Swiss Re

The risk landscape of the future

Risk perception

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Preface

Our future – according to all forecasts and prophecies – will play itself out somewhere between heaven and hell. What it really becomes will depend on how successful we are in taking advantage of our opportunities and mastering the risks they entail.

Clearly, insurers must concentrate on risks when looking into the future – not intending to spread panic, but in their own best interest: risks already identified offer the insurance industry and society an opportunity for a future of greater promise.

Insurers are used to consolidating individual risks into manageable bundles. In the narrower insurance context, these translate to portfolios or – more generally – to a risk landscape, a term used in this publication to describe the totality of risks faced by a community.

A risk landscape is never viewed in isolation from individual requirements and experiences. This is why the insurers' risk landscape differs, for example, from those of parents, manufacturers, researchers or environmentalists. What all risk landscapes have in common is that, rather than occurring by chance, they are determined by the way a given community copes with risks.

This publication goes beyond the discussion of individual future risks and shows that it is possible both to understand and consciously configure the risk landscape. The work does not promise any ready-made solutions, for there are none. All of us must first learn how to deal with the many challenges dictated by the ever accelerating rate of change as well as the new and modified risks associated with it. Being prepared to face up to many unanswered and in some cases unsettling questions will also point us towards solutions. For whatever the face of the future, tackling it will take courage.

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Think about the future: With visions – many of which ultimately became reality – the French author Jules Verne launched an entirely new genre of literature. The illustration here appeared in his work of science fiction, *From the Earth to the Moon,* first published in 1865.

1 Are future risks insurable?

The term *risk landscape* will be used in this publication to refer to the totality of risks faced by a specific community, such as a nation, a business enterprise or a family. If the community changes, so does the risk landscape.

Three trends characterise this development: change as such is continually accelerating; possible consequences tend to be greater; and increasing uncertainty is rendering risks less calculable.

If we are to manage future risks successfully, we must learn to recognise the changes in the risk landscape earlier and influence them systematically in their infancy. This will require a more active dialogue among the individual stakeholders.

No future without risk

New technologies have always harboured new risks. Yet two things have changed: firstly, the dangers per se are becoming more difficult to understand. Technical systems are becoming increasingly complex, and their components are constantly being reduced in size. Whether, for example, the weak electromagnetic fields of mobile phones, genetically modified foodstuffs or nanoparticles pose any real danger is still highly uncertain. Secondly, not only is innovation achieved and produced at ever greater speed, but today's technology and business networks also disseminate that innovation faster and over wider areas. In other words, rather than prompting gradual and local damage, hidden risks may trigger widespread loss accumulations.

It would therefore be careless to insure the risks associated with new technologies before more is known about them. Insurance is a promise to compensate the insured for losses incurred in the future. If their dimensions are unknown, adequate risk financing is virtually impossible, and the insurer can at best limit the cover or, in the extreme case, refuse to offer coverage altogether. This is unsatisfactory for all concerned, however: for the insurance industry, because it sees its task and business opportunity in contributing to the management of risks, including those that are hard to assess in individual cases; and for the policyholders, because they are left with any residual risks.

The lack of available insurance cover also has negative effects for society as a whole. To benefit from the opportunities offered by progress, the risks accompanying every technical or economic change must be acceptable. A necessary – albeit not the only – prerequisite for this is the assurance of financial coverage for possible claims. Risk management is primarily interested, therefore, in knowing what preconditions must be established to manage the losses tomorrow which arise out of the risks of today.

Risk is knowledge of possible losses

The chief prerequisite for successful risk management is readiness to address questions, even if some are highly unsettling. What would happen, for example, if the Gulf Stream were to lose strength or even suddenly change its course? What would it mean if nanoparticles actually penetrated the human brain directly via the olfactory nerve? How can solar storms affect electronic systems? What would the consequences be if electrosmog were ultimately found to be harmful to health? Who bears what responsibility if machines start making more and more decisions? What risks are created by the broad rejection of genetically modified foods? What social conflicts loom if, as a result of rising unemployment and increasing life expectancy, fewer and fewer people with earning power have to cover the costs of more and more pensioners?

It would be wrong not to examine such scenarios on the simple assumption that past experience suggests that they are "improbable". In fact, predictions about the likelihood of multi-causal losses actually depend either on sound understanding of cause-and-effect relationships or on a detailed loss history, and the risks of the future have neither of the two.

The immediate purpose of discussing such scenarios therefore is to differentiate between the possible and the impossible. Only risks that are identified can be systematically analysed. And only then, on the basis of sound knowledge, can the extent and the likelihood of such risks be determined. In reality, however, the public debate about risks of the future is often dominated by equally irresponsible scaremongering and trivialising reassurance, both of which hamper any attempt at rational risk management.

Insurance is no substitute for safety

If new risks cannot be thoroughly understood, it is all the more important to fully utilise all reasonable possibilities of risk reduction. While in specific, individual cases the notion of what is reasonable may well be negotiable, the principle itself is not. Insurers are obliged on ethical grounds – if for no other reason – to limit coverage to those losses which cannot be prevented by any justifiable means.

A great deal of potential remains untapped in this respect. Risk reduction, for example, is still too often limited to efforts at reducing the probability of occurrence, even though many future risks indicate a strong trend towards ever greater potential consequences. The failure of an information or power network can already today paralyse thousands of companies in a matter of minutes. By systematically limiting the consequences, many critical risks could be reduced at little cost.

This also applies to liability risks, which are becoming increasingly difficult to calculate due to the rapid changes in societal values. The state is called upon here to launch the public debate on risk as early as possible and to bring about consensual decisions before new technologies are introduced on a large scale. How the risks of new technologies are assessed in detail is secondary from the viewpoint of liability insurance; what matters more is a set of viable ground rules.

Insurance means sharing risks

There are several reasons why the existence of large risk collectives is a prerequisite for the coverage of loss events with an uncertain probability. Firstly, the law of large numbers states that the larger the number of independent individual risks, the more reliable the assessment of the overall risk. Secondly, the larger the number of policyholders across which the overall burden can be spread, the smaller the burden on the individual. Thirdly, the smaller the amount of risk capital that must be provided per individual risk, the greater the added value.

One of the greatest challenges to the insurance industry in future will be adapting traditional risk communities to the rapidly changing risk landscape in the right way at the right time. Compulsory insurance schemes are one way of setting up risk collectives, although their coercive nature makes them controversial. More attractive are communities which offer all their members a high degree of security and substantially reduce their risk-related costs. The greatest possible homogeneity and transparency are helpful here: the more similar the individual risks are, the more equitable the distribution – both of the total loss burden and the value added – will be.

Since risk sharing within a collective should ideally take place between similar types of risk, it is recommended that new risks or ones that have changed radically in qualitative terms be removed from existing collectives and transferred to new, manageable risk communities where the burden is spread over all members equally. It might be conceivable in future, for example, to classify the liability risks of the pharmaceuticals industry according to common risk properties of their active substances and to set up pools for particularly problematical substance categories. This would facilitate the individual company's buying cover for risks which it is unable or unwilling to bear on its own.

