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SOCIETY IN THE FACE OF SCIENTIFIC AND TECHNOLOGICAL DEVELOPMENT: RISK, DECISION, RESPONSIBILITY

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The evolution of science and technology – and of their interactions with the general life of society – have accelerated tremendously over the past few decades.

Science has had a strong influence on the history of humanity: on the one hand, by clearing man's access to a better knowledge of the universe and improved understanding of its mechanisms, and on the other, by placing at his disposal the means which, by way of the development of techniques and technologies, have revolutionised living conditions.

The *growth in knowledge* is unequivocally a good thing which becomes part and parcel of cultural development. The same does not apply to the *usage of the means* generated by this knowledge. Humans can indeed use these for good, but also, unfortunately, for evil. Side by side with the immense *progress* achieved, for example, in systems of communications between people (in transport, telecommunications and so on), in agriculture, health, in the production of energy and materials, great harm on just as enormous a scale results from the increased efficiency of the means of destruction. The *risk of diverting knowledge and new technical prowess towards evil*, when they can be otherwise bring progress or are even primarily developed for such progress, undoubtedly exists. But there is more to this. *Any construction or accomplishment* (for example, large public works projects, means of communication, energy production developments, even medical operations and so on) *entails a risk*. *Any action entails a risk*. Taking the point to the extreme, *anything produced involves a risk* (it is the dose that makes the poison!). Man has been confronted with risks since time immemorial (floods, epidemics, earthquakes, wars and so on). However, with

industrialisation and factors like the concern to take accidents at work into account or the development of insurance, and, moreover, with changed attitudes, today the notion of risk takes on an increasing importance in daily life, in everyday concerns and in the media, and, with the veiled disquiet induced by present day crises, society's very conception of danger is changing. True, there are indeed objective grounds for all this, but also showing through is a loss of confidence in the future. However, many signs should be leading us to look on this in a more optimistic light. To cite just one example, life expectancy which in part takes account, at the population scale, of the whole range of attacks to which it has been exposed, has risen spectacularly since the beginning of the century.[1] The corresponding epidemiological data are not well known to the public and there are many who believe that the general level of health has been adversely affected by repercussions from technological activities whereas in fact it has never been better. The overwhelming majority of harmful effects on health are, at least among the French, linked to behaviour (lifestyle, tobacco use and so on) and not to the environment in which they live. Here I quite happily quote Maurice Tubiana:

> All innovations, whether they concern technologies, food or products, and also behaviour and practices, are today subjected to constant criticism which weakens decision processes and destabilises the decision-making powers. What in this criticism are the relative weights of uncertainties and indisputable facts? Is it a consequence of a growing trepidation among people or does it result from the rise in power of a certain number of counterbalances? Does it stem from advances in prevention, which mean that the smallest anomalies are now detectable? Or, again, does it come from new principles for action elaborated in order better to preserve the living environment of future generations?[2]

For my part, I am convinced that the current feeling of disquiet, pessimism, and the malaise created by an emphasis on the immediate rather

[1] I refer to 'Risque et société', edited by M. Tubiana, C. Vrousos, C. Carde, and J. P. Pagès, *Symposium Risque et Société* (Nucléon, Paris, 1998). See p. 24:

Life expectancy at birth

1900		1980		1997	
M	F	M	F	M	F
44	45	70.2	78.4	74.2	82.1

[2] See (1) above and (2) M. Tubiana, *L'éducation et la vie* (Editions Odile Jacob, Paris, 1999).

than on the future, essentially results, for many of our contemporaries, from a loss of solid references such as religious, moral, family or national ones.

If we stick to everyday language, the notion of risk is quite simple. It bears on a potential danger, a potential peril, that could result from a given action envisaged that would or would not be given the go-ahead. To varying degrees, people will count on *beneficial* effects and fear *unfavourable* consequences. Put in this straightforward way, certain comments or questions arise.

Are the *benefits and risks clearly set out?* Has the presentation so expounded been arrived at through a process of *rational reflection* properly conducted and founded on *established experimental facts?* Or does it come from the attraction for *short-term gratification* without taking account of *medium – and long-term – consequences* (the pleasure of driving at high speed, drugs and so on)?

