GAU: Nuclear Reactors and the "Maximum Credible Accident"[1]

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The German word "GAU" – popularly used to refer to a disaster or "worst-case scenario", particularly in reference to nuclear power plants – marks off a semantic space in which German anti-nuclear journalism has situated the nightmare of a nuclear catastrophe since the mid-1970s. A close examination of the term reveals that it is in fact ambiguous, oscillating between support of nuclear energy and criticism of it, and its history can be recounted in a series of remarkable anecdotes. This essay will trace the history of the nuclear risk discourse and policy in West Germany from the first use of GAU in the 1960s through the present, arguing that it encapsulates and mirrors important strands in the debate over nuclear power in Germany.

Following the term's history, we can see how different layers of experience accumulated over time, shaping the meaning of the term and the mindset of proponents and opponents more generally. The word GAU evokes a whole range of memories nowadays, and these memories continue to shape the debate over nuclear power. In brief, this history falls into three chapters: a debate among nuclear insiders that started in the late 1950s; a public discourse that arose as part of the anti-nuclear protest in the 1970s; and a broad popular usage of the term that has moved beyond nuclear issues. While these three strands of use related to each other, they followed different rationales and trajectories.

Although this article focuses on Germany, it does not intend to suggest that either the history of the term GAU or German nuclear history in general can be understood in isolation, without considering the international context. Nuclear history is both national and transnational, with the United States playing a pivotal role in the Western context. In fact, the word GAU, which is an abbreviation for "größter anzunehmender Unfall", was originally a translation of the American term *maximum credible accident (MCA)*. However, that term has never achieved anything approaching the popularity of its German equivalent. As the term moved from expert circles towards a broader public, new meanings were added and existing ones challenged, and the distinct context of the German anti-nuclear meaning left its mark on the word and the popular understanding of it.

We can see this change already at work in the abbreviation: the use of GAU was not considered correct within the nuclear community, which preferred the longer version. The sound of the word may

[1] This essay was translated from German by Brenda Black, including all German-language sources unless otherwise specified.

have played a role. Unlike MCA, one can actually pronounce GAU as a word. Furthermore, the word came to have echoes of the word "Grauen" (dread or horror) – however, it seems unwise to read too much into the word by itself. For instance, nothing remains of the archaic term "Gau" as the designation of a district (still seen in the name of the "Rheingau" region), which gained unpleasant associations through its reference to the administrative units of the Nazi regime.

In collective memory, the word GAU has come to be associated with Chernobyl, an event that was unrivaled in its international impact until the recent Fukushima disaster. As Karena Kalmbach discusses the events at Chernobyl and its aftermath in a separate essay, this article will concentrate on the preceding decades, decades that framed the reception of the Soviet nuclear disaster. In fact, one might see Chernobyl as an endpoint, for the meaning of GAU has not changed much over the last quarter-century. However, meanings and reference points changed tremendously in the years and decades before, and they mirror the accumulation of experiences and the learning curves of the experts and the general public. As nuclear power moved from a 1950s vision to a large technological system, the meaning of GAU became increasingly contested, and the circle of those who used the words grew from a handful of experts to the broad public. In the end, the GAU would emerge as one of the focal points of the nuclear debate.

The "maximum credible accident" was originally intended to designate a "design basis accident" (German: *Auslegungsstörfall*): that is, the maximum breakdown or technological failure that the reactors were designed to be able to withstand – in theory at least. In the interest of getting approval for the construction and operation of nuclear facilities, this was equated with the greatest possible accident that was conceivable under realistic conditions. But "anzunehmend" ("presumable" or "supposed", but also "expected") as used in the German term is at least as ambiguous as "credible" (which may mean "believable" as well as "likely") in its English counterpart. Wouldn't it be possible to "expect" more serious accidents, ones the reactor is not able to withstand? The concept of the GAU, which had actually been developed in order to assuage people's fears, took on an alarming life of its own in the imagination of the media, who invented an additional term, the Super-GAU. In contrast to the GAU, which still allowed for the possibility of being brought under control, the Super-GAU suggested both a catastrophe which could no longer be contained and an escalation of an already horrific accident situation.