The greater the uncertainty, the more important is mutual trust

In addition to the tried and true method of distributing the risk burden over many shoulders, covering risks with major consequences should be spread over time to reduce the financial burden per time unit. If the total loss burden is foreseeable, it will generally be financed by premiums paid in advance, ensuring, on the one hand, immediate availability of the requisite funds in the event of loss. On the other hand, the policyholder can be sure that he or she will not be charged more than the agreed sum, regardless of the actual degree of the loss.

Given that the total loss burden for future risks is typically uncertain, the set premium may turn out over time to be too high or too low. Both variants are possible. In such cases, a combined risk financing plan is offered in the form of financial reinsurance: there are premium reimbursements in the event of loss experience being better than expected, and a loan fixed in advance which is guaranteed to cover unexpectedly high losses. Such forms of insurance presuppose close and long-term partnerships between policyholders and insurers, in which the shared uncertainty about the experience of future loss is compensated by mutual trust.

Warn earlier, react faster

The earlier changes in the risk landscape are recognised, the more time remains to analyse and react to them. This is where insurers can function as an early warning system because – by their very nature – they have more loss data than any other institution and hence are the first ones to be able to detect deviations from existing empirical values. Such early warning systems are still used far too rarely, however.

Indeed, many far-reaching loss developments of the past could have been contained in their initial stages, if not avoided altogether. The case of asbestos only escalated into the greatest loss event in the history of insurance because the first early indications of its detriment to health were underestimated.

In light of that experience, Swiss Re has built up expert teams to cover all aspects of risk, from questions of risk perception through the social and economic sciences to the development of future technologies. Adopting an interdisciplinary approach, they observe the changing contours of the risk landscape by holding, for example, workshops with experts from all conceivable fields in an effort to uncover new risks or changes in existing ones.

Given the vast differences in perspectives and goals among insurers, policyholders and governmental organisations, tracking down changes in the risk landscape and developing the appropriate solutions requires close cooperation among all the players. Swiss Re brings to this dialogue its technical competence in the field of risk financing and risk management, and a high degree of sensitivity regarding both the special needs of the industry and the concerns of society as a whole. In return, government agencies and business partners should involve Swiss Re in new developments from an early stage.

In the case of industry, this means providing the insurer with all risk-related information so that it can be jointly analysed, evaluated and used towards constructive solutions. Discussions with government representatives and political leaders should help locate urgent need for (public) research and establish what legal and fiscal conditions should be created or maintained to handle future risks optimally.

Absolute security is an illusion. The future is risky by its very nature, because any change entails new risks. Even so, since our communities do not evolve by chance, the risk landscape associated with them can be shaped accordingly. To do so, however, we must grasp the opportunity to identify and influence risks early on, and make adequate provision for the event that a loss occurs.

With this in mind, the following chapters take stock of areas in urgent need of formative action and present a catalogue of realistic options to this effect.

Visualize the future: Albert Robida (1848–1926) was one of the first illustrators of science fiction. Here, he depicts the departure of the *First Commission for the Discovery and Colonisation of the Moon*.

2 The future is approaching at ever greater speed

Ray Kurzweil,[1] one of the pioneers of Artificial Intelligence, predicts a gradual merging of man and computer over the next few decades. For this reason, Bill Joy, co-founder of Sun Microsystems, in his essay "The future doesn't need us",[2] suspects that humankind will end up making itself superfluous. According to the renowned astronomer, Martin Rees, "the odds are not better than fifty-fifty that our present civilization on earth will survive until the end of this century"[3]. Contrary to such gloomy forecasts, the physicist Michio Kaku[4] sees humanity making the transition from the "age of discovery to the age of mastery", in which it will succeed in overcoming all diseases and most catastrophic perils, resolving social conflicts forever.

Prophecies of doom are of little use

For the purposes of risk management, prophecies of doom such as Kurzweil's are of little practical use; they describe developments which – although conceivable in detail with a great deal of imagination – we do not yet know whether they may become reality. And the future entails more than just new technologies and knowledge; the assessment of risks will also change. To date, for example, robots have been thought to be machines assembled from cog wheels, chips and lengths of cable. Perhaps one day they will actually grow of their own accord out of programmed germ cells. The exact dangers of electrosmog will only be clarified with research methods whose details are still beyond our imagination. As for genetic engineering, it remains to be seen what stance future generations will take. It is conceivable that genetic authenticity will be seen as a flaw rather than something natural which deserves protection.

As we are only able to imagine the distant future – but not to predict it with any certainty – risk management is confined to the more immediate future and hence to those risks that we are already able to influence selectively today. To do so, we do not need to assess what the distant future will hold. Rather, we must identify the drivers and mechanisms of change, because they determine the changes of the coming months and years.

All future technologies, for example, have one motive in common, namely to technically reproduce and "optimise" natural processes. The aim of nanotechnology[5] is to manipulate atomic and subatomic particles by means of special tools and arrange them at will. Artificial Intelligence is intended to empower machines with thought capability. Genetic engineering[6] is aimed at selectively changing the genetic code. Or, as futurologists put it: "Following steel and plastic, flesh will be the material of the future."[7]

And that future is not far off. Cancer research is delving into how somatic cells communicate with one another and control their own growth. Once we have found out how a liver cell knows that it is a liver cell and when it must cease to divide, this knowledge will be put to real use. By way of example, this would mean programming cells by genetic modification such that they – just like our human body cells – differentiate themselves and form new types of organisms. These, in turn, would produce food and medicines, perform complex operations and, sooner or later, think as human beings do.

1 Ray Kurzweil: *The Age of Spiritual Machines*, London, 1999
2 www.wired.com/wired/archive/8.04/joy.html
3 Martin Rees: *Our Final Century*, London 2003
4 Michio Kaku: *Visions – How Science Will Revolutionize the 21st Century*, New York, 1997
5 Swiss Reinsurance Company: *Nanotechnology – Small matter, many unknowns*, Zurich, 2004
6 Swiss Reinsurance Company: *Genetic engineering and liability insurance – The power of public perception*, Zurich, 1998
7 Chancenpotenziale; www.trendbüro.de (2004)

Future risks arise in the present

Even so, there is no need to fear that we will suddenly be confronted by our cloned doubles. Even if technical progress does occasionally make great strides, it will not leap into utopia with a single bound. Conversely, it would be wrong to assume that the risk landscape will undergo major change only when future technologies are fully developed. For new risks to arise, no quantum leaps are necessary, just making the approach will suffice.

In fact, experience shows that the initial phases of innovation cycles are particularly risky because we – as part of the innovation process – must first learn how to cope with the new hazards. As a case in point, one of the most costly errors in the history of technology dates from the beginnings of computer science when, in order to save what was then extremely expensive memory space, year dates were entered only with their last two digits. The conversion to Y2K-compatible systems at the end of the last century cost billions of US dollars.

On the road to global simultaneity

The fact that technological progress transforms our communities and thus gives rise to new risks is as commonplace as perpetual change is certain. What actually has changed is the speed of change itself. Development processes are constantly getting shorter in duration. While the life of the steam engine spanned more than 80 years from its conception to eventual "retirement" at the Museum of Technology, innovation cycles in electronics have now shrunk to only a few months. From the risk management perspective, however, the increased dissemination speed is much more important.

