> Resilien-Tech

"Resilience by Design": a strategy for the technology issues of the future

Klaus Thoma (Ed.)

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Editor:
Prof. Dr. Klaus Thoma
Institutsleiter
Fraunhofer-Institut für Kurzzeitdynamik, Ernst-Mach-Institut, EMI
Eckerstraße 4
79104 Freiburg
klaus.thoma@emi.fraunhofer.de

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Munich Office
Residenz München
Hofgartenstraße 2
80539 Munich

T +49 (0) 89 / 5 20 30 90
F +49 (0) 89 / 5 20 30 99

Berlin Office
Unter den Linden 14
10117 Berlin

T +49 (0) 30 / 2 06 30 96 0
F +49 (0) 30 / 2 06 30 96 11

Brussels Office
Rue d'Egmont/Egmontstraat 13
1000 Brüssel
Belgium

T +32 (0) 2 / 2 13 81 80
F +32 (0) 2 / 2 13 81 89

E-mail: info@acatech.de
Web site: www.acatech.de

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> ASSIGNMENTS/CONTRIBUTORS

- Dr. Lars Gerhold, Research Forum on Public Safety and Security/Freie Universität Berlin
- Gabriel Bartl, Research Forum on Public Safety and Security/Freie Universität Berlin
- Lucas Daus, KPMG AG WPG
- Burkhard Kesting, KPMG AG WPG
- Timo Kukuk, KPMG AG WPG

> CONSORTIUM MEMBERS/CONTRIBUTORS

- Daniel Hiller, Fraunhofer Institute for High-Speed Dynamics – Ernst-Mach-Institut
- Dr. Tobias Leismann, Fraunhofer Institute for High-Speed Dynamics – Ernst-Mach-Institut
- Benjamin Scharte, Fraunhofer Institute for High-Speed Dynamics – Ernst-Mach-Institut

> PROJECT COORDINATION

- Dr. Anna Frey, acatech
- Dr. Martina Kohlhuber, acatech

> PROJECT PROCESS

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1 INTRODUCTION

BENJAMIN SCHARTE, DANIEL HILLER, TOBIAS LEISMANN, KLAUS THOMA

On the morning of 7 July 2005, 56 people (including the bombers themselves) were killed in a series of four suicide bombings in London that targeted three underground trains and a double-decker bus. More than 700 commuters on their way to work were injured in the blasts. It was the worst Islamist terror attack ever carried out on UK soil.[1] Nevertheless, by the morning of 8 July, bus services had been resumed and by the end of the day much of the underground network was also up and running again, except for those parts that had been directly affected. Most Londoners had already started using public transport again, in part as a conscious signal to the terrorists that they would not be cowed by them.

Terrorist attacks, natural disasters and major accidents can cause serious, irreversible disruption and changes to the daily lives of large numbers of people. While the greatest impact is felt by those who are directly caught up in catastrophic events of this nature – the dead and the injured, their families, trauma victims, first responders and professional members of the emergency services – they are not the only ones to be affected. In addition to the direct impacts on the groups described above, adverse events can also have numerous indirect negative repercussions. Terrorist attacks can paralyse transport infrastructure, natural disasters can cause huge areas to become uninhabitable and accidents at power plants, for example, can wreak havoc with the energy supply. They can thus seriously impair the ability of society as a whole to function normally and, in the worst-case scenario, can even lead to the failure of the entire system.

The impact of Hurricane Katrina provides a case in point. When it hit New Orleans in late summer 2005, it left the city virtually uninhabitable for several months, provoking the collapse of law and order, medical care, the energy supply, communication systems and a whole host of other important services.[2]

In addition, the annual financial cost of all the natural disasters around the world comes to more than 200 billion US dollars,[3] while the combined financial losses resulting from terrorism, organised crime, accidents and other catastrophic events are even higher. Furthermore, the growing complexity of our modern world combined with parallel long-term change processes such as the declining population in Germany and the threat of global overpopulation will simply serve to accentuate the negative consequences of any future adverse events.[4] In an increasingly interconnected world, even minor and superficially harmless disturbances can ultimately result in severe damage to the system as a whole.

However, none of this necessarily means that individuals, societies and their technological systems must be completely defenceless in the face of these adverse events and powerless to prevent their negative consequences. There are significant differences in the way that different people and different social and technological systems anticipate and react to adverse events. All have the potential to be – or fail to be – "resilient" in response to threats such as terrorism, crime, natural disasters and major accidents.

