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Risk - A Subjective Notion Differently Perceived

Le risque - une notion subjective différemment perçue

Risiko - ein subjektiver unterschiedlicher aufgefaßter Begriff

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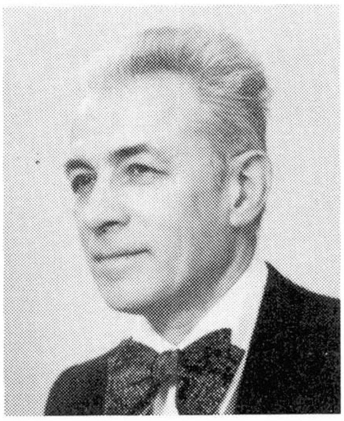

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SUMMARY

This introductory paper proposes a few thoughts on the perception of risk in individual life as a member of society, in the face of development and economic constraints, and in engineering activities. The accent is placed on a general transition from determinism to probabilism in many domains of man's endeavours and on the rôle of engineers in promoting safety. A plea is made for the development of the individual sense of responsibility as the most efficient way of meeting accepted risks.

RÉSUMÉ

Cette contribution propose quelques réflexions sur la perception du risque dans la vie individuelle, dans la vie en société, en présence de contraintes de développement et de contraintes économiques et dans l'activité de l'ingénieur. L'accent est mis sur une transition générale du déterminisme au probabilisme dans de nombreux domaines de l'entreprise humaine et sur le rôle des ingénieurs dans l'amélioration de la sécurité. Un appel est fait pour le développement du sens individuel de la responsabilité, qui apparait comme la façon la plus efficace de faire face à des risques acceptés.

ZUSAMMENFASSUNG

Dieser Artikel beinhaltet einige Überlegungen zur subjektiven Risikowahrnehmung vor, als Mitglied der Gesellschaft angesichts der allegemeinen Entwicklung und wirtschaftlichem Zwang sowie im Rahmen von Ingenieurtätigkeiten. Das Schwergewicht liegt hierbei auf einem allgemeinen Übergang vom Determinismus zum Probabilismus in vielen Bereichen des menschlichen Strebens sowie auf der Rolle des Ingenieurs als Förderer der Sicherheit. Die Entwicklung des eigenen Verantwortungsbewußtseins wird befürwortet als die beste Art und Weise, akzeptierten Risiken zu begegnen.

1. ETYMOLOGY

The organizing committee of the International Colloquium on Ship Collision with Bridges and Offshore Structures has honoured me in asking me to prepare an introductory paper for this symposium. For the sake of brevity, I choose to use no illustrations, only a few tables and to make no references.

Having to affront the peril of discussing risk, it is perhaps well that I make first an attempt at finding out what risk means. Dictionaries define "risk" as: "the chance of injury, damage or loss", "danger, inconvenience, more or less foreseeable". The word might stem from the latin "riscus" or "resecare". In turn, we find that "riscus" means an object made to contain jewels, clothes ..., and that "resecare" means to sever, to shorten, for example: "collum resecare", to sever the head (Seneca). Also, "risk" might come from the French "risque", for which Latin dictionaries give the equivalent of "alea", for example: "alea belli", the risks of war (Varro). Interesting is the synonym "periculum"; "rem periculi sui facere", to undertake something at one´s own risk.

This little etymological trip was only meant to introduce the character of risk: (1) risk is not easy to define; (2) risk is a subjective notion, associated with fear that an unwanted event may occur: for example, losing one´s jewels or having one´s head severed; (3) risk is associated with randomness (alea).

My modest purpose, in this talk, is to develop the subjective and aleatory character of risk (sometimes, I shall substitute the opposite of risk: safety) in some domains:

- individual life,
- life in society,
- risk/safety with development and economic constraints,
- risk/safety in engineering,
- and, as a peroration : imposed safety against self-responsibility.

2. RISK IN INDIVIDUAL LIFE

The sense of risk is not, by and large, innate, but acquired by experience in life. To be sure, the instinct of fear corresponds to a broad perception of risk and, perhaps, in some cases, to a more precisely defined danger. I have read (a long time ago, so that I cannot make the proper quotation: Julian Huxley?) that the feeling of free-fall, which sometimes wakes us up, comes down from our ancestors, small mammals, which slept in trees to avoid predators. The fact that the species which survived were those having the keenest perception of falling and the reaction to grab for support is sufficient to explain the hereditary transmission of that perception and that hereditary transmission has nothing to do with the experience gained by the animals, i.e., that, if they fell from the tree, they would probably end up being eaten by predators.