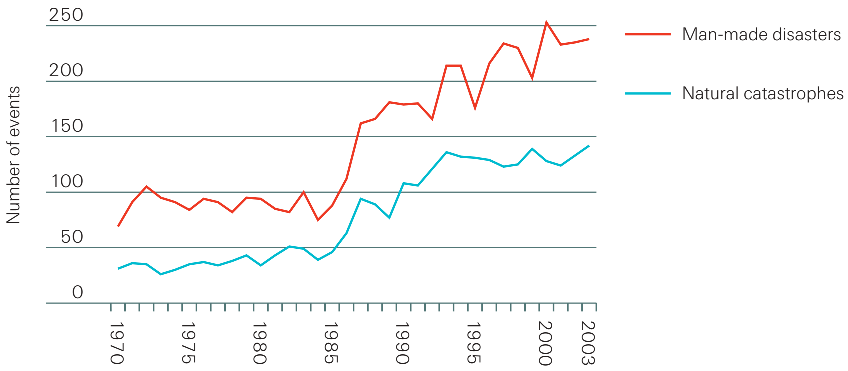
The modern technologies of computer technology, automation and virtualisation, and the establishment of communications, research, commercial and transport networks which span the globe have created the conditions which not only generate, but disseminate, innovation much faster across wide areas. Geographical distance is losing in importance. Supply and demand are already only a mouse click apart. Once new ideas, research results, goods and services are available at one location, it is not long before they can be obtained anywhere on the free market throughout the world – together with all the hazards and risks they entail. Computer viruses need hours, pathogens, days, and manufacturing defects, just a few more days beyond that, to spread out throughout the world.

To sum up: the future is not a question of distance in time. The future is what radically differs from the present. The faster our communities change, the faster the risk landscape of the future will become the reality of the present.

Animate the future: In 1926, screenwriter and director Fritz Lang made the first science fiction film, *Metropolis,* with – for these days – startingly convincing animated scenes.

3 Fewer accidents, more disasters?

Since the mid-1970s, the number of serious natural catastrophes and technical disasters has increased. Such disaster statistics are distorted to a certain degree because the more recent catastrophes are better documented than those of 100 years ago. But even in countries which kept historical records, the same effects are to be observed as on the global scale: the period from 1900 to 1929 showed an average of 1.7 disasters a year in the US, whereas between 1980 and 1989, there were 18. Over the past ten years, the number has risen to more than 38 events.[8]



The number of catastrophes between 1970 and 2003,
Source: Swiss Re, sigma, No.1/2004

Despite this increase in disasters, the world still seems to have become safer.

Life expectancy

In nearly all countries of the world, average life expectancy has risen by several years since 1970.[9] Heading the list are the Solomon Islands, whose inhabitants now have an average life expectancy of 69 years, 29 years more than they did in the past.

Fires

Although the number of buildings is constantly increasing, the number of fires in most industrialised countries is declining. Whereas in 1977, the US had just under 3.3 million fires,[10] 2002 recorded "only" 1.7 million.[11]

Traffic and industrial accidents

The statistics for traffic accidents show an equally positive trend. Between 1980 and 2002, despite increasing motorisation and expanding highway networks, the number of road deaths in Germany, for example, dropped from 15,050 to 6,842.[12] The same holds true for industrial accidents, which, in the US in 2001, fell to their lowest level since the recording of statistics began in the 1970s.[13]

8 Catastrophe database of the Catholic University of Belgium; www.cred.be

9 *The New York Times Almanac 2003*, New York, 2002

10 Michael J. Karter Jr: "Fire Loss in the United States During 2000", Quincy, Massachusetts, National Fire Protection Agency, 2001; www.npfa.org

11 Michael J. Karter Jr: "Fire Loss in the United States During 2002", Quincy, Massachusetts, National Fire Protection Agency, 2003; www.npfa.org

12 Statistisches Bundesamt: *Statistisches Jahrbuch 2003 für die Bundesrepublik Deutschland*

13 Bureau of Labor Statistics: *Workplace Injuries and Illnesses in 2001;* www.bls.gov

Safer means faster, bigger, higher

More disasters on the one hand, fewer accidents on the other – these opposing trends are only apparently contradictory. In fact, they are the result of the way in which risks are handled: many safety measures are confined to a reduction of the probability of occurrence. Thus, although the number of fires in the US has fallen, the average level of property damage per fire rose by a factor of 1.6 between 1977 and 2000 – despite immense advances in extinguishing techniques.

Aviation
The same development is to be observed in aviation: whereas the number of flying hours increased by a factor of ten between 1965 and 2002, the number of serious accidents per one million take-offs fell drastically.[14] The number of fatalities per accident has risen from 12.5 to 29.2 since 1945, however. And if aircraft are soon to carry close to 800 passengers, the possible consequences of an individual accident will be almost doubled.

Flood protection
That reduced incidence leads to graver consequences when an event does occur can be seen in the case of flood protection; although dams and similar protective measures reduce the probability of floods, this safety advantage leads to denser settlement of the fluvial plains. The result is fewer floods, but higher losses per event.

Rail transport
The systematic use of state-of-the-art safety technologies has noticeably reduced the probability of accidents in rail transport in recent decades. At the same time, the introduction of high-speed trains has multiplied the possible consequences, because a doubling of the speed means a quadrupling of the collision impact.

Urbanisation
People flock to cities because they expect to find more social and economic security than in more rural areas. In 2007 for the first time, according to United Nations estimates, the size of the world's urban population will exceed that of the rural population. In 1950, New York was still the only city to have a population of over ten million inhabitants. By 1975, however, there were six mega cities, and by 2000, 19 of them accounted for a total of 263 million inhabitants. It is expected that by 2015, some 23 mega cities will be home to some 375 million inhabitants.

In response to this powerful influx, cities are growing downwards and upwards. In all metropolises, more and more traffic areas and shopping centres are being relocated underground, where fires can have particularly devastating consequences: emergency exits and escape routes are getting longer and longer. Worldwide, there are now 37 residential blocks that are higher than 200 metres, 36 of which went up in the last three years.[15] Dozens more – especially in Asia – are on the drawing boards or under construction.

As such, a hazard little heeded to date gains importance. Depending on their type of construction, high-rise buildings may, in the event of a fire or terrorist attack, either collapse into themselves – as the twin towers of the World Trade Center did – or come crashing down on neighbouring buildings.

14 The Boeing Company: *2002 Statistical Summary*, May 2003; www.boeing.com
15 www.emporis.info

According to Swiss Re estimates, collapsing high-rise buildings can cut a swathe of destruction through the neighbouring buildings that is 1.2 times their own height and somewhat wider than their width. Assuming a building with a height of 260 metres and a circumference of 180 metres, the damaged area would cover 30,000 square metres.