All of this raises the question of what exactly is meant by "resilience". Over the course of the past 60 years, the term has been adopted by a variety of completely different disciplines, beginning with developmental psychology and going on to include ecology, the social sciences and engineering.[5] This study will focus on the use of the concept of resilience in the context of security research.

Security research aims to identify and analyse vulnerabilities of all types – for example in relation to natural

1 Muir/Cowan 2005.
2 Westrum n.d., p. 1.
3 United Nations Secretary-General's High-level Panel on Global Sustainability 2012, p. 47.
4 Coaffee et al. 2009, pp. 122 – 132.
5 CSS Analysis 2009, p. 1; Flynn 2011; Kaufmann/Blum 2012, p. 237ff; Plodinec 2009, p. 1.

disasters, terrorism, crime or accidents – and develop recommendations and technologies geared towards mitigating or preventing the associated risks without impinging upon people's freedom or civil rights. It involves researching ways of helping to protect against unlawful or deliberately harmful actions targeted at people, infrastructure or organisations. This also includes minimising the damage caused by active attacks or by natural disasters and industrial accidents. Security research also investigates strategies and procedures for rapidly returning the system or infrastructure to normal functioning in the event of a disturbance. The overall long-term goal is to build an infrastructure that isresistant fault-tolerant and robust. Since security research cuts across a wide range of academic disciplines and policy areas, its future development calls for new approaches. In its early days, it was dominated by a "bottom-up", technology-based approach where individual basic technologies were developed separately from each other for security research purposes and were only combined and put to practical use when it came to engineering the final product. Nowadays, however, a "top-down", scenario-based approach centred on threat and hazard scenarios is increasingly coming to the fore. The goal of this more recent approach is to develop systematic, security-relevant global concepts and use risk analyses to minimise the susceptibility and vulnerability of the systems in question.

Against this backdrop, acatech's "Resilien-Tech" project – which provided the basis for this study – aimed to achieve a better understanding of the concept of resilience as applied in the field of security research, so that concrete recommendations could be formulated for decision-makers in government, business and society as a whole. The project partners were acatech – National Academy of Science and Engineering and the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut EMI. acatech is an autonomous, independent, non-profit organisation whose remit is to represent the interests of Germany's technological sciences both at home and abroad. As a working academy, acatech provides up-to-date advice to policymakers and the general public on strategic issues relating to the technological sciences and technology policy. This was also the joint goal of acatech and the Fraunhofer EMI in the Resilien-Tech project. Although the concept is being used more and more in security research theory, no consensus had previously existed in Germany regarding a framework for defining the application of resilience in the field of security. The Resilien-Tech project therefore identified the opportunities and prospects that this approach provides for the development of future scenarios in the areas relevant to the security of our society. In addition, three expert workshops were held on the national perspectives on resilience, international perspectives on resilience and resilient businesses. These expert workshops enabled the full range of themes associated with resilience in the field of civil security research to be comprehensively analysed and investigated. Concrete approaches to developing resilient technological and socioeconomic systems were formulated, with particular emphasis on the protection of critical infrastructure systems. These are encapsulated in the recommendations, which are intended as guidelines for shaping future research strategies and roadmaps. The recommendations are published in the acatech Position Paper "Resilien-Tech – 'Resilience by Design': a strategy for the technology issues of the future".

The term and/or concept of resilience has been used across a variety of different scientific disciplines for at least 60 years. As a result, it is not a straightforward concept to work with when it comes to implementing policy strategies. Nevertheless, the very fact that a wide range of different research areas are interested in resilience suggests that it is a concept with the potential to deliver value-added. American resilience researcher Stephen E. Flynn argues that it provides an "intellectual center of gravity to inform and support a concerted multidisciplinary effort to better understand and manage global and societal risk."[6] The goal of this study was to define the specific

6 Flynn 2011.

meaning that resilience has taken on in the field of security research. In order to do this and to better understand where this definition fits within the overall context, we will begin with a brief outline of the history of resilience as a term and a concept. Our overview will begin in the field of developmental psychology and in particular with the work of American psychologist Emmy Werner. It will subsequently examine the ideas of Canadian ecologist C.S. Holling and US political scientist Aaron Wildavsky, before ultimately arriving at the field of security research. This section will also discuss which level of resilience was focused on in the Resilien-Tech project. It is necessary to clarify from the outset whether the term "resilience" refers to an individual, a group of people, society as a whole or perhaps specific parts of a society such as the relevant technological systems. Moreover, the primary focus of resilience can either be on the social aspects or on predominantly technological solutions. Both the following discussion of the concept's origins and the description of the Resilien-Tech project are key to understanding the specific focus of this study.

