Hazards with Escalation Potential

Governing the Drivers of Global and Existential Catastrophes

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CENTRE FOR THE STUDY OF EXISTENTIAL RISK

Simon Institute for Longterm Governance

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EXECUTIVE SUMMARY

The future of humanity and the planet hinges on human choices. How societies invest in critical infrastructure, political systems, military capacity and technological development creates both opportunities and risks. The impact of human activity has become so extensive that the risk of global and existential catastrophe is increasing fast.

What could cause global and existential catastrophe? What set of events and processes would lead to such worst-case scenarios? And what are the implications for risk research and governance?

This briefing note answers these questions by identifying the hazards that, once paired with corresponding vulnerabilities and exposures, would escalate and cause global and existential catastrophes. Its goal is to distil governance insights on risk cascades from a review of the literature, an expert survey and expert consultations.

Overall, out of the 302 hazards identified in the Hazard Information Profiles (HIPs) developed by the United Nations Office for Disaster Risk Reduction (UNDRR) and the International Science Council to guide more holistic disaster risk reduction,[1] 10 geological, biological, technological and social hazards were identified as having a global escalation potential. In addition to this list, climate change and artificial intelligence were identified as the most transformative processes with the potential to create, modify or amplify other hazards, vulnerabilities and exposures. This minority of known hazards, which could trigger cascades leading to global and existential catastrophe, warrants focus.

Escalating hazards share core characteristics such as the ability to affect multiple systems and to bypass established response and coping capacity. Focusing on these characteristics of the worst hazards can refine governance strategies, making them more adaptive to the various manifestations of risk. Current governance systems are built to prepare and respond to events with known frequency and manageable severity, but they are not fit for purpose to address worst-case scenarios, which are emerging, exponential and global in scope. This briefing note calls for important changes in risk research and governance to remedy these gaps.

Implications for risk research	
1.	**Not all hazards have the potential to become existential or catastrophic risks.** By focusing on the most critical threats and leveraging common characteristics, we can enhance prevention strategies, and foster resilience across all disaster scenarios.
2.	**Learning from large-scale disasters such as the Ebola outbreak or the COVID-19 pandemic is crucial to understanding hazard escalation.** These lessons can offer insights into how impacts spread, revealing system vulnerabilities that can guide improvements in preparedness, response strategies, infrastructure and governance.
3.	**Improved comprehension of hazard escalation characteristics can contribute to more accurate risk modelling.** By identifying trends and sensitive variables, we can deepen our understanding of risk, leading to more effective prevention strategies and empowering decision makers with the necessary information.
4.	**A deeper understanding of hazard escalation can reveal potential "circuit-breaker" actions that may slow or halt disaster growth.** By identifying and implementing these measures, we can lessen the severity of future events, safeguarding lives, conserving resources and minimizing societal impacts of escalating hazards.

Implications for risk governance at the national and international levels	
1.	**The global scope of hazards with escalation potential necessitates governance at both national and international levels.** Effective risk management requires strong public-private collaboration, multisectoral approaches, adaptive governance mechanisms, and a proactive stance towards prevention and preparedness due to the complex and severe nature of such hazards.
2.	**The global risk governance community's definition of a large-scale event inadequately considers global catastrophic or existential risks.** Addressing this gap calls for joint analysis and planning across duty bearers, focusing on government intervention and fostering capacity-building in regions where risk governance may be lacking.
3.	**Understanding escalation potentials can contribute to the development of better standard operating procedures for duty bearer organizations.** This knowledge can foster more effective mitigation and response strategies, helping prevent the exponential growth of potential hazards.
4.	**While risk assessments prioritize the most likely and frequent events, governments and duty bearer organizations must focus on hazards with the greatest escalation potential.** Incorporating measures to halt escalation into all disaster risk reduction efforts and contingency planning can lead to more proactive, effective and resilient risk management strategies for risks of any scale.