Natural hazards
More people, buildings, factories and infrastructure per unit of area mean that events of equal magnitude will affect more people and cause more damage to property. According to an OECD estimate, a repetition of the 1923 earthquake in modern Tokyo would cause losses amounting to up to 75 percent of the Japanese gross domestic product.[16]

Economic concentration
Economic strength also magnifies the possible consequences. The current market value of Exxon Mobile, the world's highest earning company in 2001, is higher than the gross domestic product of many countries. Just as in the past, the ruin of the biggest employer in a locality led to the economic downfall of whole towns, so too will the losses of transnational companies will have national, and possibly even intercontinental effects in future.

At the same time, the relentless increase in production volumes drives up the potential for damage. In the year 2000, a serial defect forced a tyre manufacturer to withdraw over 6.5 million tyres whose tread threatened to come off at high speeds. This defect is blamed for numerous accidents in which 174 people were killed and 700 injured. The loss caused by the recall is estimated at USD1.3 billion. As if that were not enough, the recall of a further 13 million tyres in 2001 is supposed to have caused an additional loss of USD 3 billion.[17]

Power supply
More and more consumers, functions and values are hooked up to power networks. If the power supply fails, it is no longer just the light that goes out: most business processes grind to a halt.

In August 2003, the power failure that hit the northeastern US affected 22,000 eateries in New York alone. Foodstuffs to the value of USD 75 to 100 million were spoilt.[18] The Broadway shows lost box office takings amounting to some one million US dollars.[19] The 2001 power failures in California caused productivity losses of USD 21.8 billion, loss of income among private households to the tune of USD 4.5 billion, and the loss of about 135,000 jobs.[20]

Telecommunications
Between 1990 and 2002, the worldwide telephone network more than doubled and now numbers some 1.1 billion users. In the same period, the number of registered mobile phone subscribers rose from 11 million to 1.3 billion. The total time spent on the phone during international calls quadrupled during this time, coming to 135 billion minutes. In purely arithmetical terms, over 250,000 international calls are made round the clock every day.[21]

16 OECD: *Emerging Risks in the 21st Century*, Paris, 2003
17 Randy J. Maniloff: "A Product Recall: The (Limited) Role Of Insurance Lessons To Be Learned From Firestone", *Mealey's Litigation Report*
18 New York Restaurants Association
19 The Holland Online Sentinel Business: *Blackout damage may total up to $6 billion*, November 17, 2003; www.hollandsentinel.com
20 Silicon Valley/San Jose Business Journal: "Blackout losses estimated", May 9, 2001; www.bizjournals.com
21 International Telecommunication Union

Telecommunications networks are no longer mere links. Instead, they constitute virtual spaces in which commerce is conducted and work colleagues all over the world interact intensively. Power cuts nowadays have thus attained the status of market and institution collapses, such that the cyber-quake is considered one of the most damaging scenarios. An aggressive computer virus could trigger a worldwide collapse of entire markets and industries within hours.

Mobility
Between 1991 and 2001, the global fleet of commercial aircraft grew from 14,308 to 20,771. Sea freight volume grew from 1.6 billion to 5.4 billion tons a year in the years between 1965 to 2001.[22]

The effect of this increasing mobility – as in the case of all networking – is that losses can proliferate faster, over greater distances and on a wider scale. An example: on 21 September 1999, an earthquake struck Chi-Chi in Taiwan, damaging several factories which produce memory chips. The resulting two-week interruption of production caused a supply shortage on world markets and drove prices up fivefold.[23] Finally, the increase in networking allows familiar hazards to attain new orders of magnitude. Even the plague that raged through Europe between 1347 and 1352 was only made possible by the founding of so many new towns and the intensive traffic and commerce they fostered. With a death toll of 25 million – a third of the then population – the Black Death is considered to have claimed more victims than any disaster in history. By comparison, Aids, according to estimates by the World Health Organisation (WHO), has already caused the deaths of 20 million people. This figure could rise to 68 million by the year 2020.

According to WHO estimates, a new influenza epidemic could claim up to 650,000 fatalities even in the medically best-equipped industrialised countries within two years. It could cause economic losses of up to USD166 billion in the US alone.

Similarities of scale but differences in quality

In sum, security – in the sense of reduced probabilities of occurrence – promotes growth and concentrations of value which magnify the possible consequences of disasters. This does not necessarily imply a greater overall risk. If the increases in the consequences are compensated by reduced frequencies of occurrence, the average loss burden may even be smaller.

Consequences, however, may be qualitative as well as quantitative. In the course of a year, ten air accidents – each with 80 fatalities – are not perceived the same as one single accident which takes the lives of 800 people. Nor is it the same for the insurer if an insured loss of USD 10 billion resulting from a natural disaster is distributed over many thousands of policies or – say in the case of an industrial fire – is derived from an individual risk.

22 World Tourism Organisation
23 OECD: *Emerging Risks in the 21st Century,* Paris, 2003

Consequences and probabilities must be considered separately for a complete description of the risk landscape. For whereas high-frequency risks involving a slight average loss do not necessarily require systematic risk management, risks whose consequences are extreme may constitute an existential threat despite their low probability of occurrence. This is why insurers have been recommending for some time now that security should not be limited to loss prevention, but that the possible dimensions of the loss should also be limited, so as not to "put too many eggs in one basket".

Although the limitations on the financing of risks cannot be fixed at a given figure, the possibility of having recourse to the international financial markets makes cover to the order of USD 100 billion for a single event perfectly conceivable. However, as the consequences increase, the probabilities practically cease to play a role; the very provision of such sums is bound up with extremely high costs that make little economic sense. If, however, the consequences – as in the examples above – continue to be extended indefinitely, more than just the insurance industry will be driven to the limits of its capacity.

Shape the future: To warn of the dangers of totalitarianism, François Truffaut's *Fahrenheit 451* (the temperature at which paper ignites) is a bleak portrayal of a future state which burns all books in an attempt to exercise thought control.

4 Risk is defined by public opinion

The risk landscape can change merely as a result of a different value being attached to hazards, losses and risks. Environmental risks, for example, have only been with us since an intact environment has been considered worth protecting.

In 1948, the World Health Organisation (WHO) defined health as a "state of complete physical, mental and social well-being and not merely the absence of disease or infirmity". Since the mental effects of accidents, natural disasters, wars and crimes have been officially recognised as illnesses, completely new scientific disciplines have arisen, such as psychotraumatology. And the risk landscape acquired a new kind of risk: being mentally well was added to the value of being physically unscathed.

From the victim's perspective, this is a risk mitigating progress, since qualified help is now provided to those who, in the past, could hope at best, for words of comfort and at worst, for embarrassed silence, as in the case of rape victims or soldiers traumatised by war. By contrast, seen from the perspective of those who cause accidents, the risks have an added dimension – now, in the event of liability under some jurisdictions, for example, they no longer have to pay up "only" for property damage and bodily injury, but also for the consequences of any mental harm inflicted.

Risks are (just) a matter of definition

What the risk landscape of the future will look like thus depends, for example, on whether – and to what extent – the World Health Organisation's definition of health wins long-term acceptance. The more this vision becomes the norm – in other words, the more "valuable" health becomes – the greater the burden on the social security systems will be.