Is it a question of an *individual decision* within the reach of the individual or of a *collective decision* involving public powers (as in for instance the construction of large infrastructure projects, or health policy)? The probabilities brought into play will not be the same; I would even go so far as to say that, in the second case, on condition that certain thresholds are respected regarding the protection of individuals, the decision maker will work more on mathematical expectations focused on the community level rather than on individual probabilities. In the case of decisions that must be taken regarding projects affecting the community, it must be realised that, even if technical feasibility studies are conducted with the greatest care and lead to clear conclusions, there remains, for them to materialise, a stage which takes into account *economic* (cost, viability in competition with other projects and so on), *social* (such as people's wishes, acceptability by society), *political*, *moral* and other considerations. In this process, the roles of each actor – scientist, expert, politician and citizen – should be distinguished, although evidently one person may have more than one role. As Jean-Yves Le Déaut, Chairman of the Parliamentary Office of Assessment of Scientific and Technical Choices (France), has said, the politician's responsibility is a particular one: 'There is limited room for manœuvre: a policy of *prevention* (when the danger is known), even though necessary in the greatest number of departments, is neither possible nor sufficient. There are constraints that could hold a decision in abeyance: scientific knowledge on a subject evolves very rapidly; at the time when a decision must be made, this knowledge is not fixed. The time for action is short, with set limits; the time-scale for

acquiring scientific knowledge is very long, expanded and "hard political decisions must be made on soft scientific certainties".'[3]

It is in order to handle these uncertain situations that the precaution *principle* was developed. This appeared on the international scene at the moment when fears were first expressed about *climate changes caused by the greenhouse effect*. The Rio Declaration of 1992 stipulated: 'If there is a risk of serious or irreversible harm, the absence of absolute scientific certainties must not be used as a pretext to postpone the adoption of effective measures aiming to prevent degradation of the environment.' France is one of the few countries to have introduced this principle into its legislation. The Barnier Law of 2 February 1995 on the strengthening of environmental protection stipulates that 'the absence of certainties, taking account of scientific and technical knowledge of the moment, must not hold back the adoption of specific measures, taken in proportion, aiming to prevent risk of serious *and* irreversible damage to the environment for an acceptable economic cost.' There is a certain discrepancy here between the Rio Declaration which talked of serious or irreversible harm and the French law which says serious *and* irreversible. In addition, the Barnier Law states that the cost must be economically acceptable and recommends that the measures to be taken should be in proportion to the risk. Such proportionality would necessitate an assessment of the size of the risk and the cost of the measures.

These aspects could be discussed in order to gain a perception as to whether, given the scientific uncertainties that exist and the need for research and for additional observations, to which no definite lengths of time can be attributed, the precaution principle is a *legal* principle, an expression of *common sense* or a *rule of ethics*. It seems that depending on the classical approach founded on the link between scientific knowledge and action, the idea of precaution should, at Rio, have led to two decisions:

1. To extend to their maximum potential scientific studies on the relations between human activities (production of CO_2 and other greenhouse gases) and climatic modifications.

2. To study the means of production of sizeable quantities of energy without carbon dioxide emission and to encourage them.

In all cases, 'zero risk' does not exist, and one is still made to wonder if

[3] 'Political Responsibility in the Face of Risk Management', 'La responsabilité politique face à la gestion des risques', paper by Jean-Yves Le Déaut, symposium *Risque et Société,* mentioned in (1). See p. 264.

a risk is acceptable considering the anticipated *benefits*. But *what is meant by acceptable risk?*[4]

This is a complex question: a *government* that decides on large infrastructure projects (for energy, transport, civil engineering works and so on) is not in the same *position* as a *judge* who has the duty, some years later, of declaring a verdict on a question (a lawsuit or complaint before the courts) involving a development of that kind. Let us briefly analyse this point.

In the first case, the notion of *risk* is linked to the idea of *choice*. Before the final decision is taken, it is essential to define all options that could possibly be suitable. In a given situation, or confronted with a given problem, these are:

– To do nothing, let the situation 'rot' and take its natural course. Whether deliberate or the fruit of a certain unconscious passiveness, this attitude is indeed a choice in the sense that it will leave its mark for the future and there will be *consequences*.

– To weigh up several different solutions. Each will have its attendant *hope of benefits and fear of risks*. It makes no sense to fix attention only on the benefit and risk relative to just one of the possible solutions: they must be compared with benefits and risks associated with other solutions, not forgetting the one that entails doing nothing. Before proscribing a technology in order to eliminate the risks, the question must be asked if, by doing so, we are not condemned to accept another at least as dangerous, if not more so. For example, an unreasoned hostility to nuclear energy must not be allowed to obscure the fact that coal burning liberates carcinogenic products and intensifies the problem of carbon dioxide.