David Okrent, a mechanical engineering instructor at UCLA and a member of the US Advisory Committee on Reactor Safeguards (ACRS) in the 1960s, has published what continues to be the most knowledgeable and detailed insider description of the early discussions by US experts on reactor safety. In it he traces the history of the term "MCA" back to the internal documents of the Atomic Energy Commission (AEC) in 1959.[2] In the documents of the German Atomic Commission (Deutsche Atomkommission, DAtK) the word appears for the first time in the same year as well – here still in its English form.[3] Even Okrent cannot provide an explanation of the exact origins of the term. But the silence in the records suggests that the concept of an MCA was not the result of either safety-related experiments or theoretical discussions by the experts. And why, indeed, should this have been the case? In 1959 no one had had much experience operating nuclear reactors in a civilian context. Shippingport, the first non-military nuclear plant in the United States, first began to operate in 1957; furthermore, it was a small reactor in comparison with later units. "MCA" was evidently created in order to provide the formal reassurance needed for authorization of reactors, a useful fiction analogous to the definition of compressive strength for steel girders and similar components of large-scale engineering projects: When such an object can withstand a certain maximum level of pressure, one can assume that it will also hold out under lesser amounts of pressure, at least when the

[2] D. Okrent, *Nuclear Reactor Safety: On the History of the Regulatory Process*, University of Wisconsin Press, Madison 1981, p. 32.

[3] J. Radkau, *Aufstieg und Krise der deutschen Atomwirtschaft 1945-1975: Verdrängte Alternativen in der Kerntechnik und der Ursprung der nuklearen Kontroverse*, Rowohlt, Reinbek 1983, p. 359.

pressure is exerted in the same manner. It is, of course, not possible to address the risks of highly complex technology such as a nuclear reactor using such a simplistically linear causal approach, and this was in principle clear from the very beginning. If a railroad bridge can withstand the weight of 60 train cars, it won't collapse under the weight of 30; for nuclear reactors, however, the maximum risk is difficult to determine precisely, and even if effective measures are put in place to prevent this, it is by no means certain that all other risks are thereby brought under control. For there are many different kinds of risks and these can't simply be ranked according to size as though they were qualitatively the same.

The situation was not entirely new in all respects, however. Even steel girders which have withstood a stress test may lose strength over the course of decades as a result of material fatigue. Bridges may be destroyed by flood waves or gale-force winds, as happened to the railroad bridge over the Firth of Tay in during the famous storm in December 1879. Material fatigue and external events are engineering risk factors that are among the most complex and difficult to predict; the recent proposal to extend the operating life of the nuclear plants in Germany, as well as the disaster at Fukushima, have made this a more hotly-debated topic than ever before. The concept of the GAU, as formulated by nuclear engineers, made no allowance for such risks.

However, these conceptual issues were not discussed in a vacuum. Nuclear power became a multi-billion-dollar industry where safety issues determined the fate of huge investments. Recent stock-market trends of companies operating nuclear power plants demonstrate the significance of these financial considerations. When this article was finalized in August 2013, RWE shares stood at less than half of what they were worth on the eve of the Japanese disaster, and E.ON shares had fallen by more than 40 percent. However, the early debates over nuclear safety took place before these investments were even on the horizon, and that gave experts a chance to talk about these issues with remarkable candor.

In June 1959 Clifford Beck, the leader of the Hazards Evaluation Branch of the AEC, stated the problem bluntly in his presentation

"Safety Factors to Be Considered in Reactor Siting" during a nuclear conference in Rome: "It is inherently impossible to give an objective definition or specification for 'credible accidents' and thus the attempt to identify these for a given reactor entails some sense of futility and frustration, and further, it is never entirely assured that all potential accidents have been examined".[4] What conclusions does he draw from this? For one, a requirement for a massive containment system that would hopefully remain intact even in the worst possible situation and that would also offer a visually impressive and "intuitively attractive" safeguard against horrendous eventualities. At the same time, he formulates the axiom that nuclear facilities should be constructed far away from highly populated areas.[5]

