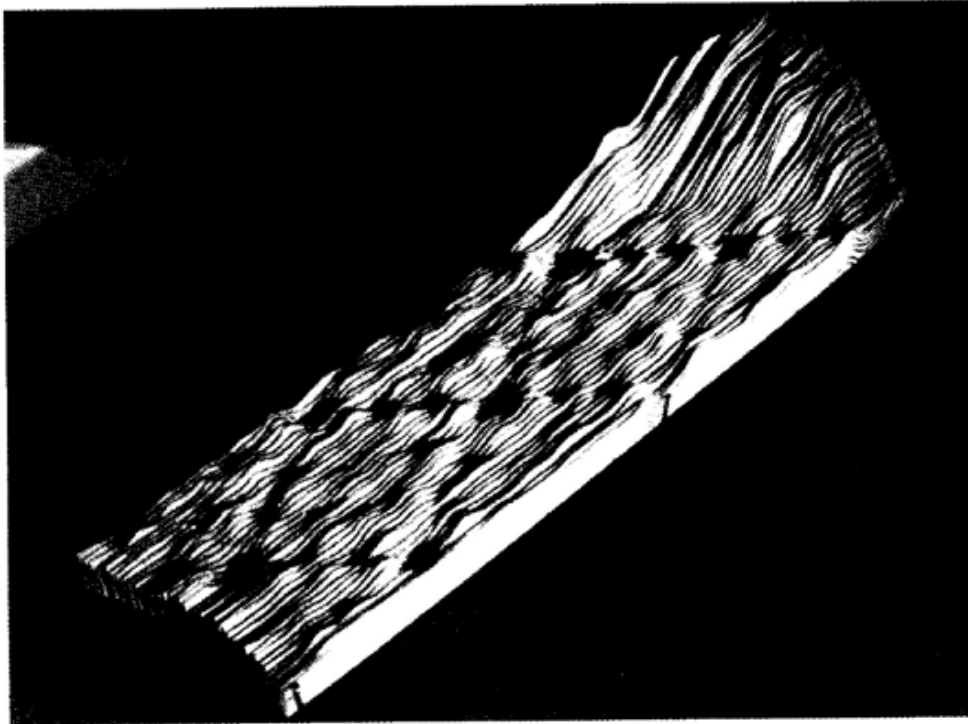
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[5] See Nordman (2004) for an account of the relation between the narrative of nanotechnology and space exploration.

Figure 1. Surface studies by scanning tunneling microscopy
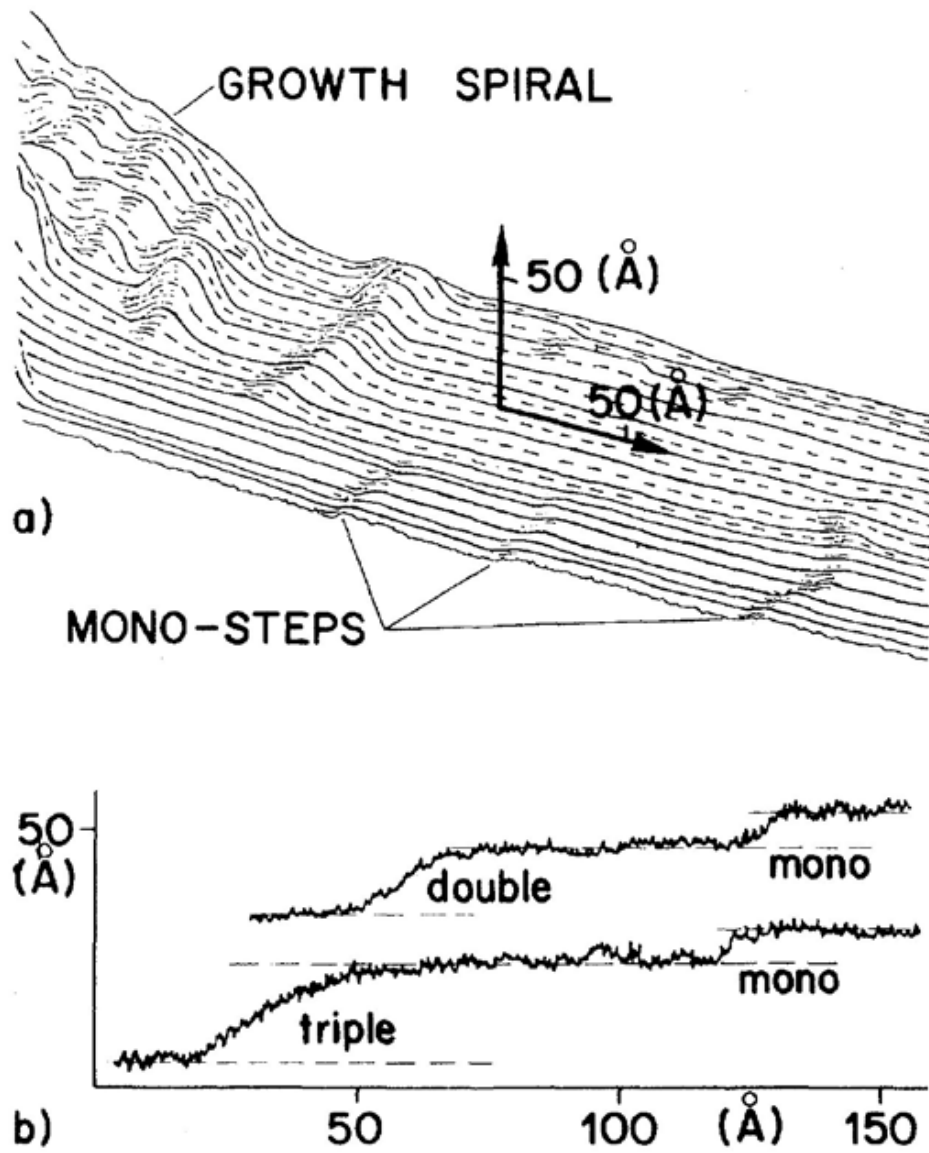
Source: Binnig *et al.* (1982).