Risk-benefit analysis is made more difficult as the number of highly diverse factors increases: advances anticipated, people's safety, economic repercussions, acceptability among the populations concerned, and so on.

Moreover, it has to be noted that a quest for ever increasing *safety* in a given field in the end generates costs which rise extremely rapidly (safety has no price, but it has a cost!) and, beyond a certain degree of safety, it is reasonable to wonder if it would not be preferable to allocate additional sums to other needs of humanity, for example to other domains where safety is less well assured.

[4] On the notion of acceptable risk, here I am taking up again and adding to some ideas I aired during the 1996 Plenary Meeting of the Pontifical Academy of Sciences in a paper entitled: 'Science and Society – Reflections on the Evolution of their Interaction and on their Consequences for Culture and Education'.

A point which appears to me essential is that the choice made at the moment the decision is taken, even if it results from the then most objective and far-reaching study possible, will only prove itself to be a good one if the processes it sets in train are watched rigorously so that the conditions required for it to run smoothly are constantly met and the safety rules enacted are continually updated so that benefit can be gained from experience.

In the second case, involving the judge, the situation seems to be different because it does not entail comparison between several possible policies in order to choose one, which, rather, is the domain of the legislature and executive authorities. Instead, it involves saying if, in the actions carried out, the law has been complied with, the regulations observed, the official safety standards met, and whether or not the people involved have fulfilled the duties assigned to them among their responsibilities or could, instead, be guilty of professional misconduct.

In order to make a judgement on an action, it is absolutely essential *to base deliberations on scientific and technical knowledge as well as on the corresponding legislation in force at the moment of the action, not at the moment of judgement.* As for the issue of 'precaution and law of responsibility', I think it important to quote from a text by Marceau Long, Honorary Vice-President of the Conseil d'Etat, (which is taken up again in that Council's report of 1998): 'I am, for my part, sensitive to all that precaution brings to us. My personal conclusion is, however, that even if it is incorporated in the legislation, it is still only a political principle. Although precaution does not protect us completely from risks, it can sometimes allow us to escape from them, or much more often to avoid or soften their harmful consequences. We have to be careful not to derive from it too hastily the converse of the principle: if harm has been done, there has been a lack of precaution, and avoid making from this a foundation of responsibility.' It must not be allowed to happen that according to a notion of '*responsibility without fault*' someone might be responsible for what he *had to know*, which is quite usual, but also for what generally *had or should have been suspected*.

Let us come back to the *probabilistic* aspect of risk. In anything that is realised there exists a 'residual' risk 'due to chance' resulting generally from the chance succession of unfortunate events, each one haphazard in itself, none of which, most of the time, are particularly serious, but which, happening altogether, can lead to a disaster. It may be that if just one of these events were not to occur, that would be enough to preclude an accident. Quite astonishingly, *probabilistic risk analysis* was developed only in the early 1970s, with the report of N. Rasmussen, of the US Nuclear Regulatory

Commission. This report drew up the first general analysis of nuclear power stations. It examined a very broad spectrum of possible accidents, given the probabilities of occurrence of corresponding scenarios, and assessed the repercussions. Probabilistic methods have been applied in a great diversity of fields. They bring into play the systematic study of *fault trees, accident initiators, status graphs and so on*.

A certain reserve that could be termed 'popular' has emerged concerning probabilistic methods. This, generally speaking, results from two kinds of reasoning.

On the one hand, the notion of probability is not always well grasped. On tossing a coin, if we have found heads 100 times, we often think that tails will come up – and in doing so forget that, as Joseph Bertrand put it so well. more than 100 years ago, 'the coin has neither *memory nor conscience*'.

Another, deeper problem comes from the fact that the accidents that are considered correspond in general to very small risks: their *probability* is very small and the notion of *frequency*, much more meaningful than that of probability, is practically inaccessible on the scale of a human lifetime.

Among the specialists, much attention is given to the following point. Work is performed on *models*, for example models of existing nuclear power stations, whose operation and safety we want to monitor more effectively and improve, and for which we have feedback from experience, or models linked to 'virtual power stations' if there is a question of new installations being planned. Naturally, these models must be improved continually and it is, in particular, essential to make sure with the utmost care that one has not considered as independent certain faults which are in fact linked. The probability of finding oneself faced with the simultaneous faults of three *independent* organs each having a probability of 10-3 is 10-9. On the contrary, if these three faults are a *consequence of* each other, this probability stays at 10-3. This is the problem of the screening of all problems of common origin, associated with the breakdown of shared feed systems, or with a fire, and so on. At present, on passenger aircraft each hydraulic control system is installed in triplicate. It is clear that the considerable gain in safety resulting from this *redundancy* would be cancelled out if they had a common feed mechanism, the failure of which would paralyse the systems simultaneously.