Infants have no sense of risk. They have to be taught what represents a danger. Even if not taught, however, a normal human eventually develops a substantial sense of risk, by experience (unless some early risk is fatal to him; present aborigines show this to be true). But, a complete "imbecile", left to his own devices, might never acquire the broad notion of risk and, therefore, we may say that risk may never "exist" for him. There are such "imbeciles", as we shall see in a moment.

The last statement may shock you. However, you will agree with me that many (not to say, most) of us are impervious to the notion of risk when we act on our free will. Examples are easily found: most ordinary citizens do not check that they may be short-circuited when working on the house electrical lines or appliances (not so many years ago, a famous singer was electrocuted while removing a bulb, both his feet in his bathtub), or that their chain saw does not drive the chain when the engine is at idle speed. There are also people - a fair percentage - who, not only go skiing, but even fight to get a reservation to some resort, returning, as a final result, with a broken limb. I found statistics of accidents for a Western European middle-sized country, for the year 1977, which indicate 13,000 deaths by accidental fall.

In opposition to the sense of risk, there is the feeling of safety, which we derive from experience, even more so than the sense of risk, since most of our actions are safe. We use public - or mass - transportation, on land, on the water or in the air, without particularly worrying about the accident rate involved. Here, we - not quite as complete "imbeciles", but like sheep in a herd - implicitly accept risk.

But the "activity" which tops them all, for our purpose, is driving - or riding in - an automobile. In a certain country of around 50 million inhabitants, there were 12,500 killed two years ago (1980) in automobile accidents. If all these inhabitants had been driving or riding in automobiles, this would give a yearly death rate of 2.5 deaths per 10,000 people. But, people, especially if we consider the whole population, do not spend, on the average, one hour a day, all year round, in their car (meaning more than 18,000 km car travel a year), while 8 hours a day are spent at work. So, compared to death by work accidents, the auto death rate, in the (real) example is over 10^{-3} deaths/person-year. As we shall see later, this compares very "favourably" with the rates of all kinds of industrial endeavours. There is more : for the same year, in that same example country, there were more than 300,000 wounded in automobile accidents. Say, that out of these, 125,000, or less than one-half, were seriously injured, as would be the case for recorded accidents at work, then the auto rate is 10^{-2} accidents/person-year, a rate that beats, by far, any record in industry. For car drivers and passengers, we might say that risk does not exist. Yet, who would be so idealistic as to believe that, today, he can educate his fellow beings in automobile risks? We should never forget such figures of self-imposed risk in discussing other aspects of risk perception or, more positively, of safety enhancement.

3. RISK IN SOCIETY

The perception of risk in society evolves under three influences which are: (1) groups of "users of safety" - that is, people engaging in some activity for a salary, or who feel that some activity in which they do not take part may impinge on their safety - exert a pressure to obtain an increased safety; (2) national and international regulators have the vocation of ensuring safety; (3) the prevention of accidents in industrial undertakings is of paramount importance for humanitarian, employees' morale (with increased pressure for improvement), image, and economic reasons.

Users' pressure invariably comes from some responsible people in a group who make a speciality of looking after the safety of the group, rather than from individuals in their separate ways. In this case, like in the case of regulators and that of a company working for increased safety on humanitarian grounds, the altruistic aim is to protect the individual better than he can protect himself, a situation very akin to teaching an infant not to put his fingers into an electrical socket.

This attitude has a somewhat self-defeating tendency, asking too much from the entity "society" and not enough on the part of the individuals, in what should be a common effort to improve safety. In group action, too much results from attractive slogans for factual aspects of risk to be perceived.

On the contrary, interest of industry in reducing risks for economic reasons might stick too much to facts and somewhat inhibit progress towards more safety.

There is thus a need to strike a balance between a somewhat irrational - and often demagogic - clamour for more safety, on humanitarian grounds which are well accepted in their principle, if not, often, in the use that is made of them, and a perhaps too down-to-earth approach to the avoidance of risks. One might think that regulations would bring that needed balance. One would be wrong. For one thing, official regulators shrink at defining risk and even more - to using a pretentious verb - to "quantify" it. For another thing, they are loath to take the real responsibility of accidents. Risk levels are obviously implicitly assumed, and accepted, and the endorsement of this acceptance by the public is considered "de facto" acquired, as in the case of public transportation. The public might be informed, by sundry media, of accident rates, it never is officially, unless some individuals (who cannot, by their sheer paucity, represent the public) engage in an arduous hunt for official statistics.