The word "resilience" is derived from the Latin verb resilire, which means to spring back. The Duden dictionary of the German language defines resilience as "mental endurance; the capacity to overcome difficult situations without suffering any lasting damage".[7] This definition is indicative of how the term is normally used in the field of psychology (see below). In medicine, resilience is sometimes used to describe a person's resistance to disease – particularly infections –, or their ability to make a swift recovery.[8] Meanwhile, the fields of physics and materials science stick closer to the original Latin meaning, using resilience to refer to a material's ability to deform elastically when acted upon by energy. In this context, resilience is measured as the maximum energy that the material is capable of absorbing per unit volume without creating a permanent deformation (i.e. without deforming plastically or becoming brittle). A good illustration of resilience is provided by the behaviour of springs, which are able to return to their original state even after being subjected to extreme forces. A material's resilience is thus characterised by its elasticity, flexibility and ability to withstand high loads.[9]

The first time that resilience was used as a scientific concept rather than simply as a measurement was in the field of developmental psychology. Indeed, the Duden dictionary still states that the word is used especially in psychology.[10] In this context, it is taken to mean mental endurance or resistance. Even before they started using the term "resilience", trauma researchers in the 1940s and 1950s were already studying how people manage to lead successful lives despite living in difficult circumstances. Their investigations were centred on the idea of emotional strength, i.e. individuals' capacity to overcome misfortune and cope with stress and[11] adversity. The initial studies focused primarily on the specific stress and difficulties experienced by subjects suffering from schizophrenia. The researchers were interested in explaining why the impact of the condition was relatively mild in certain individuals. They found that the people who were best able to cope with their schizophrenia were also those subjects who had already been coping relatively well with their lives before being diagnosed with the condition – i.e. the people who had a job, were married, had good social skills and were able to take responsibility. Subsequent studies of the children of schizophrenic mothers revealed that a surprisingly high proportion grew up to lead successful adult lives. It was clear that certain individual characteristics enabled them to overcome the adverse circumstances experienced during their childhood.[12]

The concept of resilience achieved its breakthrough in the field of developmental psychology during the 1970s thanks

7 DUDEN 2013 (own translation); Plodinec 2009, p. 1.
8 Kaufmann/Blum 2012, p. 237.
9 Kaufmann/Blum 2012, p. 237, Plodinec 2009, p. 1f.
10 DUDEN 2013.
11 DUDEN 2013; Kaufmann/Blum 2012, p. 237; Ungericht/Wiesner 2011, p. 188.
12 Luthar et al. 2000, p. 543f.

to the groundbreaking work of Emmy Werner. Unlike the earlier trauma research studies, she investigated subjects who had experienced a much wider range of adverse circumstances while growing up. Rather than simply looking at their parents' mental illnesses, she considered a whole host of social and economic factors and other influences. In her celebrated longitudinal study "The Children of Kauai", she followed the development of just under 700 children born on the Hawaiian island of Kauai in 1955, assessing and comparing their development at the ages of one, two, ten, 18, 32 and 40. Werner was able to confirm her expectation that the circumstances experienced by a person during their childhood had a significant influence on their individual success later in life. People who had uncomplicated, carefree childhoods had a better chance of leading successful adult lives than those who had grown up in unstable family or financial circumstances or had to contend with other serious problems in their immediate social milieu. More surprisingly, however, she also recorded positive development in a third of the 210 study participants who had grown up in extremely difficult circumstances. These subjects also somehow managed to achieve a regular income, a stable family life and a healthy social environment in their adult lives. In other words, they had shown themselves to be resilient. Werner then turned to the question of why some children were able to develop positively despite growing up in unfavourable circumstances. She sought to detect possible protective factors that may help people build up their resilience to adversity. The protective factors that she identified included personality traits such as healthy self-esteem, the ability to distance oneself emotionally from problems and a lack of inhibition in terms of approaching other people which enabled subjects to find role models outside of their unstable family lives, for example at clubs or other social institutions. In the years following the publication of Werner's seminal work, the concept of resilience continued to be developed in the field of developmental psychology. Whilst strong individuals were described as "invulnerable" in the early studies, "resilient" has now been widely adopted as the term of choice. The word implies positive adaptation by an individual to changed circumstances and, importantly, it eschews a simplistic, black-and-white approach. It encompasses the underlying mechanisms that build resilience with the help of certain factors. The protective factors were expanded to include not only purely internal, individual personality traits but also external factors that enable the development of resilience. It is now customary to distinguish between three different types of factors: a person's innate, genetically determined characteristics, the characteristics of their family and the characteristics of their wider social milieu. Notwithstanding the occasional persistence of theoretical and terminological vagueness and inconsistency, most of the literature continues to argue that resilience has considerable potential to improve our understanding of the development of high-risk groups.[13]