What is the significance of the probability values that result from the probabilistic analysis? What, for example, is meant by saying that the probability of a total loss of control of an airliner is in the order of 10-9/hour? It must be realised that such figures are linked to the study of models, which

makes them more of relative value, even if these models are, as it happens, improved unceasingly by feedback from experience. However, if, by using the same model, we gain a factor of 10, we can admit that the safety has by the same token increased by a factor of the same order. In this way, the analyses that entail the use of these methods are important as starting points for improvements in safety.

The various people involved in decisions regarding the problems already referred to are all, to a varying extent, confronted with the notion of *responsibility* in the broadest sense of the word, not only of *justification* if afterwards they are called to account in the courts, but also of *action* in the sense of an objective to achieve, of an advancement to promote, or of a *mission* to fulfil. The responsibility can take a variety of forms depending on the nature of the question it relates to: the *responsibility of the 'scientist'* if it is a question of declaring on the state of the science involved; *the responsibility of the technical expert* for equipment and installations; *the responsibility of the judge* who applies the law; *the responsibility of the politician* who has to govern while taking full account of several aspects such as budgetary, sociological and international situations; and, of course, *the moral responsibility* from which nobody can be exempt. Naturally, one and the same person may be vested with more than one of these responsibilities at once, to varying degrees. The need for the clarity of a situation and well-prepared decisions, however, calls for a precise unambiguous description of the mission assigned, in the name of the knowledge and skills, and in virtue of the mandate, through which each player expresses himself. If a politician calls on *the expertise of a scientist and a technical specialist*, the latter must brief him on the state of current scientific and technological knowledge, possibly on the uncertainty attached to this knowledge, and on studies that could reduce this, while holding back on any input related to his own philosophical, political or other points of view. Naturally, the person who has the duty to decide must combine the arguments advanced by the scientists and technical experts with input that bears on economic, political, social and other motivations. He takes the decision and is responsible for it. The part played by each actor is thus defined, transparency is possible, and, probably, the decision is made under favourable conditions, with the responsibilities of each of these 'agents' clearly marked out.

To finish, I would like to stress the role that the scientific community, the universities and the Academies of sciences should play, *without compromising on the fact that risks are real or that they should be assessed in a reasoned way*, in assuaging the excessive and often irrational fears current-

ly expressed which, indeed, can paralyse any zest for research and enterprise. The role seems to me to be a dual one:

– on the one hand, *to enlighten public opinion* on the exact current state of up-to-date scientific knowledge available that is relevant to large projects underway by scrupulously distinguishing what science can and cannot say and by indicating what types of research could improve this knowledge. This contact with public opinion can pose problems for scientists because high levels of ability to explain and instruct are needed to find a common language, but it is essential to make the effort;

– on the other hand *active participation is needed in training young people, either directly or through their involvement in elaborating study programmes*. I believe that it is essential, in today's world, to develop experimental sciences to develop contact with real situations and, also, to cultivate a critical mind to enable people to sift and make proper sense of the enormous mass of information, truths and counter-truths which surge onto the scene.

I still believe that our young people are not put into contact early enough with the notion of *probability*, by which I mean the deep sense of what probabilities, statistics and related conceptions really are.

I have no doubt that if 'probabilist culture' was more widespread among the public and in the media, there would be less talk of the mysterious 'serial law'. This translates the idea that a catastrophe is not an isolated event in time. That could be described in considering the models that envisage the intervention of catastrophes occurring at random instances (Poisson) such that each of these instances would be associated with a cluster of concomitant catastrophes happening in a short period of time.

It appears to me highly important that students who do not intend to enter the scientific professions (aiming for fields like law, literature, the arts, medicine or the media) should receive the benefit of a good grounding in the processes and methods of science, incorporated into their courses, in the same way as they do for the development of their own culture. This does not mean going through in detail for them any particular chapter of science, but enabling them to capture the essence of scientific thought, of the way it has evolved, and its integration in the general body of knowledge.

Finally, in closing, I would like to stress one important point. That is, the weight which is attached to the problem of a rational assessment of risks in any action which is undertaken in the interest of ensuring a *development which is sustainable*.