This last requirement posed problems for the densely populated countries of Europe. In the USA, it did not develop into an official dogma regarding reactor safety; even so, it increasingly became an unofficial rule that influenced policy in West Germany as well. This was made clear in remarks by even such an unlikely person as Heinrich Mandel, later referred to in the media as the "high priest" of atomic energy because of his leading role in nuclear development at the energy company RWE (Rheinisch-Westfälische Elektrizitätswerk). In 1966 he used this argument before the West German Ministry of Education and Research in order to thwart plans by the chemical industry to create company-owned nuclear plants in "Hoechst, Leverkusen, or Ludwigshafen".[6] The plans for a project by the chemical company BASF in Ludwigshafen were already well underway when the RWE, which itself was planning the construction of the Biblis Nuclear Power Plant in the immediate vicinity, helped convince the federal government to prohibit the BASF project. The heads of the chemical industry complained about the "barbarian brutality of the RWE".[7]

Up to that time nobody had been forced by the government in

[4] Quoted in Okrent, *Nuclear Reactor Safety* cit., p. 33.

[5] Ibid., p. 32 ff.

[6] Radkau, *Aufstieg und Krise* cit., p. 373.

[7] W. Abelshauser, "Die BASF seit der Neugründung von 1952", in *Die BASF: Eine Unternehmensgeschichte*, W. Abelshauser (ed.), C.H. Beck, Munich 2002, p. 514.

Bonn to take such concrete measures in response to the "residual risk" of a "design basis accident" as in the confrontation involving the Ludwigshafen project.[8] The origin of the GAU as a significant – if surprising – site of memory might be located here. The hidden irony of history is that in a certain sense it was none other than Mandel, the "atomic high priest" and advocate of the light water reactor technology, who thus popularized the concept of the Super-GAU – a concept that would later become a beacon of the largest anti-nuclear movement in the world. However, that movement was still beyond the horizon: the GAU had already had a turbulent career by the late 1960s, but it was still strictly a word for insiders.

The nuclear safety advisor of the West German Nuclear Ministry was skeptical about the MCA concept from the very beginning: it was, he argued, "something that cannot be observed in conventional safety practices". The DAtK working group noted as early as 1958 that it is necessary to distinguish between the "maximum controllable" and the "maximum conceivable" accident: ultimately a very straightforward logical argument, but one which was later invoked only by opponents of nuclear energy, however. K.E. Zimen of the Hahn-Meitner Institute in Berlin explained to the West German Nuclear Ministry in 1961 that:

> by nature a "credible" maximum accident is not an objectively defined measure, but instead is dependent on subjective factors. Only the "greatest possible" accident (equivalent to the instantaneous release of all fission products into the atmosphere in the form of a radioactive cloud above the destroyed building) can be formulated in an objective manner [...] Therefore it is only natural that the safety reports of different nuclear energy facilities show very different "philosophies" in their definition of the credible maximum accident.[9]

For if one were to insist upon using the only truly precise definition of the greatest possible accident, there would be scarcely any location within the "inhabited regions of the globe" where a reactor might be built.

[8] Radkau, *Aufstieg und Krise* cit., p. 379 ff.
[9] Quoted in ibid., p. 358 f.

No insurance company would have been able to offer reasonable conditions for coverage of such a maximum disaster. Therefore, government guarantees were a must for the development of nuclear power. These guarantees took much of the pressure out of safety discussions, and that had enormous repercussions for the design of nuclear reactors. If the nuclear industry had been required to bear full responsibility for the risk, inevitably the only types of reactor to have become generally established would have been those which had a lower maximum risk factor due to their construction and mode of operation. This was not the case for what became the most common type of nuclear power plant: the light water reactor. Since light water reactors need to be turned off for reloading fuel, and since that process is laborious and time-consuming, builders sought to maximize the amount of fissile material that reactors could process before needing to be reloaded. As a result, even the "residual risk" presented by these reactors is particularly horrific. During the early days of nuclear energy other types of reactors were considered such as the pebble-bed reactor (in German *Kugelhaufenreaktor*), in which the fissile material is enclosed in graphite balls that constantly cycle through the reactor. This type of reactor never made it past the prototype stage, however. This new kind of reactor, which departed from the existing path of technological development and brought different kinds of risks with it, didn't have any powerful community behind it that might have been able to bring it to technological perfection and make it marketable. The light water reactor, which became widely-used throughout the world, profited from the fact that its cooling system built upon existing steam power plants and that the facilities it needed for enriching uranium were already available in military complexes. Private-sector industries would not in their wildest dreams have considered constructing such expensive facilities using their own funds. At the same time, the light water reactors gave a new, civilian purpose to the costly remnants of the nuclear arms race and lent them an illusion of economic rationality. For the nuclear states this also offered a possibility to disguise some of their military expenditures.