Figure 2. The relief

Source: Binnig and Rohrer (1986).

Observing and intervening are inherently coupled at the atomic scale, given the dominance of quantum mechanical laws, so the ability to determine the position of individual atoms with controlled precision would require a further technological advance. Binnig and Rohrer address it towards the very end of their Nobel lecture, and Richard Feynman is invoked once again:

> *Besides imaging, the STM opens, quite generally, new possibilities for experimenting, whether to study nondestructively or to modify locally […] and ultimately to handle atoms and to modify individual molecules, in short, to use the STM as a Feynman Machine. (Binnig and Rohrer, 1986)*

The "Feynman Machine" is an explicit reference to a talk about the possibilities of miniaturization that Feynman gave in 1959 at the California Institute for Technology, entitled "There is plenty of room at the bottom". In that talk, he essentially advocated a fundamental shift from a

reductionist model privileging the use of theoretical, mathematical language to describe and understand the book of nature, to an instrumental and applied reductionism based on the development of new technologies for observing and manipulating matter at the atomic level.

> *We have friends in other fields — in biology, for instance. We physicists often look at them and say, "You know the reason you fellows are making so little progress?" (Actually I don't know any field where they are making more rapid progress than they are in biology today.) "You should use more mathematics, like we do." They could answer us — but they're polite, so I'll answer for them: "What you should do in order for us to make more rapid progress is to make the electron microscope 100 times better." […] The problems of chemistry and biology can be greatly helped if our ability to see what we are doing, and to do things on an atomic level, is ultimately developed — a development which I think cannot be avoided (Feynman, 1959).*

As a celebrated theoretical physicist who had given a Nobel lecture in the very same room in 1965 in respect of the discovery of quantum electrodynamics (QED), Feynman was ideally positioned to confer the epistemic and moral authority of Mertonian science on the new technoscientific endeavour of the STM. As a visionary figure bridging old and new phases of modernity, he functioned as a credible, propelling force for the demarcation efforts of the newly recognized nanotechnologists. In fact, Feynman's symbolic role was so effective that his 1959 talk was retroactively 'discovered' and became the foundational narrative of the field of nanotechnology[6].

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[6] Carefully planned and coordinated for more than a decade by the engineer Mihail C. Roco, the delineation of the field of nanotechnology culminated with the announcement by President Bill Clinton of the first federal government programme for nanoscale research and development projects, defined as the National

Meanwhile, the "Feynman Machine" became a reality in 1990, in the hands of another pair of IBM scientists, Don M. Eigler and Erhard K. Schweizer. Their achievement was announced simultaneously on the cover of *Nature* (Eigler and Schweizer, 1990) and the *New York Times* (Browne, 1990), with another iconic hybrid image (Figure 3), working at once as a representation of experimental scientific evidence — a number of xenon atoms purposefully arranged on a layer of nickel at extremely low temperature — and as a demonstration of corporate power — IBM conquering matter at its very core[7].