In developmental psychology, resilience thus refers to an individual's ability to cope with and defy adverse circumstances in their lives. Against this backdrop, the work of Canadian ecologist Crawford S. Holling marked a quantum leap in the field of resilience research. In 1973, he published an article entitled "Resilience and Stability of Ecological Systems" in the Annual Review of Ecology and Systematics. As well as extending the application of the resilience concept from developmental psychology to the field of ecology, Holling's article also ushered in a paradigm shift in how people thought about resilience. This was the first time that the term "resilience" had been used to refer not to a specific individual ability but to entire ecosystems. Holling radically challenged the prevailing view of ecosystems as stable entities that exist in a state of equilibrium.[14] This was a fundamental concept of traditional ecology that had been widely accepted for many years. Rooted in classical mechanics and thermodynamics, it stated that after being exposed to an external shock, systems would continuously, steadily and smoothly return to their original state of stable equilibrium. Holling's seminal article strongly disputed this idea of a

13 Kaufmann/Blum 2012, p. 237; Luthar et al. 2000, p. 544; Ungericht/Wiesner 2011, p. 188f.
14 Holling 1973, p. 14ff.

"balance of nature" where, given enough time, a system would always be capable of healing itself.[15] His conclusions were based on observations of the behaviour of real ecosystems such as fish populations in the Great Lakes.[16]

According to Kaufmann/Blum and Walker/Cooper, Holling's 1973 article marked a "complexity turn" in the field of ecology.[17] By identifying a completely different fundamental problem, Holling had shifted the focus of his research. He was no longer primarily concerned with looking for minor deviations from the optimal state of inherent stability. Instead, he believed that in order to fully understand how ecosystems work it is necessary to study highly unstable situations, critical disturbances and major deviations from what had hitherto been perceived as a state of stable equilibrium. Ultimately, what Holling was interested in was the system's ability to survive adverse events.[18] This is why he also drew a fundamental distinction between an ecological system's stability and its resilience. He believed that both properties – stability and resilience – represent possible responses of an ecosystem to external disturbances:

> *"The behavior of ecological systems could well be defined by two distinct properties: resilience and stability. Resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variable and parameters and still persist. In this definition resilience is the property of the system and persistence or probability of extinction is the result. Stability, on the other hand, is the ability of a system to return to an equilibrium state after a temporary disturbance. The more rapidly it returns, and with the least fluctuation, the more stable it is."*[19]

Another factor that sets Holling apart from the work and ideas of Werner and the developmental psychologists relates to the type of disturbances and adverse events for which resilience can exist or be developed. Werner focuses on the extremely difficult circumstances that characterise people's lives, i.e. constant, long-term conditions that resilient individuals are able to process and come to terms with. Although she does not completely exclude events such as the subject suffering a death in the family, falling seriously ill themselves or other short-term changes of this type, she does believe that they are secondary compared to difficult circumstances of a more general nature. Holling, on the other hand, turns this approach completely on its head. He is not interested in predictable, known shocks or long-term disturbances which in his opinion belong to the antiquated concept of a balance of nature.[20] Instead, he wants to discover how ecosystems are able to win the evolution "game", where the only prize for the winners is "to stay in the game".[21] According to Holling, the main threat to an ecosystem's ability to survive comes from abrupt, radical and irreversible changes triggered by unusual, unanticipated and surprising events.[22] In non-resilient systems conceived only with stability in mind, the deterministic features that previously enabled an equilibrium to be maintained prevent the system from responding flexibly to such events, causing it to collapse.[23]