I am sure you will agree this is a very unsatisfactory situation for engineers, who devote an increasing proportion of their activities to designing systems ensuring an increased safety, or, even more, to devising new procedures for improving safety and to indicating the appropriate way for their incorporation in new designs.

"Decipimur specie recti" wrote the Latin poet, Horace - we are deceived by the appearance of what is good -. I am prone to agree with my old Latin book.

4. SAFETY AGAINST DEVELOPMENT AND ECONOMIC CONSTRAINTS

The crux of the discussion of risk is, I believe, centred on the perception of risk by those who "do the job". This vast group includes technical people, in administrations, designers, builders and their subcontractors, and the specialists who have to evaluate the worthiness and safety of a project, from "assurance of quality" to "certification". This group is extremely documented and is, by and large, at the top of those capable of understanding and using the most modern techniques for design, incorporating an added degree of safety.

Of course, added risk avoidance - or, as we prefer saying, safety improvement, which is a more constructive concept - can only be achieved with a cost. The problem then is: up to what cost are we capable of ensuring safety? Posed by an industrial concern, the question would seem ludicrous, not to say unacceptable. Safety, by all standards of developed societies, must, implicitly, be ensured at all costs by all those who employ paid personnel... except states, which regulate for a certain "social security" coverage, never (that I know of) challenged by courts.

Yet, it is comparatively easy to assess the industrial cost of given safety measures, with modern methods of analysis. It is not acceptable to evaluate safety, in the industrial domain, in terms of deaths or of personal injuries. Rather, if this is done, the level of safety, taken as a threshold is considered as at least equal to a tacitly accepted level. For example, an accepted level of personal accidents of all kinds and severity in public transportation might be 300 in 10 billion passengers, as is the case in the Paris "Métro". It is obvious that the pursuit of safety - perhaps extended to the more encompassing notion of welfare (but with limits difficult to define) - has economical constraints and, conversely, exerts a constraint on economic development. This is to be borne in mind, at a time when, at the bottom of the fourth industrial cycle of Kondratieff, we are in want of innovations to climb from depression to the expansion and prosperity of a fifth cycle. Table 1 shows that we are in the recessive (R) stage of a cycle, which, in the past, has been followed by depression (D), then by an innovative, recovery period (I), leading to the years of prosperity (P) of the next cycle. If this evocation of the impact of an uncontrolled demand for safety on economic development, in connection with the theories of Kondratieff, Schumpeter, Mensch and Kuznets, seems far-fetched to you, just remember the ecologist agitation concerning nuclear power plants. We might forecast many difficulties with "safety-oriented" people when biogenetics - seen as an important domain of activity in the next upswing - really gets on the move, not to mention spatial activities.

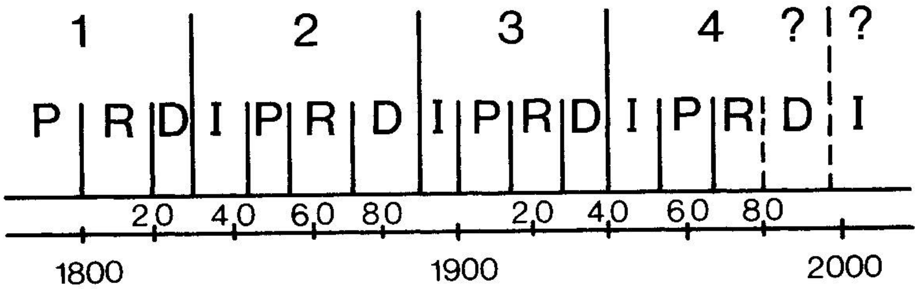

Table 1. Industrial/economic cycles (after Mensch - "Stalemate in Technology")
I - innovative, recovery stage
P - prosperity stage
R - recession stage
D - depression stage

The economic rules of the game we have to obey set natural limits to our endeavours. Safety can be superimposed on these rules, but cannot supplant them altogether, for fear of having to forego the activities involved, if it is meant to achieve it at all costs.

I remember visiting a plant, a few years ago, in a faraway, large, developing country. To a question about the total lack of posters reminding workers of possible accidents, the reply of the plant manager was: "we do not have time for that".