Figure 3. Cover of *Nature* 344(6266), 1990
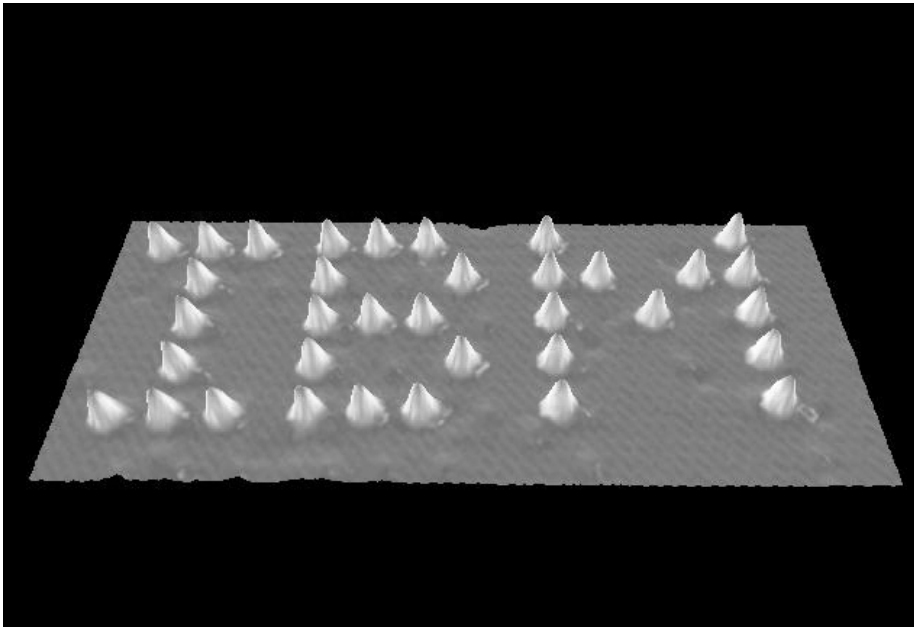
Nanotechnology Initiative, at the California Institute of Technology in 2001 (McCray, 2005).

[7] The image conjures up the American flag on the surface of the Moon, in a display of national power and in celebration of the American victory in the Cold War space race. Even more interestingly, it calls to mind the gesture of Hiram Maxim, the inventor of the first portable automatic machine gun in Victorian England, who shot the letters V.R. ("Victoria Regina") into a wall in the presence of the Queen, to demonstrate the military potential of his invention.

Precaution and post-normal science

While the atomic logo of IBM signalled a triumph of the Cartesian ideals of power and control, awareness of the possible unforeseen consequences of technoscientific development continued to grow. The public and political acknowledgement that "nature cannot be fooled" and that the modern ideal of separation of facts and values had to be adjusted in view of the pathologies of technoscientific progress predicated the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992. Also known as the "Earth Summit", the conference coincided with the emergence of the sustainable development movement. Principle 15 of its official statement, the "Rio Declaration on Environment and Development", introduced a political mode of demarcation, based on the notion of precaution:

> *In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost effective measures to prevent environmental degradation. (United Nations, 1992)*

The precautionary approach introduced the idea that science can be *temporarily* unable to produce a conclusive and exhaustive body of knowledge fit to serve as a basis for rational decision making. Certainty about the future consequences of action was substituted with quantitative, statistically manageable uncertainty—that is, with risk assessment and cost–benefit analysis. Through this "taming of chance" (Hacking, 1990), uncertainty was officially recognized as a third value, along with truth and falsity, in the realm of possible scientific outcomes.

Uncertainty was accepted, however, only as a temporary state of knowledge which was bound to shift sooner or later to one or the other value on the true/false scale.

Meanwhile, a political choice would have to be made in order to minimize the risk of harm to people and the environment, even if it implied a potential economic loss. The "endless frontier" of science-based technological progress and growth could and had to be temporarily circumscribed, until new predictive certainty could be achieved. The implicit assumption in this model is that any lack of knowledge can be reduced with time, resources and more computational power, leaving untouched the modern relationship between the truth of objective scientific knowledge and the good of rational, evidence-based decision-making. In other words, the precautionary principle can be interpreted as a technical fix to alleviate the conflict within the dual legitimacy system, without modifying its underlying assumptions.