Risk implies possible loss. As we can only "lose" what is of value to us, risks are a direct reflection of religious, social, political and economic perceptions of value, and as such, the risk landscapes of various cultures differ considerably. Whereas most industrialised countries are investing ever greater sums in environmental protection, Nature in many of the so-called developing countries is still regarded as threatening and not at all deserving of protection. And while not even basic medical care is ensured in poor countries, services such as psychotherapy for household pets are already being offered in leading industrialised countries.

Value perceptions also determine the distribution of risk or loss burdens within society. In continental Europe, liability claims are largely limited to compensation for medical expenses and loss of income. Physical and mental pain is assigned only a low monetary value. By contrast, the Anglo-Saxon legal system provides for punitive damages, which may grant satisfaction to the injured party far in excess of any measurable losses.

Both systems have specific advantages and drawbacks, which will not be addressed in further detail here: different countries have different customs and different risks. What is much more important from the perspective of practical risk management is to recognise that the increasing interdependence among different social systems is triggering new risks. And still uncertain is how the various national legal systems will be aligned as globalisation progresses.

Many causes, many perpetrators, no liability?

Even within a given culture, perceptions of value can change rapidly – as a result of scientific progress, for example. The natural sciences traditionally defined a cause as something that invariably produced a given effect. What could not be explained as a cause in this sense was considered to be accidental – most diseases, for example. Yet modern science sees effects as the result of the complex interplay of many individual factors and circumstances, none of which is the sole cause in the classical sense, but just makes a greater or lesser contribution to the overall effect.

Consequently, cases of cancer, for example, can no longer be regarded as simply strokes of fate. They have concrete causes, many of which lie beyond the patient's control. This brings up questions of responsibility, culpability and liability.

However, our scientific knowledge is not yet sufficient for us to assign the parts of a given overall effect to the individual contributory causes. The multi-causal and multi-conditional weave of cause and effect is only partially clear. For example, some epidemiological studies have found a higher incidence of leukaemia among children living in the vicinity of high-tension power lines. Since most of the exposed children do not contract the disease, however, it remains unclear whether electromagnetic fields are involved at all and, if so, in what way. Further, since cases of leukaemia had been recorded prior to the introduction of electronics, electrosmog can – if at all – only be one of many influencing factors.

Today, we know that many diseases result from the sum of a large number of harmful influences. There is, however, no method of determining what influences were decisive in a specific individual case. If a child falls ill with leukaemia, electrosmog can neither be excluded nor proven to be one of many contributory causes.

Under current law, such evidence is not strong enough to enforce liability claims in court. There must be proof that a given phenomenon was the actual cause of the illness, not just a possible aggravating factor. This is unsatisfactory for those concerned, because the actual involvement of certain causes would be left out of account merely because it is not legally recognised as evidence.

For that reason, many consumer and environmentalist groups are demanding a general or at least partial reversal of the burden of proof. This would oblige the supposed perpetrators to prove that a given loss occurred through no fault of their own – which is even more difficult in practice, since there is hardly any technology which can be excluded with absolute certainty as a cause of health impairment.

A general reversal of the burden of proof is hard to imagine at present – just as all revolutions seem highly unlikely up to the moment when they actually occur. Increasingly, people are rejecting any further automation of our communities and see a reversal of the burden of proof as an effective instrument for implementing their own political vision.

When fears cause damage

Even if the existing conventions of civil law continue to apply, we must not assess risks solely on the basis of the current state of scientific knowledge, as the "StarLink" case clearly illustrates.

In summer 2000, traces of StarLink, a genetically modified variety of maize, were found in numerous food products in the US. StarLink had been approved for use in production of animal feed, but not for human food. As a reaction, tons of products were withdrawn from the markets, causing manufacturers and dealers to claim damages estimated at USD 1 billion.

Just how the genetically engineered maize entered the human food chain has since been largely explained. Firstly, StarLink grains were accidentally mixed with other corn varieties during harvesting, storage and transport. Secondly, pollen from genetically altered corn was transmitted, in some cases, to conventional corn varieties.

Meanwhile, it is still not clear if this ever represented any concrete danger. The genetic modification has made StarLink maize resistant to parasites such as the corn-borer. This resistance is given by a protein that is only broken down slowly in the human alimentary canal and may trigger allergic reactions. As yet, however, this suspicion has not been confirmed.

From a strictly legal point of view, the recall operation ("rechannelling") resulted from an inadmissible mixing of genetically modified and conventional maize varieties. The regulations that were violated, however, are based solely on a supposed health hazard which has been impossible to substantiate or exclude to date. If the principle of prevention were to be applied with the same degree of consistency to all other foodstuffs, most supermarket shelves would be empty. The real issue in the StarLink case is thus the broad public rejection of genetically modified food staples.

What to believe – or whom to believe

Only science can prove how dangerous genetically engineered maize, mobile phones, nanoparticles and pork sausages really are. But the "common sense" of democratic societies determines what is considered to be true and real. Risk acceptance is not only a question of objective measurement, but of individual and collective perceptions of value. No civil technology kills and maims more people or emits more pollutants and noise to the environment than road traffic. And yet automobility continues to be widely accepted.

It is hard to foresee how risks will be evaluated in the future because the evaluation criteria themselves are subject to change. While there is more information on risks available today than ever before, a greater number of risks are becoming harder to perceive. The hazards of road traffic can be experienced directly, but specialist knowledge is required to assess the risks of nanotechnology, for example. Since the experts themselves often fail to agree on new risks, risk evaluation is becoming less of a question of what to believe than whom to believe.

As a side-effect of this development, reputational risks are gaining in importance. Since consumers are hardly able on their own to assess technical data indicating the efficiency and reliability of products, confidence in brands becomes the decisive criterion in deciding what to buy, and the loss of a sound reputation looms large as one of the greatest corporate risks. It takes far less time to shake confidence in persons, companies or institutions than to acquire a stock of factual knowledge. This phenomenon also explains the increasingly frequent, sudden shifts in the public perception of risk, which are mostly triggered by external events.

On 21 September 2001, a chemical factory in Toulouse, France, was the scene of one of the most devastating explosions in the history of the chemical industry. The detonation tore a crater 10 metres deep and 50 metres wide into the factory premises. Window panes within a radius of five kilometres were shattered. Thirty people were killed and more than 2,400 injured.

Had it not been for the events in New York and Washington only a few days before, this chemical disaster would certainly have generated a wide-ranging discussion on the risks related to the chemical industry, just as similar events in Bhopal, Seveso and at Sandoz in Basle had done earlier. As it was, however, this explosion was not even registered by many international media. And the risk topics of climate change and genetic engineering that had dominated the debate up to 11 September 2001 vanished from the headlines for many months.

Risk landscapes are shaped by value perceptions

Communities are shaped by perceptions of value; which is why Western dwellings look different from Far Eastern ones, and different laws apply in theocracies than in democracies. If by *risk landscape* we mean the totality of risks within a community, then shifts in values will be the main driver of change in the risk landscape. Perceptions of value will also determine, for example, how intensively the development of new technologies is advanced, or whether and for what purpose innovations are used.