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01

HUMAN CHOICES DRIVE RISK

- Global catastrophic and existential risk
- Methodology

Credit: Unsplash/Vladyslav Cherkasenko

1. Human choices drive risk

Since the 1950s, the world has become increasingly globalized in terms of flows of information (via the Internet), goods (via trade and transport), capital (via insurance, investments, foreign direct investment, official development assistance) and people (via transport and migration).[2] A globalized system has at least three implications for the creation of risk. First, risk becomes increasingly systemic because of the multiple forces that create, amplify and absorb–or fail to absorb–its impacts.[3] Second, natural and human-made hazards may trigger cascades of impacts by disrupting flows of information, goods, capital and people.[4] Third, while decentralized resilience might prove more robust in many circumstances, it may also have more local points of failure, which, if reached, may overwhelm surge capacity and precipitate societies into extreme disasters.[5]

When systemic, cascading and extreme risks reach a global scale, they can become catastrophic and even existential.[6] Such risks threaten societies worldwide and result from human choices. How societies invest in critical infrastructure, political systems, military capacity and technological development involves both opportunities and risks. As such, there is a need for risk-informed development at scale to prevent these global worst-case scenarios.[7]

The development of this briefing note stems from a growing interest from the international community to better understand how hazards can escalate and how public and private institutions may strengthen their foresight capacity to better prevent, prepare and manage the resulting large-scale risks. This briefing note brings together insights from experts from the disaster risk community and from the global catastrophic risk community to respond, among others, to the need identified by the United Nations Secretary-General's report, Our Common Agenda,[8] which states that:

> **Our success in finding solutions to the interlinked problems we face hinges on our ability to anticipate, prevent and prepare for major risks to come. [...] Where global public goods are not provided, we have their opposite: global public 'bads' in the form of serious risks and threats to human welfare. These risks are now increasingly global and have greater potential impact. Some are even existential: with the dawn of the nuclear age, humanity acquired the power to bring about its own extinction. Continued technological advances, accelerating climate change and the rise in zoonotic diseases mean the likelihood of extreme, global catastrophic or even existential risks is present on multiple, interrelated fronts. Being prepared to prevent and respond to these risks is an essential counterpoint to better managing the global commons and global public goods. An effort is warranted to better define and identify the extreme, catastrophic and existential risks that we face.**

António Guterres,
Secretary-General of the United Nations

This briefing note aims to inform national and international policymakers, non-governmental organizations and academic experts about global worst-case scenarios and draw attention to the need to enhance strategic foresight on catastrophic risks, and anticipatory decision-making across the full spectrum of risks. Improved understanding of existential and global catastrophic risk can make investments more effective in key areas such as strengthening health-care systems to reduce pandemic escalation or setting standards to reduce the adverse impacts of artificial intelligence (AI). A better understanding of the hazards underpinning potential catastrophes could drive better responses and preparedness for both known and potential unknown future events and improve the modelling of major systemic risks and cascades.

1.1. Global catastrophic and existential risk

There are multiple definitions of global catastrophic and existential risk. For the purposes of this briefing note, we will use the following definitions:

- Global catastrophic risks (GCRs) are those events that could lead to widespread disaster beyond the collective capability of national/international governments and the private sector to control. If unchecked, GCRs could lead to great suffering, loss of life, and sustained damage to national governments, international relations, economies, societal stability and global security (generalized from a definition of global catastrophic biological risks).[9] GCRs could result in the loss of at least 10 per cent of the global population or the alteration of the future trajectory of humanity, but from which recovery is possible.[10]

- Existential risks are events that, either directly or indirectly, could cause the extinction of humanity or the irreversible collapse of society worldwide.[11]

The 10 per cent threshold in the GCR definition is an arbitrary value, but one that has been widely adopted within the field of existential risk as a kind of shorthand representing the scale and scope envisioned. Noting the arbitrariness of this definition, researchers in the field proposed higher thresholds, comprising the loss of at least 25 per cent of the global population, as well as "severe disruption of global critical systems (such as food) within a given time frame (years or decades)".[12] The use of a threshold that is higher than usual is for the purpose of setting apart catastrophes historically unprecedented from those experienced before.

For comparison, COVID-19 has caused an estimated 6–20 million deaths worldwide, equivalent to around 0.1 per cent of the global population. A global catastrophic risk would have a death toll or impacts at least 100 times larger than COVID-19, and an existential risk would lead to full societal collapse. Criticisms of this definition point to the fact that the timeframe over which the impacts are considered is not specified and that it overlooks wider social and ecosystem impacts that may occur across a range of temporal and geographical scales that ultimately condition the chance of global catastrophes.