Around the same time, a new mode of demarcation was proposed in the philosophical work of Silvio Funtowicz and Jerome Ravetz, under the label of "post-normal science" (Funtowicz and Ravetz, 1993). This approach held that uncertainty around a technoscientific issue cannot be treated as an independent variable and linearly reduced, as in the conventional approach associated with the precautionary principle. Rather, it must be understood to be closely related to the stakes involved and to be governed by highly non-linear, trans-scientific dynamics. When the stakes are low, as in confined laboratory science, the correlation is less evident, and uncertainty can be externalized with no visible effects; when the stakes are high, as they are in big technoscientific projects, the correlation is pronounced, and the consequences of disregarding uncertainty can be severe. In this perspective, the facts of science and the values underlying decision-making processes cannot be separated, and the decision-making process must be opened up to the participation of "extended peer communities" (De Marchi, 2015).

In tracing the trajectory of innovation along its course from science and technology we have witnessed a progression in three stages: first, curiosity-motivated science, competing with technology, metaphysics and the realm of human affairs for epistemic authority and material resources; second, basic science as 'scientific capital', underpinning technological development for prosperity and growth; lastly, big technoscientific enterprise, entailing inherent risks and drawbacks and the inevitable intermingling of facts and values. With the last shift, uncertainty and complexity cannot be fully and explicitly externalized, and conflicts consequently arise within the dual legitimacy system of the contemporary state.

At this stage, two main ways forward appear on the horizon. One corresponds to a commitment to abandon the delusive modern ideal of separation: this would be the continuation of the trajectory from trans-science to post-normal science. The other, representing the institutional and corporate reaction, focuses on implementing measures to contain the tensions, in order to preserve, and even reinforce, the modern power divide: this is the trajectory of quantified, operationalized uncertainty and complexity, based on (more or less) precautionary risk assessment and management. As we will see below, the current dominant narrative of innovation follows this latter path.

Substitution: innovation for growth and survival

Starting with the attack on the heart of the American financial system on 11 September 2001, the first decade of the new millennium was characterized by a growing awareness of systemic crisis, with economic, social, political and environmental components. Climate change, biodiversity loss, resource scarcity, the rise of terrorist movements and political instability became public and

urgent concerns to be addressed on a global level; in 2008, a financial meltdown hit the U.S. economy and propagated to the European Union, triggering the worst global economic crisis since the Great Depression of the 1930s.

In 2010, against this backdrop, Máire Geoghegan-Quinn was appointed Commissioner for Research, Innovation and Science of the European Commission—a post previously denominated "Commissioner for *Science and Research*". This shift, with science slipping quietly to the end of the title, corresponded to the advent of a new demarcating narrative, in which the term 'innovation' took the place, quite literally, of technoscientific development, not only as a source of growth, prosperity and social good, but also as a salvific solution to the ongoing crisis.

The naming of innovation as the engine of economic growth, social prosperity and environmental sustainability was the last semantic manoeuvre in a powerful and highly articulated narrative of progress intersecting with the trajectory of sustainability (Benessia and Funtowicz, 2015). Within this coevolving path, society has been asking science and technology to fulfil (at least) three essential functions: to increase or at least to sustain our wellbeing; to preserve us from the possible adverse consequences of our acting towards this goal; and to manage those adverse consequences or unfavourable circumstances, should they arise. The unchallenged economic policy aims of growth, productivity and competitiveness, reinforced by the globalization of the economy, are fundamental aspects of this relationship with science. In effect, if we accept these goals as a given for improving and extending human welfare on this planet, then we (continue to) set ourselves the paradoxical ambition to sustain a steady increase in global resource consumption within a closed, finite system with limited stocks and bio-geo-chemical resilience (Rockström *et al.*, 2009; Elser and Bennett, 2011; see the discussion in Chapter 1, this volume). The situa-

tion is becoming even more complex, as both the technological and ideological lock-ins of our life-support systems present us with a double-bind, quite painfully clear in the wake of the 2008 financial collapse: we cannot keep moving indefinitely along our current trajectory — but not doing so would jeopardize the economic prospects not only of future generations, but also, decidedly, of our own.

The narrative of innovation offers a repertory of potential solutions to this paradoxical situation. In particular, it counsels us to take into account an essential hidden variable, which Malthus proverbially overlooked: even though natural supplies may be limited, human creativity is *unlimited* and so is the potential to decouple growth from scarcity, improving efficiency in the use of natural resources and ultimately *substituting* them altogether with substantively equivalent, technologically optimized artefacts. At the same time, innovation is invoked to control and even eradicate complexity, uncertainty and the risk of failures through the implementation of effective *ad hoc* technoscientific fixes. The Cartesian ideals of power and control which were at the root of the transition to technoscientific hybridity have become instruments of economic and even of human survival.