15 Holling 1973, p. 1f; Kaufmann/Blum 2012, p. 238; Walker/Cooper 2011, p. 145ff.
16 Holling 1973, p. 6ff.
17 Kaufmann/Blum 2012, p. 238; Walker/Cooper 2011, p. 145.
18 Holling 1973, p. 14ff; Kaufmann/Blum 2012, p. 238f; Walker/Cooper 2011, p. 145ff.
19 Holling 1973, p. 17.
20 Holling 1973, p. 21.
21 ibid., p. 18.
22 Holling 1973, p. 21; Kaufmann/Blum 2012, p. 239.
23 Holling 1973, p. 21.

> *"A management approach based on resilience, on the other hand, would emphasize the need to keep options open, the need to view events in a regional rather than a local context, and the need to emphasize heterogeneity. Flowing from this would be not the presumption of sufficient knowledge, but the recognition of our ignorance; not the assumption that future events are expected, but that they will be unexpected. The resilience framework can accommodate this shift of perspective, for it does not require a precise capacity to predict the future, but only a qualitative capacity to devise systems that can absorb and accommodate future events in whatever unexpected form they may take."*[24]

Without Holling's work, the subsequent transfer of the concept of resilience to what is today broadly referred to as security research (see above) could never have happened.[25] Several ideas that play an important role in the context of security were already present in Holling's seminal 1973 article. These include the emphasis on flexibility as a key property of resilient systems, the focus on serious adverse events that are both unanticipated and abrupt, the adoption of a wider perspective that goes beyond the purely local context and the importance of heterogeneity to resilience. Holling's work also led to the idea of resilience being taken up by a variety of different, frequently interdisciplinary research fields. One example is the field of information science, where resilience describes the ability to tolerate errors and deviations, thus constituting one of the key traits of the Internet, alongside its global and decentralised nature.[26] Further examples include its association with the technological sciences, ecology and behavioural science, as well as the use of the term in geography, especially at the interfaces between individual fields such as ecosystems and political structures.[27] It was the 1980s before resilience finally came to be used in connection with disasters, primarily by engineers in the context of technical infrastructure. They used resilience to describe the capacity to cope successfully with a disaster.[28] The term was also adopted by the social sciences at around the same time. Today, this dual approach featuring technological sciences on the one hand and social sciences on the other is no longer only a characteristic of security research but also of the study of resilience itself.

It was the US political scientist Aaron Wildavsky who was initially responsible for "translating" the concept of resilience into the language of the social sciences. In his 1988 book "Searching for Safety", Wildavsky embedded the idea of resilience into his holistic vision of society as a whole. His principal interest was in how (technological) innovations come about. This led him to go one step beyond classical theory, just as Holling had done before him in the field of ecology. In Wildavsky's case, this involved challenging classical uncertainty theory, which regarded uncertainty as a problem that is automatically solved by technological and intellectual progress. Wildavsky, on the other hand, sees risk and uncertainty as positive factors, since innovation and social progress would be impossible if people did not take risks and confront uncertainty. In his view, security arises as a result of anticipation and/or resilience:[29]

> *"Anticipation is a mode of control by a central mind; efforts are made to predict and prevent potential dangers before damage is done. [...] Resilience is the capacity to cope with unanticipated dangers after they have become manifest, learning to bounce back."*[30]

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24 ibid.
25 Kaufmann/Blum 2012, p. 240.
26 Gürtler et al. 2010, p. 132.
27 Coaffee et al. 2009, p. 116; Gebhardt et al. 2011, p. 760; Plodinec 2009, p. 1.
28 Plodinec 2009, p. 1.
29 Kaufmann/Blum 2012, p. 240f.
30 Wildavsky 1988, p. 77.