The term "maximum credible accident" could be manipulated to serve various purposes. Around 1960 members of the West German nuclear industry even tried to use the GAU as an excuse for getting a special license under certain circumstances: The tolerance dose of 0.5 rem of radiation per year set by the Euratom (European Atomic Energy Community) standards, should, they argued, be increased to 50 times as much in the case of a GAU! Karl Wirtz, the technological director of the Nuclear Research Center in Karlsruhe was forced to go head-to-head with some of the more persistent combatants.[10] In the early 1960s a concrete definition of an MCA or GAU became established on both sides of the Atlantic, a definition that satisfied not only the law books but the engineers as well: the GAU was specified as a malfunction in the primary cooling system leading to overheating of the reactor, and emergency cooling systems were instituted in order to take over in case of a disturbance in function.

Since then, however, the question hangs in the air: how much can such an emergency cooling system be relied upon when it is only put to the test rarely and in extreme cases, under circumstances where it is likely that escalating chain reactions could heat reactor cores to such a degree that they would cause the cooling water to evaporate instantaneously? Fukushima has given this question new, burning relevance. There were doubts about the efficacy of this backup system from the very beginning, not least among experts who had a clear understanding about what actually takes place within reactors. The international boom in nuclear energy at the end of the 1960s made this an urgent and hotly debated issue, in particular since light water reactors, which used enriched rather than natural uranium (thus leading to a higher density of radioactive material), were becoming more and more common. But precisely because of the new awareness of the stakes involved, it became increasingly difficult to draw conclusions about the practical implications of these risks.

An expert of the German Institute for Reactor Safety warned in 1969 that "there was a very real knowledge gap regarding the effec-

[10] Ibid., p. 358 f.

tiveness of emergency cooling systems [...] for all light water reactors around the world." In response, the West German government initiated research projects, as did other nations such as the USA. However, for all the results, these projects had a significant drawback: they were inevitably restricted to tests using modeling and computer simulations. The huge costs in combination with the potentially disastrous consequences of an ill-fated simulation ruled out realistic large-scale experiments – a fundamental dilemma of nuclear technology and other high-risk technologies!

But even with these limitations, research produced results that were not exactly reassuring.[11] At precisely the time when light water reactors began to enjoy worldwide success, behind the scenes a "revolution in light water reactor safety" (David Okrent) was taking place. Researchers increasingly recognized that a nuclear meltdown and the accompanying damage to the containment system were very far from being implausible or unlikely possibilities.[12] But billions of dollars had already been invested in the technology, and people either could not or would not abandon this technological path. When the discussions of nuclear risks came to a standstill among the relevant experts, they migrated into the view of the general public. There was a certain logic to this: there were very good reasons why the nuclear energy conflict began to reach a wider audience during this time, even though there had been no concrete nuclear catastrophe that would have caused widespread panic. This point is important, as the history of nuclear power is littered with speculations about irrational psychoses that drove the masses into opposition: the case of radiophobia that Karena Kalmbach chronicles in her article thus stands in a long tradition. But safety was a matter of concern in expert circles before the public took notice, and on the whole, the history of the anti-nuclear movement is a history of enlightenment, not of mass psychosis. It was primarily insider information, not the wild speculations of hysterical laypeople,

[11] Ibid., p. 370; for an extensive discussion of research in the USA see Okrent, *Nuclear Reactor Safety* cit., p. 294-305.

[12] Okrent, *Nuclear Reactor Safety* cit., p. 296.

which led to the protests against nuclear energy and the focus on the "Super-GAU."[13]

The first comprehensive collection of arguments by the West German opponents of nuclear energy was Holger Strohm's 470-page book *Friedlich in die Katastrophe* ("Peacefully towards Disaster") which appeared in October 1973,[14] and its page count grew with each successive volume until it competed with the Bible in size. It drew on anti-nuclear publications from the USA, which even then were remarkable for their scope and richness of knowledge. Strohm was the founder of the German branch of Friends of the Earth, the first international environmental NGO which had been started by the charismatic David Bower, who had left the (at the time) nuclear-friendly Sierra Club in protest of their policy. The Friends of the Earth's famously paradoxical motto "Think globally – act locally!" was particularly suited to the issue of nuclear energy, more than for many other battlegrounds of environmentalism.[15] The first edition of Strohm's book, however, makes no mention of the MCA, nor was the Germanization GAU as yet a familiar term. These terms still belonged to the vocabulary of the supporters of nuclear energy; not until several years later did the term GAU develop a life of its own in the German popular media.