In 1979, in order to slow down population growth, the Chinese government decided on a policy of one child per family. Since girls – because of the subsequent dowry – are considered an economic burden, boys are preferred. Many Chinese couples therefore use the opportunities of modern medicine to establish the sex of their child with ultrasonic testing as early as possible and to abort the female foetuses. As a result, in China of the early 1990s, the number of newborn boys exceeded that of girls by 20 percent.

In sum, in order to form a reliable picture of the future risk landscape, it is not enough to enquire about objectively measurable, rationally comprehensible risk factors. The driving forces of change are needs, interests, visions, hopes and fears.

Plan the future: The *Bionic Tower,* planned for Shanghai by the Spanish architects Javier Pioz, Maria Rosa Cevera und Eloy Celaya, might one day have the distinction of being the world's first building to exceed a kilometre in height.

5 Too little experience with the future

For simple, linear systems, loss events can be predicted precisely if all cause-and-effect relationships are known and all relevant variables are measurable with sufficient accuracy. That is why we can, for example, calculate how many hours an aircraft propeller can operate before becoming critically warped through the centrifugal forces which cause the metal molecules to migrate gradually to the tips of the propeller blades.

For complex systems, however, accurate predictions are extremely difficult. No one can calculate when, where and with what consequences the next aviation accident will occur. Yet it is possible to estimate the risk, or average frequency and severity of air accidents to be expected over the next few months, for example.

Such risk assessments are based primarily on empirical data, ie on a systematic evaluation of accident trends in the past. Forecasts concerning future accident trends can be derived from this data with a certain degree of reliability. If the world stayed exactly as it is, the risks would correspond precisely to the claims history.

The future, too, holds nasty surprises

Thus the real difficulty of risk assessment does not lie in the complexity per se, but in the accelerated change of complex systems. The faster the risk landscape changes, the more risks remain entirely unidentified for the time being or become incalculable, because it is no longer just individual parameters but entire systems that keep changing with increasing speed. As such, the potential for unpleasant surprises becomes ever greater.

The care of the elderly in France, and especially in the capital, Paris, was long known to be in a bad way. Further, climatologists have been warning for years that the rising temperatures in the summer months could drive up the mortality rate. Nevertheless, no one had foreseen that more than 11,000 people, most of them elderly, would fall victim to the European record summer of 2003 in France alone. Many young families had gone off on holiday, leaving grandparents at home alone. There was a notorious shortage of staff in old people's homes. Water shortages forced many power stations to go off stream, which, in turn, caused air-conditioning systems to shut down. And in the dog days of the summer, one heat record succeeded another.

While many new risks are perfectly recognisable as such, their dimensions are hard to estimate. As a case in point, cattle – which are vegetarian by nature – are ill-protected from the pathogens contained in meat. So while feeding them with ground offal from slaughtered cattle was regarded sceptically by many from the start, the practice gained wide acceptance. It was cheap, indeed, but over a period of 20 years it made sensational headlines over what has gone down in history as mad cow disease (BSE).

From the risk assessment perspective, three details are of particular interest. Firstly, it took more than ten years to clarify BSE transmission from cattle to humans via the food chain. In the meantime, it has been established beyond doubt that prions ingested by human beings via animal nerve tissue can cause a new, hitherto unknown kind of brain disease which is so far invariably fatal – the new variant Creutzfeldt-Jakob disease (vCJD). Secondly, the investigation is complicated by the fact that the incubation period lasts several years, and when the first cases occurred, it was natural to seek more immediate causes. Thirdly, since a definitive diagnosis is impossible while the subject is living, there is still no way of knowing how many people have been infected and in how many cases the illness will break out. Various studies put the number of fatalities over the next few years between a few hundred and 100,000 cases.[24]

vCJD is a typical example of a long-latent risk. More importantly, it serves to illustrate how – in the long run – even complex risks can be understood well enough to be successfully handled.

Complexity

Complex systems consist of many independently operating, yet networked subsystems. This creates a large number of simultaneous processes which mutually influence one another and occasionally provide feedback.

Light falling into our eye influences the body's own production of melatonin, which plays a role in the tumour defence system. This establishes a link between artificial light and the course of cancerous disease.

There is a widespread misapprehension that complex systems behave chaotically to deserve an analogy: a butterfly, by beating its wings, could unleash a hurricane. In fact, the "butterfly effect" refers to the technical and organisational limits of variable system parameters' measurability.

In 1961, the meteorologist Edward Lorenz[25] developed the first computer model for simulating meteorological phenomena, discovering by chance that if the initial values of the calculations were changed minimally, the results remained the same at the start. The longer the forecasting period, however, the farther the forecasts moved apart. This "sensitive dependence on the initial conditions" became known as the butterfly effect because the differences in the initial values – picturesquely expressed – were as slight as the air pressure generated by the beating of a butterfly's wings.

Complex systems follow natural orders as fixed as those of the planets in their orbits round the sun. Yet they sometimes react extremely sensitively to minimal, hardly measurable and recognisable changes in individual variables whose effects are not foreseeable.

If, however, complex systems are observed over long periods, they show – despite their high variability – a constant frequency distribution of clearly defined system events. Thus, the annual number of road deaths in a country – despite the many variables involved – remains largely the same. Between 1990 and 2000, there was an annual average of 43,126 road deaths in the US, the maximum being 46,814, the minimum, 40,982. Given that, the number of 44,000 deaths[26] for 2002 could be reliably predicted.

Such extrapolations into the future from observed accident trends are, however, only reliable if the system itself does not change. In purely statistical terms, some 480 traffic deaths were to be expected for the German state of Saxony in 1990. In fact, 747 people lost their lives. In 1991, the figure rose to 863. The explanation? After the fall of the Berlin Wall, the people of the former German Democratic Republic suddenly had access to high-powered vehicles from the West, cars which took some time to get used to.[26]

24 Bernd Salzberger: "Epidemiologie von BSE und vCJD", *Der Internist*, 2002
25 James Gleick: *Chaos*. Munich, 1988
26 Accident statistics of the Free State of Saxony; www.statistik.sachsen.de