Global catastrophic and existential risks are often considered either as events that may directly cause the extinction of humanity (e.g. asteroid impact) or those that may begin a cascade of impacts that drive humanity towards unrecoverable collapse (e.g. nuclear war that causes sunlight blocking scenarios, with disruption to global food production).[13] A common misconception is that GCRs concern only far-off risks that emerge over the next decades or centuries. However, one of the catastrophic risks we face today is the threat of nuclear war, which has been present for over 75 years. To take a more recent example, we may not need to reach superhuman artificial general intelligence before we experience the global and pervasive impacts of near-term or transformative AI, developed on a much shorter, more rapid timescale.[14]

Definitions of existential risks and GCRs often centre on the outcomes. Similarly, many attempts at classifications, especially those that stem from moral philosophy, also focus on the nature of the end state.[15] However, this briefing note argues that more attention is needed to understand the process by which hazards escalate. Arguably, better understanding the paths to escalation can help us better identify the relevant potential hazards and combinations thereof that would cause global catastrophes. This briefing note aims to unpack these potential paths and use them to guide the direction of risk governance.

1.2. Methodology

A useful way to examine the systemic processes underlying global catastrophic and existential risk is through the lenses of hazard, exposure and vulnerability.[16]

- Hazard: a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.
- Exposure: the situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas.
- Vulnerability: the conditions determined by physical, social, economic and environmental factors or processes that increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.

This briefing note is structured in four sections:

1

Identifying hazards with escalation potential:

Through an interplay with exposures and vulnerabilities, hazards may cause global or existential catastrophes. Starting with hazards is important to identify the corresponding exposures and vulnerabilities. It is also the step required to bridge the academic literature on global catastrophic and existential risk, which primarily focuses on hazards, with wider scholarship on systemic risk.

2

Inferring shared hazard characteristics:

Based on the set of hazards with escalation potential, investigating key characteristics allows us to generalize findings, anticipate unknown future hazards and improve governance systems to be fit for purpose for a wide range of risks rather than siloed subsets. It also allows us to tackle common governance challenges and possible solutions without needing an exhaustive list of hazards with escalation potential.

3

Distilling governance challenges:

The characteristics shared by hazards with escalation potential shed light on common governance challenges that make governments and multilateral organizations less effective at tackling these hazards.