Opponents of nuclear energy debated whether it was smart to focus too much on the risk of a nuclear catastrophe. First, the prospect was a somewhat nebulous risk in the days before Three Mile Island and Chernobyl – a matter of speculation rather than experience. Second, from a critical perspective, the GAU competed with other issues, most notably the essentially unsolvable issue of a permanent storage facility for nuclear waste that could withstand the passage

[13] J. Radkau, "Die Kernkraft-Kontroverse im Spiegel der Literatur. Phasen und Dimensionen einer neuen Aufklärung", in *Das Ende des Atomzeitalters? Eine sachlich-kritische Dokumentation*, A. Hermann, R. Schumacher (eds), Moos & Partner, Munich 1987, p. 308 ff.

[14] H. Strohm, *Friedlich in die Katastrophe: Eine Dokumentation über Kernkraftwerke*, Verlag Association, Hamburg 1973.

[15] J. Radkau, *Die Ära der Ökologie: Eine Weltgeschichte*, C.H. Beck, Munich 2011, p. 611f.

of millennia. Over the decades the nuclear protest movement has in fact alternated between these two targets. When a Super-GAU in fact took place in the form of the disaster at Chernobyl in 1986, it shocked even many long-standing members of the anti-nuclear camps, who in the course of their campaigns against nuclear armament had directed their efforts primarily against the proliferation potential inherent to nuclear technology, that is, the preparation of fissile material and the knowledge of how to use this to produce atomic weapons. Since the 1990s, the most popular protests went along with nuclear waste transports to the Gorleben interim storage facility in Lower Saxony. Thus, when the disaster at Fukushima occurred in 2011, the disposal of radioactive waste had long since become the primary target of the opposition movement, both in Germany and in other countries. How "credible" a catastrophe is held to be is highly dependent on unforeseeable events.

While GAU and Super-GAU continue to be provocative words in the German media, the safety discussion – to the extent that it ever treated the GAU concept seriously – has long since abandoned this approach. Although Ludwig Merz was one of the leading figures of the West German Reactor Safety Commission in the 1960s, his growing awareness of the dangers of nuclear reactors later led him to become a proponent of constructing reactors underground, a position that isolated him from the nuclear community. He confessed to the present author in 1981 that the "unfortunate GAU" was in truth merely a fiction used for the official authorization process and not a philosophy about nuclear safety – even though it had been misused to serve this purpose.[16] The inertia that led to continuing use of the GAU fiction in authorization procedures, he stated, was observed with a sense of unease even in the Nuclear Research Center in Karlsruhe.[17]

On 29 March 1979, the day after the accident at the Three Mile

[16] See similar comments in Id., "Sicherheitsphilosophien in der Geschichte der bundesdeutschen Atomwirtschaft", in *S + F (Sicherheit und Frieden)*, 6, 3, 1988, p. 113.

[17] Compare the remarks by D. Smidt in *Sechstes Deutsches Atomrechts-Symposium*, R. Lukes (ed.), Heymanns, Cologne 1980, p. 40, 41, 46.

Island reactor, the West German Parliament set up the study commission "Future Nuclear Energy Policy." It was succeeded by a whole row of other committees and continues to be held up as an example even today. It succeeded in establishing a consensus between the supporters and critics of nuclear energy, or at least as much of a consensus as was possible in a situation where the conflict had escalated nearly to the point of civil war between the opposing parties. It was agreed that probabilistic calculations regarding the frequency or infrequency of a Super-GAU could not be relied upon and that therefore it was not proper to trivialize the extreme consequences of a maximum accident by pointing to the extreme unlikelihood of such an occurrence.[18] The insurance industry, too, which normally based its calculations on the probability of a given event, could not rely upon this in the case of nuclear reactors.