In the European Union strategy for the second decade of the century, innovation is considered instrumental to achieving and nurturing "smart, sustainable and inclusive growth" (European Commission, 2010a). It is furthermore named as the "only answer" (European Commission, 2010b) to some of the world's most pressing societal challenges: "combatting climate change and moving towards a low-carbon society" (European Commission, 2011a) and managing the problems of "resource scarcity, health and ageing" (European Commission, 2010b). The principles of the so-called 'green economy' and the Ecomodernist Manifesto, published by the Californian Breakthrough Institute, provide other poignant, exemplary instantiations of

this Promethean approach (Breakthrough Institute, 2015; Lewis, 1992).

In addition, innovation is cast as the mainstream solution to the problem of sustaining growth in a hypersaturated market, with its potential to open up new avenues of competition and consumption and to populate them with new jobs and ever more seductive products and services. One of the seven flagship initiatives designed and launched to deliver on the objectives of the European Union's 2020 Strategy is the "Innovation Union", "aiming to improve framework conditions and access to finance for research and innovation so as to ensure that innovative ideas can be turned into products and services that create growth and jobs" (European Commission, 2010a: 3).

To all intents and purposes, this set of arguments is a reformulation of Vannevar Bush's ideals of science-based technological development for growth and prosperity, but, interestingly, the words 'science' and 'scientific' rarely figure in this discourse. Rather, economic growth and new jobs are produced by "research and innovation" which are transformed into "innovative ideas". In essence, the demarcating strategy is the same, but the object to be demarcated is different and vaguer. Moreover, the context in which the narrative unfolds is radically changed. In the post-World War II period, the American people were ready to welcome the great expansion of production with the enthusiasm of a new-born culture of mass consumption. The horizon of resource scarcity and environmental degradation was still far away. Moreover, in a period of peace, and while Europe lay in ruins, the USA could rely only on itself and the "endless frontier" of scientific and technological development.

By contrast, in the race for market share that characterizes the early 21st century, European technoscientific de-

velopment has to withstand the pressures of the global market:

> *We need to do much better at turning our research into new and better services and products if we are to remain competitive in the global marketplace and improve the quality of life in Europe. (European Commission, 2010a)*

The immediate post-war challenge to emerge and expand has by now turned into a struggle for economic survival. Sustaining growth requires competitive technoscientific innovation. In a lecture given in Brussels with the eloquent title "Winning the innovation race", Commissioner Geoghegan-Quinn made reference to this pressure (Geoghegan-Quinn, 2012):

> *There is no shelter for un-competitive firms or economies. Competitiveness is the new law of economic gravity, which no one can defy.*

Further, only innovation can bear the weight of this law:

> *And now it is knowledge and ideas that drive competitiveness, not tangible assets.*

The knowledge and the ideas evoked here are clearly still anchored to the worldview of Vannevar Bush. Once again, however, 'science' is completely absent from the stage: the term is not used by the Commissioner in her speech, other than to refer to the life and social sciences. This omission presages the beginnings of a significant new transition from 'science-based' technology and big, industrialized technoscience to a fragmented, broader ideal of creative research at the service of market-oriented technology. This embryonic new form of scientific research is related to the Victorian ideal of the practitioner/gentleman amateur, today embodied by the individual entrepreneur/do-it-yourself (DIY)/citizen/garage scientist (Ravetz and Funtowicz, 2015).

Finally, a crucial assumption must hold for this narrative to be viable: citizens of developing, developed and declining economies have to value and ultimately buy, both metaphorically and literally, the processes and products of technoscientific innovation. This means that societal expectations of the products have to be stimulated, and concerns about their ills deflected (European Commission, 2013; ESF, 2009).

In the words of Geoghegan-Quinn, in a short video interview at the Lisbon Council in 2010:

Innovation means that we bring all the wonderful scientific research that we have, all the way along a chain, until we get it into products, we sell it on the market. We develop products and create products that the markets are there for, and the people will want to buy. That is, at the end of the day, how we can develop research to retail. (Geoghegan-Quinn, 2010)

To sum up, innovation can now be defined as a process of creative (scientific) research that leads to the production of new technologies that sustain growth and ensure survival: through the optimization and the substitution of our natural resources, the creation of new goods and jobs, and the deployment of suitable silver bullets, protecting us from the complexity of socio-ecological problems as they emerge.

Technology, sustainability, growth and science thus comprise a constellation of dynamic forces in a space with mutable and ambiguous boundaries. To better understand the emergence and development of the current dominant narrative of innovation, we will focus now on how these forces have been operating and how the corresponding boundaries have been drawn. As we will see, new demarcating strategies emerge from these complex dynamics, based on a principle of substitution.