I have said a few moments ago, that only states - I mean, of course, governmental administrations - can, with impunity, get away from the costs of safety. And yet, it is not because their solvency is illimited, as we know. It is just because they, alone, have the right to impose regulations. Let us take, for example, the regulations concerning civil construction, in particular those relating to scaffolding protection. It is often pernickety enough to be a hindrance to builders and not enough imaginative to be a real addition to safety. Yet, that I know of, never was any study made, not only of the impact of regulations on industrial activity, but also of the expected gains in safety.

This leads me to the next argument of this short and general introduction: all in all, safety is left in the hands of the engineer.

5. SAFETY IN ENGINEERING

Engineers, by virtue of their basic work, are devoted to safety. Whether they design or they build, their products have to be safe if they are to be of practical use. Thus, engineers have always used "factors of safety". Such factors were, until less than 25 years ago, matters of "engineering judgment". Their evolution in that span of time follows, naturally, the evolution of the philosophy of design. For structures, both in civil engineering and in marine engineering, probabilism has to a large extent replaced determinism and, thus, safety factors - often referred to as "factors of ignorance" - can, in principle, be replaced by a given probability level of structural safety or the complementary level of risk. This is not to say that it is often done or, even, possible. Perhaps, spending a moment on this transition from determinism to probabilism is appropriate. For this, we shall take the example of ships and, generally, marine structures.

Probably long before Homer wrote the Odyssey, man has recognized the aleatory character of the sea and a nineteenth century poet said: "The sea never tells what it means to do ... it advances and retreats, it proposes and retracts, it prepares a squall and then gives up its plan, it promises destruction and does not keep its word". Treating wave action in a probabilistic manner requires many more calculations than using, as in the past, a single deterministic wave. Yet, it is not the advent of easy computer calculation which promoted this transition: the statistical representation of the sea was introduced in 1953 by Saint-Denis and Pierson, with the use of wave energy spectra, and the spectral motion response of ships was first calculated by hand. To be sure, refined treatment of wave action, taking explicit account of diffraction, and of the entrained water effect, as well as the estimate of the structural behaviour of a ship at sea, could not be dealt with by hand calculation and were made possible by the computer.

Along with the development of computational tools, sea-state data have been acquired for areas of important activity at sea, both by ships and by offshore platforms. This gives the engineer the possibility to assess the demand on a structure from the dominating sea action, although he is less advanced concerning winds and currents. Programmes exist today for the obtention of stress histograms, including stresses resulting from vibrations, and for fatigue estimates. What often prevents the engineer from being able to make a real risk/safety analysis is the lack of corresponding data on the capability side: distribution of the material properties, of the resistance characteristics of the welded connections ... It is not easy to obtain data on fabrication defects, for example.

This situation is reflected in the national regulations concerning fixed and mobile offshore platforms and in the Classification Societies/Certifying Authorities rules relative to ships and to offshore structures. It is also reflected in civil engineering codes, such as the code of the Fédération Internationale de la Précontrainte (International Federation of Pre-stressing) and the Code Européen du Béton (European Concrete Code). The transition from determinism to probabilism is gradual and the design procedures invoked are, at the most - in the hierarchy of development - semi-probabilistic procedures, using partial safety factors. A measure of probabilism is added by attempting to determine the partial safety factors by more advanced procedures, based at least on a more or less precise knowledge of the mean value and variance of the stochastic parameters from which depend the demand and the capability (these simpler advanced procedures are the First Order Second Moment - or FOSM - procedures for the structural buffs).

The situation is thus that proven methods, implicitly recognized in regulations, rules and codes, do not completely allow for a safety/risk analysis, nor do these documents call for such an analysis. But this short recollection shows the magnitude of the engineer's effort toward a rational assessment of the structural safety/risk.

This effort is pursued, not only in developing advanced design procedures which will, tomorrow, allow for safety/risk analyses to come into the purview of codes, but also through a number of special studies, for example, aiming at comparing the safety level achieved for typical jacket platforms, concrete gravity platforms and semi-submersible platforms, when using accepted safety factors (such work was carried out by the Association de Recherche sur l'Action des Elements - Research Association of Environmental Actions) or at presenting possible schemes of risk/cost trade-offs for jacket structures (P.W. Marshall, Shell Oil Company).

Considering a structure as a system of structural elements, the engineer is attempting to approach the estimate of its safety by application of the methods used for systems, i.e., reliability theory, fault-tree induction and event-tree deduction, taking into account the eventual redundancy at some locations of the structure.