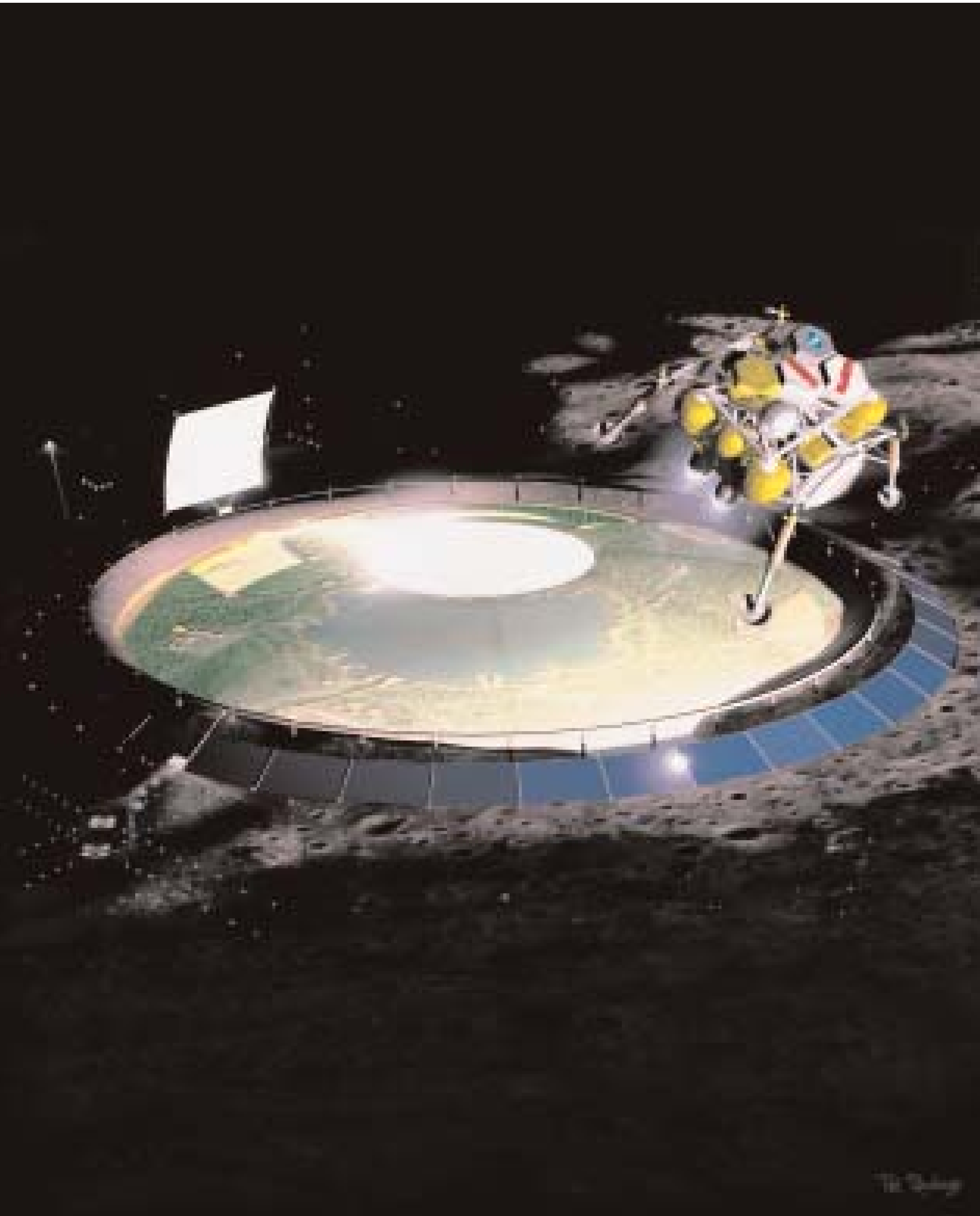
The future is (not entirely) uncertain

Thus, it is not that future risks cannot be assessed at all, but merely that they cannot be assessed definitively and conclusively. Take terrorism: no one can predict how terrorist groups will behave in the next few years, but we could now start learning to understand their motives better than we have thus far.

This should not be done in the illusionary hope of eliminating the relevant threats, but to gain time. In a few years' time, reliable forecasts of climatic change will be possible. We will only be able to draw the right conclusions, however, if we have found out in the meantime how changed weather conditions can affect anthropogenous systems. Only if we adopt a serious and differentiated approach to the phenomenon of terrorism will we be able to react correctly to the unexpected events of tomorrow. And only if we subject new technologies to scrutiny in their early stages will we be able to recognise undesirable tendencies for what they are as soon as they appear.

In conclusion, it may be true that many future risks cannot be reliably quantified at present. But they could be understood better if the parts of the puzzle we have were pieced together to form an initial picture. That would make clearer what parts are still missing. The sooner the risk assessment begins, the more time will be available for the time-consuming process of learning.

Prepare for the future: The NASA strategists argue that all forms of technological progress should target one goal: mankind carrying life on Earth out into space.



6 Seek and ye shall find

The sluggishness of traditional risk management is explained by a natural mechanism of perception: ingrained in human behaviour is a general reluctance to register weak signals.[27] The lower our attention threshold, the more signals we have to process simultaneously and the greater the probability of an excess of stimuli triggering parallel or excessive reactions. For this reason, we human beings are basically forced to screen out the bulk of the risk information received from our surroundings – at least for the time being – as irrelevant. The following extracts from the seemingly endless list of generally accessible risk signals put this premise to the test:

Global warming causes the sea level to rise. For this reason, some 90 million people now inhabiting the coastal regions of China, India, Egypt and Bangladesh will have to be resettled in higher lying regions by the year 2050.[28]

Hacker attacks on computer systems cause costs of some USD 7.3 million per hour worldwide, and the figure is increasing.[29]

In the industrialised societies, the traditional family is progressively losing significance. Between 1930 and 2000, the number of one-person households in the US rose from eight to 26 percent. The average number of persons per household has fallen from 4.1 to 2.6.[30]

Since the beginning of the 17th century, at least 480 animal species and 654 plant species have become extinct. The earth's biodiversity is in constant decline. A lot of natural "genetic material" is being lost or remains unused: of the 50,000-odd edible plants man only uses about 200 species, with wheat, rice and maize covering about 60 percent of global food requirements.[31]

One of the most frequent industrial causes of lung disease is flour, followed by other fine dusts of the kind that arise during the manufacture and processing of food and animal feed, as well as during welding and cutting operations.[32]

In 1949, the western flank of the Cumbre Vieja, an elevation on the Canary Island of La Palma, began to break away. Since then, a mass of rock – measuring some 200 cubic kilometres and moving towards the coast at a speed of one centimetre a year – will one day plunge into the Atlantic. Very likely is that this will unleash a perilous tidal wave, which could hit the East Coast of the US soon afterwards.[33]

The continuing increase in allergic disorders seems to be caused by an excess of hygiene. The less "clean" the environment in which children grow up, the more intensively their immune system is trained and the less susceptible they are to allergies and asthma.[34]

According to a survey made in the year 2003, the ten most important current values in Germany are: personal responsibility, quality of life, joie de vivre, love, meaning in life, friendship, justice, genuineness, health, learning. The following values of earlier years have been dropped from the top 30: extension of consciousness, eroticism, individualism, morality, sex, high-tech.[35]

Bold new trends in social thinking: the UN could dissolve itself because it has not succeeded in solving the crises of the 21st century. Young people could break all ties to the older generation because the burden of pensions has become too heavy to bear.[36]

27 Hans Christian Loew: "Frühwarnung, Früherkennung, Frühaufklärung – Entwicklungsgeschichte und theoretische Grundlagen", Marie Henckel von Donnersmarck, Roland Schatz: *Frühwarnsysteme,* Fribourg, 1999

28 OECD: *Emerging Risks in the 21st Century,* Paris, 2003

29 Claudia Eckert: *Einführung in die IT-Sicherheit,* Darmstadt, 2004

30 www.census.gov/pubinfo/www/1930_factsheet.html

31 Jürgen Mayer, *Biodiversitätsforschung als Zukunftsdisziplin,* Münster, 1996

32 Xaver Baur, Ute Latza, Martin Burz: "Arbeitsbedingte Erkrankungen der Lungen und der Atemwege sowie Neoplasien," *Deutsches Ärzteblatt,* October, 2003