Smarter planets and the demarcation of the Internet of Things: decision making and data management

In the autumn of 2008, in the middle of the financial storm, the U.S. multinational company IBM launched one of its most ambitious global campaigns, based on the idea of building a "smarter planet"[8]. On 8 November, a few days after the election of Barack Obama to the U.S. Presidency, IBM Chairman and CEO Sam Palmisano presented his narrative of smart innovation in a fifteen-minute speech at the U.S. Council of Foreign Affairs (Palmisano, 2008). In his talk, the planet as a whole was described as a single, highly complex and interconnected socio-technical system, running at a high and increasing speed and demanding more and more energy and resources; climate, energy, food and water needed to be efficiently managed in order to meet the challenges of a growing population and a globally integrated economy; a number of sudden and unexpected wake-up calls such as the crisis in the financial markets had to be recognized as the signs of a dangerous fracture that had to be controlled; the leaders of both public and private institutions had to acknowledge this radical change and seize the opportunities offered by technoscientific innovation to "change the way in which the world works" (Palmisano, 2008). The planet was thus conceived of as a complex machine that would cease to function if not manipulated with the appropriate technological tools.

No sooner had the crisis scenario been presented than IBM's demarcating narrative of innovation moved straight to the resolution: namely, that we *already* have the technological power and control to turn our predicament into an opportunity. As the boundaries of our finite, physical world become more evident in the transition to an era of

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[8] IBM's "Let's build a smarter planet" campaign by Ogilvy & Mather won the 2010 Gold Effie Award in marketing communications.

resource scarcity, this narrative imagines a technoscientific transition to an apparently boundless universe of digital information, virtual connectivity and computational power, allowing us to optimize our way of living and become efficient enough to sustain increased consumption. The three fundamental axes of the new technological revolution are articulated by the terms 'instrumented', 'interconnected' and 'intelligent', which in combination define the notion of 'smart' and, in the context of the European Union, describe the so-called Internet of Things[9]. *Instrumented* reflects the indefinite proliferation and diffusion of the fundamental building block of the digital age, the transistor (up to one billion per human at the infinitesimal cost of one ten-millionth of a cent). As all these transistors become *interconnected*, anything can communicate with anything else. In this vision, we can monitor and *control* our planet with unprecedented precision and capillarity by causing the realms of the physical, the digital and the virtual to converge. Finally, everything can become *intelligent*, as we are able to apply our ever-increasing computational power to sensors, end-user devices and actuators, in order to transform the ocean of data that we collect into structured knowledge and subsequently into action.

Palmisano portrays this transition not only as possible and desirable, but also as required and urgent, both to prevent further collapse of our life-support systems and to sustain competitiveness in the global market:

> *It's obvious, when you consider the trajectories of development driving the planet today, that we're going to have to run a lot smarter and more efficiently — especially as we seek the next areas of investment to drive economic growth and to move large parts of the global economy out of recession […].*

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[9] The Internet of Things is defined as a dynamic global infrastructure of networked physical and digital objects augmented with sensing, processing and networking capabilities (Vermesan *et al.*, 2011).

These mundane processes of business, government and life —which are ultimately the source of those 'surprising' crises —are not smart enough to be sustainable. (Palmisano, 2008)

The implicit assumption in this speech is, of course, that the tools for new, *smarter* leadership required are techno-scientific and that IBM can deliver them.

The technoscientific narrative of a corporate marketing initiative depends intrinsically on the function of selling goods, as products and services, and might therefore not be considered representative of a deeper political, economic, cultural and existential transition. However, on the path-dependent trajectory of innovation, the same demarcating strategies can be found in private companies' plans for market share expansion and in public institutions' long-term engagements for the future, as both sectors are engaged in cultivating and surviving the overarching model of competitiveness and consumption growth[10]. It is the case in the EU 2020 strategy for "smart, sustainable and inclusive growth", which incorporates the Internet of Things pathway in one of its key Flagship Initiatives, the "Digital Agenda". In a three-minute video by the European Commission Directorate General for Information Society and Media, we find one of the characters expressing her concerns about energy management as follows:

It's crazy that we doubled our use of energy in the last fifty years. We can't keep this up. If we want to be smart about energy, we should let energy be smart about itself. (European Commission, 2012)[11]

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[10] In this sense, the difference between public and private becomes marginal as in both cases the subject of the demarcating narrative is not a product to be promoted, but a specific *kind of world* in which the proposed innovation is the only possible sustainable option.

[11] Female character no.1.