These methods have been in use for quite some time for electronic systems and are employed today for a variety of functional systems and operations. This last application covers a vast domain of activity, from the operation of an industrial plant (a refinery, a nuclear power plant, for example) to transportation systems (ships, trains, aeroplanes). Using maritime traffic data, experimental data and calculation of the drift of disabled ships, risks of grounding can be estimated along with the risk of collision for ships in general. Such studies can be complemented by an evaluation of the danger of explosion of ships carrying dangerous cargoes, in turn threatening sensitive installations - like nuclear power plants - close to the sea (as by J.P. Jaunet and Y. Le Gal, Bureau Veritas).

This type of application amounts to a mutation in the philosophy of conducting the operations concerned. It was first the object of indepth studies for aircraft piloting and new concepts of philosophy were developed at the time "Concorde" was conceived (Etude de la Securité des Aéronefs en Utilisation - ESAU - in French; Investigation on the Safety of Aircraft and Crew - ISAAC -in English; son and father in the Bible!). The study of the safety of operations gives, aside from the reliability of material subsystems, a prominent place to human action.

In today's industrial situation, and in general, human action, in the physical sense, can only intervene during the fabrication of the elements of a system and during the use of the system. However, human action, in the full acceptation of the word, includes intellectual work and, thus, exerts an influence at the design state of the system (to begin with, of its components) and of its mode of operation (including the safety philosophy adopted and the maintenance planned). Yet, this aspect of human influence is difficult to take into account, although it is, implicitly but quantitatively, incorporated in factors of safety selected from engineering judgment. Lest this would seem like adding unnecessary difficulties to an already intricate problem, let us note that a domain of probable accelerated development toward the next economic cycle is robotics and that, while tracing a physical human action at the origin - note that we do not say "as the cause" - of an operational incident or accident, is comparatively easy, it will be much more difficult to do so for an intellectual action.

Everyone recalls an electronic fraud - amounting to a large amount of money being robbed by computer action - which was only discovered because the perpetrator was too talkative. We may also note that vote counting by computer is illegal in some parts of the USA for fear of undetectable fraud. I am reasonably sure that all those who have had something to do with debugging computer programmes will agree with me on this score. We might initiate as of now the study of methods capable of enhancing the success of our future hunt for bugs!

It is interesting to look at the probability level (in terms of return period) associated with the description, using adjectives, of the "chance" that an accident will happen. Table 2 shows, from a report by T. Moan, this correspondence in the case of mobile platforms. For comparison, the same correspondence between word description and probability description of load occurrence, but used for environmental loads in offshore (P.W. Marshall, Contribution to the Report of Committee V.1, "Design Philosophy and Criteria" to the 1982 International Ship Structures Congress) is also given in the table.

In aeronautics, the same correspondence looks somewhat different, being expressed, for the probabilistic description, in failure probabilities per flight hour. Table 3 shows this correspondence.

Word description of occurrence	Average return period years	
	Accidents	Loads
Probable	10^2	10
Reasonably probable	$10^2 - 10^4$	$10 - 10^3$
Remote	$10^4 - 10^7$	$10^3 - 10^6$
Extremely remote	10^7	10^6

Table 2. Word and return period description of the chance of occurrence of accidents to mobile platforms and of environmental loads in offshore.

Word description of occurrence	Failure probability per flight hour
Probable	10^{-5}
Rare	$10^{-5} - 10^{-7}$
Extremely rare	10^{-7}
Extremely improbable	10^{-9}

Table 3. Word and probabilistic description of the chance of failure occurrence in aeronautics.

When compared, on the basis of average yearly flight hours (or distance flown) of aircraft, and with some assimilation concerning the adjectives used in both cases, Table 2 and Table 3 appear compatible. What is interesting in both examples is the use of adjectives to describe the occurrence frequency of accidents: dealing with risk, our imagination has a better grasp of such a description than of dry numbers. This may tend to show the need, not only for the public at large, but also for those who are involved in this domain, of an adequate education concerning risk/safety. Aviation accidents are classed according to their severity, critical accidents, for example, being those which might make a forced landing necessary and catastrophic ones being liable to entail the loss of the aircraft and its occupants.