A landmark in the nuclear discussion was the book *Normal Accidents*, published in 1984 by the Yale sociologist Charles Perrow, who had acted as an advisor to the commission established by President Carter to investigate the accident at the Three Mile Island power plant near Harrisburg. Using a combination of historical empirical evidence and organizational sociology, Perrow argued the thesis that unexpected, unforeseeable accidents are a normal part of highly complex technological systems.[19] According to him the fixation on calculating the degree of risk according to some specific imaginary maximum accident was a fundamentally wrong way of approaching the issue. Rather, if such complex technological systems are used at all, it is essential to focus on safety precautions that allow for coping with unforeseen events.

Not long after Perrow's book had become known around the world, Chernobyl presented a dramatic illustration of his thesis. The nuclear disaster in the Ukraine inspired visions rather than new theories, as in the Super-GAU song composed by Wolfgang Mahn:

Oohoho Tschernobyl

[18] *Zukünftige Kernenergie-Politik: Kriterien – Möglichkeiten – Empfehlungen.* Report of the Study Commission of the German Parliament, Bonn 1980, p. 32.

[19] C. Perrow, *Normal Accidents: Living With High-Risk Technologies*, Basic Books, New York 1984.

Das letzte Signal vor dem Overkill
Heh, heh, stoppt die AKW's!
("Oohoho Chernobyl
The last signal before overkill
Hey hey stop the nuclear plants!")

The song captured the mood in the days after Chernobyl, talking about radiation detection crews checking on the dosage in milk and lettuce, and about the fear instilled in children. But in the end, the song was skeptical about whether the Germans had learned their lesson: "The chancellor and the party leaders are turning to the atom again / And leave the sun, wind, and water unused all around us." Mahn suggested that they were probably trying to outdo the Roman Emperor Nero, who only torched a single city.

Around this time, the GAU entered common parlance, a sure sign that a term has achieved a fixed place in collective memory. The context of the nuclear debate was fading over time, as everything had already been said about the sense of the concept, or lack thereof. In fact, we can argue that the technical debate had already come full circle *before* the first protests: from obscure beginnings to brief popularity to decline and disbelief. Only the legal requirements kept the term in use among a disaffected nuclear community.

But while the term was out of fashion in nuclear circles, it thrived in popular culture. GAUs were now detected in all areas of life. When France was about to vote down the draft constitution of the European Union in 2005, the German weekly *Der Spiegel* spoke about an impending "Polit-Gau".[20] One year later, *Der Spiegel* spoke of a "Medien-Gau" when the Regensburg speech of Pope Benedict XVI provoked irritation and outrage across the Muslim world.[21] In fact, it no longer takes a real disaster or someone getting hurt to evoke the good old GAU. For instance, the yellow press nowadays brandishes an otherwise unspectacular wardrobe malfunction as a "Fashion-GAU".

As the GAU becomes a somewhat noncommittal moniker for

[20] R. Leick, "Ein Fußtritt für Europa?" in *Der Spiegel*, 21, 2005, p. 110.
[21] A. Smoltczyk, "Kulturkampf: Der Fehlbare", in *Der Spiegel*, 47, 2006, p. 122.

something vaguely dramatic, one thing seems to stick to the concept: a purported certainty as to what is right. But is that a good way to think about nuclear safety? At an international symposium on reactor safety at Monte Verità near Ascona in Italy in 1999, which the author of this article took part in, one of the presenters explained that the complexity of the issue of nuclear safety – namely that dangers always seem to lurk precisely where one least expects them – can best be illustrated using an Indian legend. It is a suitable parable for concluding our discussion of the history of nuclear policy and risk-taking: A maharaja once had a beautiful daughter, and of course many suitors sought to win her hand. Therefore stringent selection criteria were necessary. The maharaja announced throughout the land that he would present each of the suitors with two closed doors. Behind one of them was his daughter, and a hungry tiger lay in wait behind the other one. Only three suitors still had the courage to try for her hand anyway. The first was an optimist, who trusted his luck and opened one of the doors without pondering very long. Wrong choice. He was ripped apart by the tiger. The second wanted to be smarter and spent a long time puzzling over which door might be the correct one. But this didn't help him any, for he, too, chose the wrong door and was killed by the tiger. The third one wanted to be even smarter, embraced the concept of the worst-case scenario, and learned how to tame tigers in a matter of a few moments. This turned out to have been unnecessary, for when he opened the door the princess waited behind it. She embraced him – and drove a dagger into his heart from behind.