Rather than regarding anticipation and resilience as mutually complementary strategies for attaining security, Wildavsky believes them to be diametrically opposed. He views anticipation as an "uncertainty avoidance strategy". He claims that avoiding uncertainty – for example by refusing to approve potentially beneficial medicines because of concerns about their safety – has the effect of hindering innovation and progress. Since we can never know *a priori* whether a technology will turn out to be beneficial or harmful to society, Wildavsky strongly argues the case for a strategy based on resilience. According to this approach, learning processes based on trial and error enable greater security to be achieved in the long term. Wildavsky understands resilience as a security strategy for finding the best way of organising and implementing a response to harmful events that have already occurred. Resilience is thus a purely reactive phenomenon in this context. According to Wildavsky's definition – which would come to be widely adopted by the research community – anticipation and prevention are only useful as strategies for combatting known, predictable and quantifiable threats. In contrast, a resilient society is able to cope with unanticipated threats, adapting and realigning its processes, organisations and systems in order to minimise its vulnerabilities, eliminate instabilities and successfully overcome unpredictable critical situations.[31]

Wildavsky drew his distinction between anticipation and resilience at a very abstract level. The understanding of resistance, protection and prevention as being diametrically opposed to resilience has been developed significantly in the contemporary debate. Today, resilience is viewed as a general, holistic problem-solving approach geared towards increasing the "general ability of technological and social systems to endure and regenerate".[32] It makes no difference in principle whether the hazards and vulnerabilities in question are known or completely new and unanticipated. A resilient society is capable of acting and reacting in the face of any kind of hazard or vulnerability. Accordingly, prevention and anticipation have now come to be regarded as key components of resilience. This is something that was already hinted at earlier. Resilience does indeed allow instabilities to be eliminated, unpredictable critical situations to be overcome and vulnerabilities to be minimised. In order for this to happen, however, societies must be as well-prepared as possible and must take the appropriate measures to ensure that avoidable adverse events are nipped in the bud. In the contemporary debate, these components of resilience are referred to as prevention and preparedness.

While some academics such as the American disaster experts Kathleen Tierney and Michel Bruneau[33] continue to draw a distinction between anticipation, prevention, protection and resistance on the one hand and resilience on the other[34], a more holistic understanding of the concept has been widely adopted in the field of applied security research. One prominent example is the definition of America's Community and Regional Resilience Institute (CARRI): "Community resilience is the capability to anticipate risk, limit impact, and bounce back rapidly through survival, adaptability, evolution, and growth in the face of turbulent change."[35] Another is the definition produced by the National Academies' Committee on Increasing National Resilience to Hazards and Disasters: "Resilience: The ability to prepare and plan for, absorb, recover from or more successfully adapt to actual or potential adverse events." In this context, a disaster is not necessarily a one-off event and may equally involve long-term changes and their consequences. Its causes may be either man-made or natural (all hazards approach).[36]

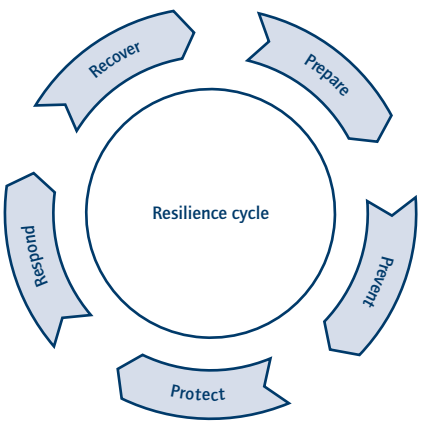
31 Kaufmann/Blum 2012, p. 240ff.
32 CSS Analysis 2009, p. 1
33 Tierney/Bruneau 2007.
34 Kaufmann/Blum 2012, p. 240ff.
35 Plodinec 2009, p. 7.
36 The National Academies 2012, p. 14.

In addition to the United States, the concept of resilience is also firmly established in security research in the UK. Leeds University's Institute for Resilient Infrastructure provides the following definition of resilience: "Resilience is the ability of a system to withstand disruption and continue to function. It is related to durability and performance to expected standards over time."[37] Although the Department for Management and Security at Cranfield University adopts a more detailed definition, it is still based on a holistic understanding of resilience:

> *"It suggests an ability of something or someone to recover and return to normality after confronting an abnormal, alarming and often unexpected threat. It is used alongside security to understand how governments, local authorities and emergency services can best address the threats from terrorism, natural disasters, health pandemics and other disruptive challenges. Resilience embraces the concepts of awareness, detection, communication, reaction (and if possible avoidance) and recovery. It also suggests an ability and willingness to adapt over time to a changing and potentially threatening environment."*[38]