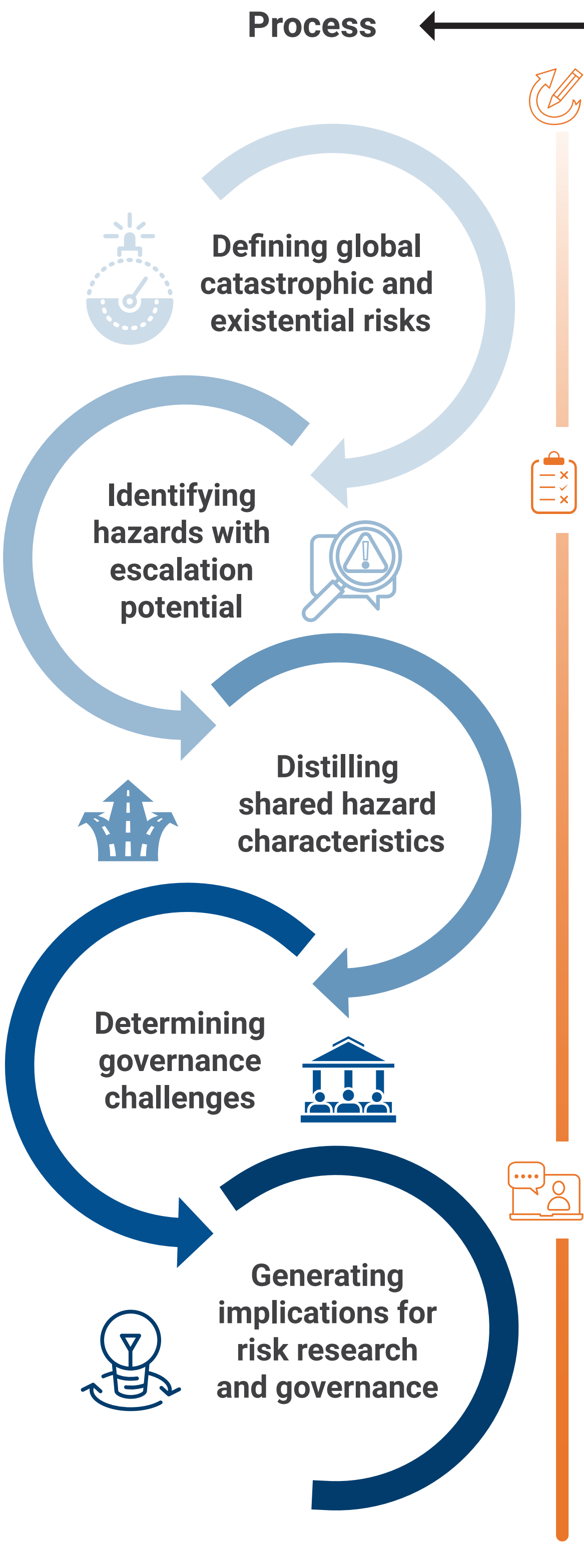
4

Distilling implications for research and governance:

The shared characteristics, together with the governance challenges, help distil implications to improve risk research and governance to inform future work.

To achieve the four steps above, the briefing note relies on the three information sources listed below. A summary of the process used to prepare this briefing note is outlined in figure 1.

Figure 1. Methodology followed for this briefing note



1. **A literature review** drawing together publications explicitly mentioning global catastrophic and existential risk. The literature review provides an overview of the field and its history, core definitions, classifications and taxonomies as well as an outline of who is responsible for the governance of global catastrophic and existential risk.

2. **An expert elicitation survey** to identify hazards with escalation potential among the 302 hazards that UNDRR and the International Science Council reported in their *Hazard Definition and Classification Review: Technical Report*[17] and subsequent set of Hazard Information Profiles (HIPs) (box 1).[1] The survey was designed to probe which hazards from the HIPs may have the potential to escalate to global catastrophic or existential risks and to identify the mechanisms by which these may happen. It was sent to domain experts across the eight hazard types (box 1) from expert groups linked to UNDRR. Of the responses received, 254 were used to inform this briefing note. Respondents provided a diversity of responses both in terms of geographies and sectors (figure 2).

3. **Two expert consultations across hazard types** (box 1) to challenge the approach taken for this briefing note, suggest additional bodies of literature, refine the conceptualization of the elicitation survey and comment on survey results. The consultations were conducted as online discussion sessions hosted on 9 September 2022 (pre-survey) and 17 March 2023 (post-survey).

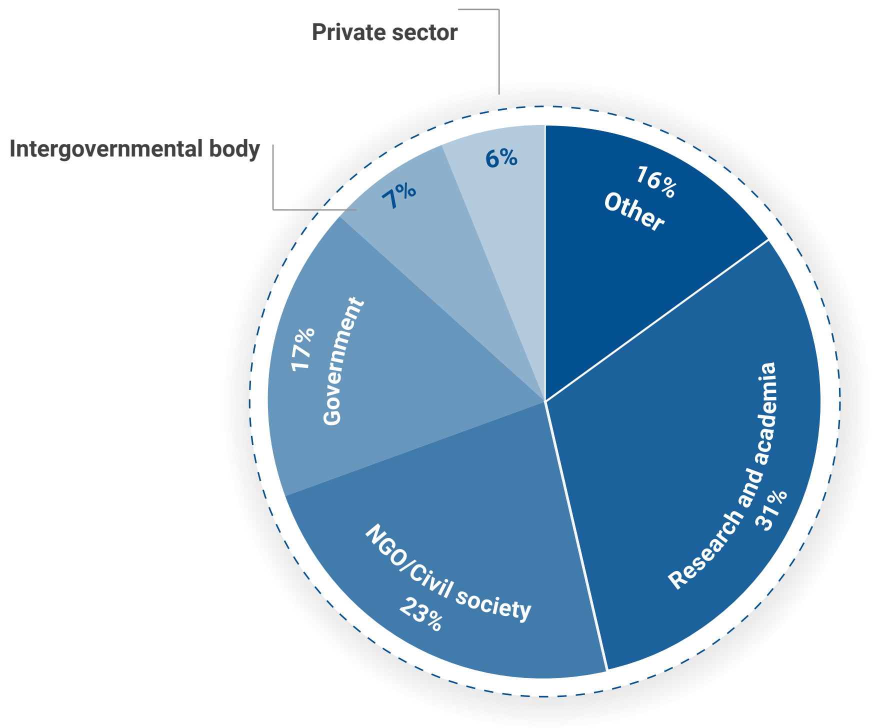
Together, the literature review, survey results and expert consultations provide a body of knowledge that reflect recent scholarship, existing hazard classification and challenges in risk understanding and governance. Moreover, given that the HIPs do not seem to include the hazards often discussed in the literature on global catastrophic and existential risk, such as AI-related hazards, this briefing note can inform an update of the HIPs in the future.