In this framework, leaders of firms, cities and nations are responsible *only* for choosing the most effective means of technoscientific optimization, in order for the system at stake to govern itself in the most efficient way. In other words, a radical shift is taking place in the dual system of legitimacy and its balance of forces, as political 'power' moves from reliance on scientific 'truth' as the basis of rational decisions, to delegating control over both the True and the Good to automatized technoscientific tools.

Three framing epistemic and normative assumptions need to be in place in order for this demarcating narrative to function. First, it must be accepted that the inherent complexity of the interaction between socio-ecological and technological systems can be reduced to a measurable set of simplified structured information. Second, the required 'facts' have to be equated with supposedly relevant data, filtered through the appropriate information technologies. Third, the *quality* of the decision-making processes must be completely independent of the normative sphere of values—a move which requires sufficient computational power to distinguish data from noise and to assign them a meaning that can transform them into an operationalized notion of knowledge. This overall scenario represents a transition from the ideals of separation and hybridization to a new demarcating strategy based on a principle of substitution, in which the normative sphere of politics and decision-making on public policy issues is reduced, hybridized and ultimately supplanted (substituted) by a technoscientific regime of data analysis and management.

Even more fundamentally, it is not only the issues which demand decision making that are transformed and reduced, but also the 'we' concerned by those issues. Indeed, the ultimate consequence of this set of assumptions is that the most effective decision-maker is in fact the fusion of a physical, a virtual and a digital being: a cyborg or a robot. IBM's supercomputer Watson, a "deep question

answering" (DQA) machine, which outsmarted its predecessor Big Blue by winning the U.S. TV game *Jeopardy!* is a clear, early incarnation of this idea (Thompson, 2010)[12].

Palmisano ended his 2010 speech at the Royal Institute of Foreign Affairs in London with these words:

> *Let me leave you with one final observation, culled from our learning over the past year. It is this: Building a smarter planet is realistic precisely because it is so refreshingly non-ideological. (Palmisano, 2010)*

The epistemic, normative and ultimately metaphysical framework of efficiency for smart and sustainable growth is presented by Palmisano as a modern, inevitable consequence of progress for the common good. If our world is a slow, obsolete and congested socio-technical machine ruled by the laws of thermodynamics rather than by those of governance, then (the promise of) technoscientific innovation to optimize its functioning becomes an objective necessity.

Conclusion

In this journey along the trajectory of innovation, we began by looking at science in the early phase of modernity: an oligarchic, exact, objective and uniquely privileged form of knowledge which should remain *separate from* the world of values and human affairs. We then transitioned into the phase of big, industrialized technoscience, in which science was *hybridized with* human affairs as a strategy to secure growth, prosperity and profit. Finally, we entered into a recent third phase, based on a principle of

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[12] Watson is conceived of and proposed as the best instrument to decide in highly complex and urgent situations, ranging from financial transactions to clinical and diagnostic decisions and the management of mass emergencies.

substitution, in which science *becomes* a human affair, defined as innovation: the unbounded, automatized tool for enhancing, treating and rescuing our slow, congested, analogue world.

Bearing in mind this progression, if we now fully accept the assumptions and promises of this last phase and imagine that all the issues regarding the inherent risks and pathologies of technoscience have been settled, we can reflect on the implications of this narrative of innovation: what kind of world is signified, populated by whom and with what consequences? Such a reflection will help to illuminate possible alternative trajectories and narratives.

Let us begin by revisiting the narrative of innovation proposed by the former CEO of IBM, essentially anticipating the EU Digital Agenda by two years.

In this perspective, we are compelled to logically deduce that the "mundane processes" of our professional, political and private lives have to be technologically enhanced (to become 'smart') in order to avoid a collective crash of the system. The crises we are facing are not at all surprising: they are caused by our own inability to cope with the overall complexity of the processes manifest in our world. Moreover, as we have seen, this technological upgrade is not only logically required, but also feasible and, above all, desirable, as it optimizes our ways of living, making life easier and happier.

However, if we look more closely at the implications of this demarcating narrative of innovation, a number of inherent contradictions emerge. First, the very same technologies that are designed to help us deal with complexity actually generate more: the intricate patterns of interactions and demands of this world, which we can supposedly manage only with the aid of ICT, are intensified by the real-time pervasiveness of the ICT itself. In practice, we

are being provoked to run faster and faster by technologies that were intended to help us catch up with ourselves. In addition, referring back to the ideas of Charles Perrow about the consequences of high complexity and tight coupling, we might deduce that this transition inevitably makes us existentially more fragile and vulnerable to technoscientific failures.