In order to better understand such a wide-ranging concept and depict it in a concrete manner, Charlie Edwards' 2009 publication "Resilient Nation" borrows extensively from classical disaster management cycles.[39] Similarly, this study draws on both Edwards and disaster management cycles in order to develop a simple resilience cycle that provides an easily understood visual depiction of this complex concept (Figure 1). It comprises five resilience phases: "prepare", "prevent", "protect", "respond" and "recover". The first phase (prepare) involves making thorough preparations for disasters, especially in terms of early warning systems. By reducing the underlying risk factors it should be possible to prevent at least some adverse events from occurring in the first place (prevent). When an adverse event does nevertheless occur, the next stage is to ensure that physical and virtual protection systems operate flawlessly in order to minimise the negative impacts (protect). It is also necessary to provide rapid, well-organised and effective disaster relief. This requires the system to maintain its basic functionality as far as possible (respond). Once the actual adverse event is over, it is important that the system should be able to recuperate and learn the relevant lessons from what has happened, in order to be better prepared for future hazards (recover).

Figure 1: The resilience cycle



Source: Edwards 2009, p. 20, author's own illustration.

The resilience cycle was used to help develop the following working definition of resilience for the purposes of this study. This definition in turn provided a basis for the discussions that took place in the workshops:

37 University of Leeds 2013.
38 Cranfield University 2013.
39 Edwards 2009, p. 20; for more on disaster management cycles, see Stangl/Stollenwerk 2011.

"Resilience is the ability to repel, prepare for, take into account, absorb, recover from and adapt ever more successfully to actual or potential adverse events. Those events are either catastrophes or processes of change with catastrophic outcome which can have human, technical or natural causes."

The "Resilien-Tech" project's focus is on the applied aspects of the global concept of resilience, in particular the resilience of critical infrastructure. However, the social aspects are just as important as the technological aspects for creating resilient societies. Resilience can only be achieved by consistently combining technological and societal solutions.[40] Consequently, the two project partners, acatech and the Fraunhofer EMI, focused their research activities on both the technological and social dimensions, as well as on other factors, e.g. economic ones. All of these are key components of resilient societies. The study's focus is not on the theoretical social science discourse with regard to terminological definitions or semantic discussions of the precise meaning of individual elements of the holistic concept of resilience. Although we recognise the fundamental need for a classification of this type, the overview presented in this introduction is sufficient for the purposes of this study. The main body of the study will concentrate on formulating a series of strictly practical recommendations. This is in keeping with acatech's remit to provide advice to policymakers and the general public on key issues relating to the technological sciences, although, in view of the broad spectrum of topics encompassed by resilience, this advice will also extend to a number of wider issues. The findings of the Resilien-Tech project provide a scientific basis for research policy and security strategy decision-making.

This study presents the results of the Resilien-Tech project. In terms of its structure, it begins with an introductory chapter that describes the reasons for carrying out the project, elucidates the origins of the term "resilience" as used in a variety of different disciplines and postulates a working definition. Chapters 2, 3 and 4 go on to present the results of the expert workshops that were held in Berlin during 2013 and were attended by the leading national and international researchers in the field of resilience. Chapter 2 focuses on national approaches to resilience, while Chapter 3 looks at international approaches. Chapter 4 concentrates on resilience within companies and how businesses can contribute to increased overall resilience. Each individual chapter provides detailed definitions of resilience and explores various different aspects of the term. They also outline the ideas of the key research players, present research initiatives in the field of critical infrastructure protection and describe different national policies and strategies for achieving a resilient society. The chapters dealing with the national and international perspectives and with resilient businesses all conclude by identifying future challenges, tasks, research themes, trends and drivers. Finally, Chapter 6 formulates a series of recommendations for political, economic and societal decision-makers that are derived from the outcomes of the expert workshops. The intention is that these should inform future security research and security strategies so that they can help to build tomorrow's resilient society.

The 2005 London bombings demonstrated the value of the systematic incorporation of resilience into planning and implementation actions that is enabled by this approach. In the aftermath of 9/11, resilience had already been adopted by the UK government as a problem-solving strategy for dealing with crisis situations in the United Kingdom. Although the attacks still had a devastating impact, the careful planning and coherent and competent disaster relief provided in the immediate aftermath of the bombings – allied with Londoners' innate resilience – made it possible to prevent serious long-term damage to London, the UK as a whole and the people who live there.

40 Bara/Brönnimann 2011, p. 33; CSS Analysis 2009, p. 1.

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