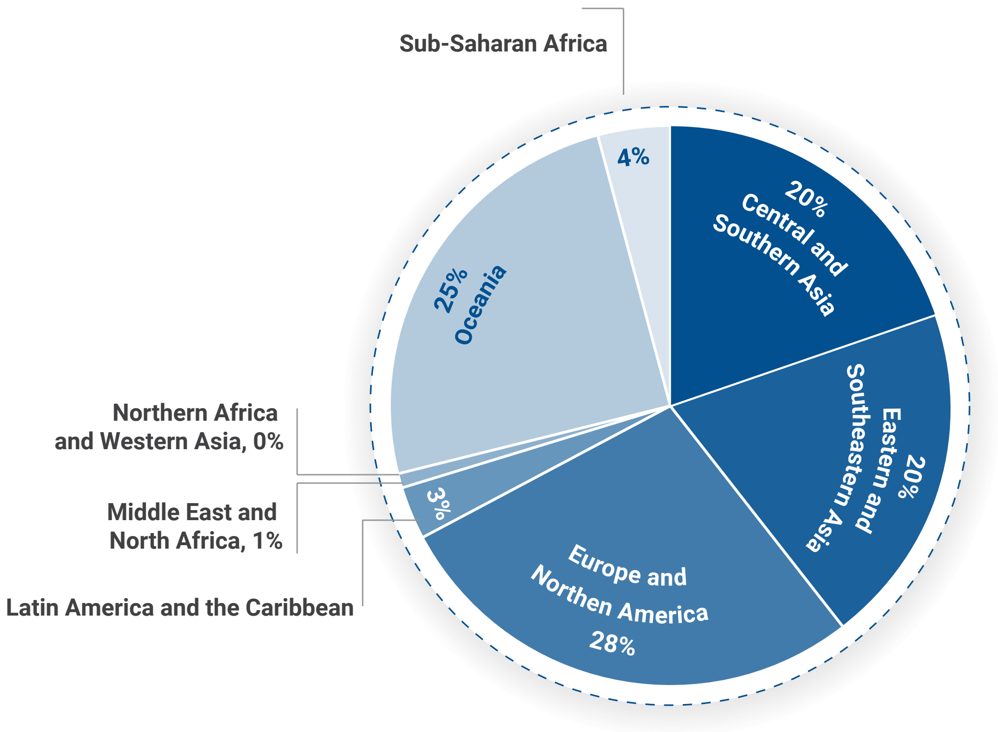
Box 1.