Second, if we fully embrace the technological upgrade and agree to delegate the management of the mundane processes of our lives to connected machines, then we are acquiescing to the idea that we should live in a world of happiness, in which we are never late, never lost and, most of all, never unprepared. This world would be a place in which every minute of our lives would need to be virtually controlled and functionally oriented. In other words, we *cannot* be late, lost or unprepared. It is a world, therefore, in which our relationship with the unknown is tacitly eliminated. This form of technological eradication of uncertainty entails renouncing one of the fundamental sources of human creativity and learning: our capacity to adapt to complexity and the unexpected (Benessia *et al.*, 2012). This in turn implies a new contradiction, intimately related to the first: what seems to make us safer and more efficient may be the cause of heightened vulnerability to change.

In this scenario, regardless of the initial conditions of our personal values, expectations and desires, the dynamics of our 'un-smart' and 'messy' planet compel us to delegate both our knowledge and our agency to the required technoscientific power and to embrace and creatively contribute to the accompanying inner transformation of living beings[13].

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[13] A fully analogous set of arguments can be articulated in relation to the technological platform of synthetic biology. See Benessia and Funtowicz (2015).

If we take these narratives seriously, the ICT-based social transformation becomes simply inevitable and moves beyond the limits of democratic discussion. More generally, if we revisit the main framework of the demarcating narrative of innovation, we find the same inevitability: there is no reason to collectively discuss the proposed technological transition, as we are supposed to want it, need it and be able to have it (Benessia and Guimarães Pereira, 2015). Inherently normative concerns are reduced to technical issues, and their technical solutions are framed in terms of economic feasibility, risk mitigation and public acceptance. In this sense, the democratic foundation of social and political action is replaced with the merely procedural coordinates of an essentially *win-win* scenario. Once again, in Palmisano's words:

> *Building a smarter planet is realistic precisely because it is so refreshingly non-ideological. (Palmisano, 2010)*

This reminds us of another key passage of Eisenhower's "Farewell Address to the Nation" (1961):

> *The prospect of domination of the nation's scholars by Federal employment, project allocations, and the power of money is ever present—and is gravely to be regarded. Yet, in holding scientific research and discovery in respect, as we should, we must also be alert to the equal and opposite danger that public policy could itself become the captive of a scientific-technological elite.*

A possible bearing for new narratives would be to challenge the inevitability of the current technoscientific trajectory of innovation and to collectively explore the normative space of values and political options, investigating the actual feasibility and desirability of the emergent technology platforms, in relation to *what kind* of world we want to sustain and *for whom*.

Indeed, the ultimate fate of any innovation fundamentally depends on identifying *what* the goods and the bads

actually are and *for whom*, at any given time. The quality of a technological innovation is a function of the underlying driving forces and how its effects are valued. If we deconstruct the dominant framing of innovation, we may find a collective democratic space to discuss different criteria of quality. For example, do we think that it is feasible and desirable to give up diversity, individuality and our relationship with the unknown in the name of efficiency and functionality, or to subordinate living to functioning? Do we believe that it is the only possible solution for our current predicament?

More generally, the question becomes: what categories are needed to describe *what* needs to be transformed and *how*? *Who* decides on the definitions to be adopted for the various categories? Reflecting on these questions makes it possible to explore alternative trajectories for innovation and to redefine the criteria to assess its quality[14]. Robust and resilient innovations can only emerge from opening up the collective space of options for both the framing of the problems to be resolved and the tools proposed to resolve them. This process will require reflection on our relationship with life-supporting infrastructures and processes and with the other living beings (including humans) that we implicitly include or exclude when we say 'we'.

In light of these considerations, the historical exploration of the trajectory of innovation that we have undertaken becomes an instrument to foster awareness of where we find ourselves along its path, so that we might collectively choose whether and how to intervene to modify its dynamics. As we have seen, terms like science, technology, democracy, ideology and sustainability are constantly

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[14] For an account of how this approach can be applied to the case of biotechnology for food production, see Benessia and Barbiero (2015).

being redefined and re-legitimized along the path, using various demarcating strategies, for various purposes, in various contexts.

For example, if we consider the democratization of science from the point of view of subscribers to the prevailing narrative of innovation, we might be inclined to value its potential to increase public engagement and participation. However, if we look at the same issue through the lens of our narrative of demarcation, we might realize that what is being democratized is a specific, normatively fixed ideal of scientific research and practice, predicated on the eradication of complexity and applied to an equally specific, normatively fixed and mechanically standardized and optimized ideal of living. Being more aware of this constant process of demarcation and redefinition might allow us to develop new tools to understand where we are actually heading and to open up a democratic space for the plotting of alternative routes.

Acknowledgements

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