33 The Geological Society of London: *The Earth in our hands;* www.geolsoc.org.uk, 2001

34 Harald Renz: *Weshalb nehmen Allergien zu? Epidemiologie und Grundlagen allergischer Atemwegserkrankungen,* Marburg, 2004

35 Sensonet: Das demokratische Delphi des Zukunftsinstituts; www.sensonet.org, 2003

36 Angela and Karlheinz Steinmüller: *Ungezähmte Zukunft,* Munich, 2003

By the year 2007, microchips will be built with transistors a thousand times faster than today's and with a computing capacity of 20 gigahertz. This will create the technical basis for controlling computers by voice instead of keyboard input.[37]

There is clearly no lack of signals. But how are we to assess them? Or react to them? Clearly we need more information, as the following example shows:

Solar wind consists mainly of protons and electrons. The sun radiates about a million tonnes of such particles every second, although the intensity of these solar storms is subject to considerable fluctuation. This constant flow of energy from the sun, which – among other things – plays a key role in the generation of polar lights, is harmless to human beings, as far as we know today.

Electronic and electric systems react to them, however, in a highly sensitive manner. The autumn of 2003 saw particularly violent solar storms which interfered with aircraft navigation systems and caused extensive power failures in Sweden, for example. A similar solar storm in March 1989 led to a nine-hour power cut in Quebec, Canada, and caused millions of dollars worth of damage.

According to the American aerospace authority, NASA, however, such solar storms are harmless in comparison to the "solar super storm" of 1859.[38] *For the duration of one whole minute, the sun radiated twice as much light as usual. Polar lights could even be seen in the night skies over Cuba and Hawaii. And short circuits caused the telegraph lines, which at that time had only been in existence for 15 years, to become incandescent.*[39]

A storm of that same 1859 force could occur at any time. Such a storm – assuming an advance warning of about 15 hours – might wreak havoc with or even completely paralyse a large proportion of all technical systems (as long as they contain electronic components) worldwide, cause enormous property damage and produce almost unimaginable economic losses.

This example illustrates the real problem of early warnings. Even if more information is provided, it must be checked for relevance, and this can only be done from the angle of the system affected.

It is not NASA's task to investigate down to the last detail how solar storms might affect the balance sheet of a given business enterprise. It would be just as senseless if every company were to conduct its own research on the assessment and combating of cosmic hazards. That it would pay off to investigate this solar storm risk more closely is not subject to question, given the spread of electrics and electronics in all areas of life. But who can afford to do it? Who has the necessary skills? And above all, whose judgment could be trusted?

37 Hannelore Crolly: "Intel baut schnellsten Silizium-Prozessor", *Die Welt*, 3 November 2003
38 http://science.nasa.gov/headlines/y2003/23oct_superstorm.htm
39 http://wwww.sness.net/weblog/archives/2003_10.html

Faint signals are ignored

All early warning systems have one inherent problem in common: To be of any use, they must amplify faint, unintelligible signals that cannot be reliably interpreted by laypersons, and translate these into a decision-making basis capable of being communicated or even into specific instructions for action.

Coastal inhabitants in the Tropics are helped little by knowing that far out at sea, a storm is brewing and threatening to grow into a dangerous hurricane over the next few days. Rather than wanting to interpret radar images or study potential hazard areas, they are keen to know if they should nail down their windows or even flee inland.

The same applies to the many open risk questions of which this publication has only touched a small fraction. It is not enough to point out that the use of silicates could give rise to a large complex of claims similar to that generated by asbestosis, that the modern full thermal insulation of residential buildings promotes the emergence and proliferation of toxic mold, or that an excessive claims mentality threatens the continued existence of proven mutual benefit associations. These items of information are too feeble to arouse more than a brief flicker of interest and a little shoulder shrugging.

Decision-makers in government and business are quite right to reject lengthy treatises in favour of more concisely worded management summaries which indicate alternative courses of action instead of risks. But who puts together the right brief to make decisions on?

Individual experts can no longer afford to do so, because most risks in the future will be system-related risks. These do not arise from individual new hazards, such as innovative industrial materials with unusual properties. The decisive changes in the risk landscape will emerge from the development and modification of ever greater and more complex technical, economic and social systems in which – as the example of solar storms showed – natural phenomena that were harmless in the past can suddenly become a threat.

For that reason, early recognition of risks cannot be delegated to individuals or institutions, since they can observe current developments only against the background of their – necessarily limited – competence and experience and are thus unable to perceive all changes, let alone assess them correctly.

As long as risk dialogue is confined to a hotbed of contradictory expert opinions, however succinctly expressed, the decision-making processes will tend rather to paralysis than to pushing forward. As a case in point, the first World Climate Conference was held 25 years ago.

There is no lack of details – what is lacking is the constructive and integrated view. That cannot be achieved by a monologue of alternately alarming and reassuring statements and appraisals. What is needed is the interdisciplinary and – in the age of globalisation – increasingly intercultural "polylogue".

Swiss Re set up numerous new communications platforms in the past few years in an effort to promote direct exchange beyond the limits of tradition, interest and competence. It may not be a novel idea, but it works, and the Swiss Re Centre for Global Dialogue in Rüschlikon has adopted the motto, "We're using a 150,000-year-old technique to grapple with global issues: talking."

At the Centre, discussions of the future go well beyond purely commercial interests. Swiss Re accepts responsibility as a globally active company, promoting the examination of long-term changes and the risks and opportunities associated with them. For that reason, Swiss Re is interested in exchanging ideas about the future with all stakeholders.

Conclusions

Efficient early-warning systems are expected to amplify weak signals received from the risk landscape to serve as a concrete basis for taking decisions and adopting a course of action. This is often done irresponsibly, however, when initial indications of new and changed risks are blown up to scenarios of doom. Although such scenarios do attract attention for a short time, they ultimately do more harm than good. They are soon followed by an all-clear which lulls people into drawing the opposite – and equally false – conclusion that there is no danger. Considering the 1980s prophecy that the Eiffel Tower in Paris would be submerged under waters unleashed by the melting of the polar icecaps, the present – fairly certain – rise of the sea level by a few centimetres seems comparatively harmless, even though the habitats of millions would be destroyed.

Reliable early-warning systems amplify signals not by extrapolating individual pieces of information, but by compressing many similar items of information. Those signals may seem irrelevant when observed in isolation, but collectively they reveal regularities from which reliable forecasts can be derived.

Thus, the art of early recognition and warning does not consist of guessing future developments correctly, but in recognising changes that have already taken place and their background as early as the available methods allow.

That is why early-warning systems require intensive communication: not in a technical, but in the interpersonal sense. To communicate means to "establish connections". In the concrete case of early perception of risk, that means enabling the scattered, single scraps of information to coalesce into strong signals.

This cannot happen, however, as long as risk is regarded merely as something unpleasant, threatening and obstructive. Risk communication is attractive only when it serves the purpose of discovering, in the risks of tomorrow, the opportunities of the day after.

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