Eight hazard types from the Hazard Information Profiles

1	Meteorological and hydrological (9 clusters and 60 hazards): e.g. convection-related, flood, lithometeors, marine, pressure-related, precipitation-related, terrestrial, wind-related
2	Extraterrestrial (1 cluster and 9 hazards): e.g. meteorite, space weather, near-Earth object
3	Geohazards (3 clusters and 35 hazards): e.g. seismogenic, volcanogenic
4	Environmental (2 clusters and 24 hazards): e.g. environmental degradation, biodiversity loss, desertification
5	Chemical (9 clusters and 25 hazards): e.g. food safety, pesticides, hydrocarbon
6	Biological (10 clusters and 88 hazards): e.g. invasive species, infectious diseases
7	Technological (9 clusters and 53 hazards): radiation, chemical, biological, radiological, nuclear and explosive, infrastructure, cyber, industrial failure, waste
8	Societal (4 clusters and 8 hazards): e.g. conflict, post-conflict, economic

Figure 2. Sectors and geographies of survey respondents





02

WHICH HAZARDS ESCALATE?

- Geohazards with escalation potential
- Biological hazards with escalation potential
- Technological hazards with escalation potential
- Social hazards with escalation potential
- Missing and underrepresented drivers of global risks

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2. WHICH HAZARDS ESCALATE?

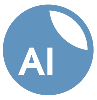
According to the survey, the 10 most reported hazards from the existing HIPs fell into four hazard types (table 1).[1] The order of hazards in table 1 does not indicate any ranking of importance. The 10 hazards were the ones that had the highest level of agreement among survey respondents. For example, 26 survey respondents indicated that international armed conflict has escalation potential and none indicates it does not, thus leading to a 100 per cent agreement. Conversely, 38 survey respondents indicated that flash floods have escalation potential, but 39 respondents indicated that they do not have escalation potential, thus leading to a 49 per cent agreement. Hazards that received fewer than five responses were excluded from the analysis. From the survey results, it appeared that a lot of disagreement seemed to lie regarding environmental hazards. This may point to the reason why climate change was highlighted as a missing hazard, because it exacerbates most environmental hazards simultaneously, such as biodiversity and food insecurity, which together may lead to global catastrophes.

Table 1. 10 most reported hazards with escalation potential from expert elicitation survey (N=254)

Hazard type	10 most reported hazards with escalation potential
Geohazards	Volcanic gases and aerosols
Biological	Deadly pandemics
	Antimicrobial resistance
	Harmful algal blooms
Technological	Nuclear agents and nuclear winter
	Radiation agents
	Infrastructure disruption
	Hazards related to the Internet of things (IoT)
Social	International armed conflict
	Environmental degradation from conflict

Additionally, survey respondents highlighted that the following two risk drivers were not represented in the HIPs but were highlighted by survey respondents, likely because they (1) group a collection of hazards and/or (2) are emerging. This finding can be considered in the on-going update of the HIPs.

1. **Climate change**, including resulting heatwaves and sea level rises: Hazards related to climate change, while primarily environmental in nature, are also geological (e.g. increased volcanic activity), biological (e.g. increased pandemics) and social (e.g. food system disruption, conflict and migration).



2. **AI and its capabilities**, including but not limited to misuse and accidents: While primarily technological, AI-related hazards may be biological (e.g. engineered pathogens) and/or social (e.g. conflict, surveillance systems, economic crashes).

The survey results align with the literature on global catastrophic and existential risks. Academic scholarship has looked at risks from volcanic eruptions,[18–23] biological risks (in particular pandemics),[9,24,25] technological risks including nuclear agents and nuclear winters[26–28] and misuse or misalignment of AI,[14,29,30–36] as well as environmental risks including climate change.[11,12,37–40] The survey results also align with the idea that a combination of hazards and vulnerabilities rather than single hazards would lead to global and existential catastrophes.

Below, we describe the top 10 hazards with escalation potential from the HIPs, as well as climate change and AI as accelerating and transformative hazards, respectively. The hazards with escalation potential discussed below do not form an exhaustive list. Rather, they serve as a basis to infer characteristics.