Examples of safety criteria in aeronautics are a probability below 10^{-5} for a critical accident and a probability smaller than 10^{-7} for a catastrophic accident, corresponding to the "rare" and "extremely rare" ranges in the word description and thus satisfying our psychological conception of safety. Levels of safety implicitly accepted in codes range from probabilities of a few 10^{-4} to a few 10^{-2}, over the life of the stucture. Levels quoted either as recommendations or accepted levels, as yearly probabilities of failure, include values such as 10^{-5} without qualification of severity, 10^{-6} for severe consequences (European Convention for Construction Steelwork), 10^{-6} - 10^{-7} for industry onshore, and 10^{-4} - 10^{-6} offshore (CIRIA). Table 4 compares annual rates of fatalities - gathered from various sources - in different domains of human activity.

Activity	Fatalities per 1000 person -years
Navigation	2.1
Mines	0.9 - 1.4
Construction onshore	0.3
Industry onshore	0.15
Offshore (before March 1980)	1.5 - 2.0
Offshore (before 1982)	3.5 - 4.7
Automobile	1.0 - 3.0
Air transport	0.8 - 1.0

Table 4. Frequency of fatalities in various fields.

6. A TENTATIVE CONCLUSION AND RECOMMENDATION

Safety/risk analysis is, if not coming of age, at least gaining ground in the evaluation of the possible, or likely, human, ecological or economic consequences of man's endeavours. It is, in effect, a tangible manifestation of a mutation in our philosophy which pervades - or will pervade - many, if not all, of our activities, in business and politics as well as in engineering : a transition from a deterministic outlook to a probabilistic outlook. The transition being in the making, some - perhaps many - parts of our industrial, sociological, or legal tissue are lagging behind in this development. There are thus gaps which we must strive to fill.

It is clear that work must be pursued both in the development of rational procedures of analysis and in the acquisition of data before the engineer is, in many areas, in a position to produce quantitative - and trustworthy - safety/risk estimates, particularly where structures are concerned.

In this effort, it is imperative to study critically scenarios of accidents in order to delineate possible sets of causes. Serious accidents indeed result, according to the unanimous opinion of those who have studied in depth such cases, from a group of causes, the elimination of any one of which would have considerably reduced the seriousness of the accident. A similar conclusion applies to the study of near-misses: the addition of an additional anomaly to those found to exist would have resulted in a catastrophe.

This last consideration is of utmost importance when considering that, in a majority of catastrophic accidents which have aroused public attention in the recent past, legal action has appeared to be aimed at finding a culprit at all costs. This is extremely counter-productive as concerns safety enhancement, as it encourages at the least omissions - perhaps distortions - in the presentation of the accident's circumstances, and since there is an imbalance in the principle of responsibility allocations: generally, administrations have the privilege of penal irresponsibility.

Such a philosophy, not only runs counter-current with the transition to probabilism, but also violates a basic principle: a conscious fault, consisting in voluntarily transgressing a law, a regulation or even an accepted code of practice, is certainly punishable, while an involuntary human error is not punishable.

Of course, the strength of the above argument mainly rests on the quality of the regulations imposed on the developers of projects and the operators of industrial systems. In many cases, these regulations leave much to be desired, particularly in defining areas - and limitations - of responsibilities, e.g. in the case of organization of rescue at sea. Laws, regulations ... are often designed - and felt such by the public - as means to protect, as much as the people, administrations, already legally irresponsible, against criticism. Hence, such helpful signs on the roads as "deer crossing", "rock falling" ... or a maze of signs from which the really useful one cannot be distinguished in time.

The official and semi-official effort to promote safety with a variety of texts, ever increasing in number and often un-coordinated, has the unfortunate effect of reducing the awareness of individual responsibility and of promoting a feeling of being an indirect member of an assisted group.

It appears to me that a real transition to the acceptance of risk and the correlated and imperative quest for more safety is, above all, a matter of education and that giving each individual a true sense of responsibility - not as the best means to avoid punishment, but as the only efficient way to improve safety - is a task of highest priority. It would be strange if, at a time when a broad-minded understanding - sometimes turning to laxity - is displayed by courts toward law-breakers, as a first step of their resertion into society, society did not make the necessary effort to teach responsibility in the first place.

This last comment takes added value in the light of our inescapable evolution towards the widespread use of automated systems with which a lack of uprightness and responsibility - very hard to detect - is liable to provoke catastrophes.

I am convinced that, in the important and exciting developments with which the present situation is pregnant, engineers will, as ever, make a decisive contribution. The level of the presentations and discussions at this colloquium are proof of it.

I shall leave you with these hopeful words.

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