2.1. Geohazards with escalation potential

2.1.1. Volcanic gases and aerosols

Large magnitude volcanic eruptions (magnitude 7 or greater) can release significant quantities of gases during an eruption, propelling them up into the atmosphere. Once in the atmosphere, the gases combine with water, eventually forming aerosols that reflect sunlight back into space, and a volcanic winter ensues. This sunlight reduction scenario can cause climate feedbacks, including global surface cooling, disruptions to ocean and climate circulations, and a reduction in global rainfall. These impacts are exacerbated in the northern hemisphere, their effects potentially lasting for a decade or more. This can be devastating for global food production, with estimates currently suggesting a loss of caloric intake in the immediate aftermath of such an event for 1 billion to 2.9 billion people.[41] The probability of a large magnitude volcanic eruption is 1 in 6 per century, yet there are no global funds specifically dedicated to mitigating or preparing for extreme volcanic risks.[21]

2.2. Biological hazards with escalation potential

2.2.1. Deadly pandemics

Natural pandemics, which arise from naturally occurring pathogens, and engineered pandemics which result from the deliberate creation or modification of pathogens (so-called gain-of-function research), have the potential to cause widespread illness, death and societal disruption.[25] While natural pandemics can emerge from animal-to-human transmitted diseases or mutations of existing pathogens, engineered pandemics stem from biotechnological manipulation with malicious intent or for foundational research purposes. Although engineered pandemics are considered less likely to occur compared with natural pandemics, they may pose a higher level of risk due to their potential for rapid spread, increased virulence and resistance to existing treatments or vaccines, as well as the increased social disruption or geopolitical tension that they might cause.[26] Engineered pathogens may be designed to target specific populations or to exploit specific vulnerabilities in the human immune system, amplifying the severity of their impacts. Both natural and engineered pandemics, through accidents or misuse, can cause deaths, strain health-care systems, disrupt global economies and lead to social unrest, with the capacity to inflict long-lasting and far-reaching consequences on human societies.

2.2.2. Antimicrobial resistance

Antimicrobial resistance, the adaptation of microorganisms to withstand antimicrobials, poses a burgeoning global hazard by severely escalating the risk of a bacterial/microbial outbreak becoming an epidemic or pandemic. Microorganisms (bacteria, fungi, viruses, protozoa) can evolve under the selective pressure of antimicrobials, rendering treatments that would ordinarily kill or inhibit these organisms ineffective.[42] Though a natural occurrence, this phenomenon has been drastically amplified by the improper use of antimicrobials, particularly in food production involving animals and crops. The resulting emergence of resistant microorganisms in the food chain raises serious concerns about food safety. Contamination of food and water with antimicrobial resistant organisms or their genes could lead to illnesses in humans, which become increasingly challenging to treat due to the resistance.[43] Comprehensive data collection and surveillance remain inadequate, hampering effective risk assessment and management efforts. The impact of antimicrobial resistance is already severe: in 2019, the global burden of deaths associated with bacterial resistance were estimated at 4.95 million.[44] Therefore, antimicrobial resistance necessitates urgent international attention and coordinated action, owing to its potential to escalate into a full-blown global health crisis.

2.2.3. Harmful algal blooms

Harmful algal blooms, composed of toxic or noxious algae, pose a considerable biological and environmental hazard with escalating potential. They are found in almost all aquatic environments and are increasing in frequency, severity and geographical spread.[45] This escalation is, in part, attributable to complex factors including climate change, excess nutrients in freshwater and oceans leading to eutrophication, habitat modification and the human-induced introduction of foreign species.[46,47] Essential to aquatic ecosystems by fixing carbon and producing oxygen, algae can form high biomass or toxic blooms under specific circumstances. These blooms inflict damage on aquatic ecosystems, disrupting food webs, causing fish mortality through gill damage or contributing to the creation of low oxygen dead zones. Some harmful algal blooms even produce potent toxins that infiltrate the food chain, resulting in illness or death in aquatic animals and humans consuming affected seafood. Non-toxic algal blooms can also wreak havoc, causing fish and invertebrate deaths by generating anoxic conditions or damage to the gill tissues of fish. This threat to aquaculture stocks can lead to substantial economic losses and compromise food security. The greatest concern to humans lies in algal species producing potent neurotoxins, which when ingested via shellfish or fish, can cause a range of gastrointestinal and neurological illnesses. The increasing prevalence of harmful algal blooms, coupled with their wide-reaching impacts on ecosystems, economies and public health, underscores their potential to escalate into a major environmental crisis.

2.3. Technological hazards with escalation potential

2.3.1. Nuclear agents and nuclear winter

Nuclear weapons and the potential resulting nuclear winters represent an extreme hazard due to their immense destructive capacity and long-lasting consequences. One significant effect of a nuclear explosion is a blast generated by a rapidly expanding fireball, which creates a pressure wave that moves swiftly away from the point of detonation. In the aftermath of a nuclear incident, numerous hazards emerge, including widespread fires and the presence of toxic materials. Importantly, nuclear explosions can cause a nuclear winter, which is a long, cold period worldwide after many nuclear bombs go off, blocking the sun's light and heat with smoke and soot. This could result in a massive food shortage, possibly causing up to 5 billion people to die from hunger.[48]

2.3.2. Radiation agents

Harmful radiation agents, comprising substances or materials emitting ionizing radiation, present a hazard with considerable escalation potential due to their extensive health and environmental implications. When humans or animals are exposed to these radioactive materials, the risk of detrimental health outcomes, such as cancer, increases significantly, as demonstrated by studies of atomic bomb survivors and radiation industry workers.[49] The threat extends beyond just immediate exposure. A nuclear explosion, for instance, yields intense ionizing radiation from the nuclear fission process and the decay of radioactive fission products, manifesting as prompt radiation and lingering as latent radiation in the form of radioactive fallout. However, radiological hazards are not limited to nuclear explosions. Accidental spills of radioactive chemicals can also occur in settings such as laboratories, reprocessing plants or hospitals, as well as accidents during radiation therapy. Accidents in nuclear power plants pose a long-lasting risk, potentially contaminating territories spanning thousands of square kilometres over extended periods, requiring extensive mitigation measures such as zoning and evacuation. Given the potential for widespread contamination, long-term environmental impact and serious health consequences, harmful radiation agents represent a high-risk hazard with significant escalation potential.

2.3.3. Infrastructure disruption

Infrastructure disruption, particularly in the realm of Internet and communication networks, represents an extreme hazard due to the critical role these systems play in modern society. Their smooth functioning is essential for the delivery of a wide array of digital services that underpin daily life and the global economy. However, these networks face numerous challenges that can compromise their operation, such as breakdown of components, wireless connectivity issues, malware, cyberattacks (interruption, interception, modification and fabrication), human error, malicious interference, power failure, and natural hazards or disasters. The geographical area of network links and nodes is also a factor to consider, as disruptions in one region can have cascading effects on interconnected systems. Extreme weather events from space, such as solar flares, could cause widespread infrastructure disruption, especially on communications networks.[18]

The potential for widespread consequences from infrastructure disruptions, including the crippling of electrical grids and pipelines vital to energy supply, underscores the extreme hazard they pose to modern societies that not only rely heavily on Internet and communication networks, but also on a stable and uninterrupted flow of power and resources.[50]

2.3.4. Hazards related to the Internet of things

The Internet of things (IoT), an ever-expanding global infrastructure interconnecting physical and virtual objects, is subject to hazards with potential for escalation, primarily due to its inherent data security and privacy vulnerabilities, as well as exposure to space weather events. With billions of interconnected devices anticipated in the near future, the IoT is becoming increasingly pivotal to critical infrastructure operations, such as health care, banking, transportation and energy, among others.[16] However, this growth brings about a heightened risk of cyberattacks, which could lead to significant data breaches or disruption of crucial services or vulnerability to space weather events. Attacks can take various forms, including denial of service and distributed denial of service attacks that overwhelm systems by flooding them with traffic and malicious software or malware, designed to harm computer networks, servers and IoT devices. Additionally, issues such as insufficient authentication or authorization processes and lack of cryptographic techniques can compromise the integrity, authenticity and confidentiality of data transmission and storage. IoT-related hazards expand the scale of the impact of terrorism, may lead to hacking of security systems and thus conflict escalation, as well as the manipulation of influential decision-making. Given the increasing reliance on the IoT and the scale of potential impacts, IoT-related hazards have potential for escalating into significant cybersecurity crises.[51]

2.4. Social hazards with escalation potential

2.4.1. International armed conflicts

International armed conflicts, encompassing declared wars and other de facto armed conflicts between two or more States, pose an extreme hazard due to their potential for widespread destruction, loss of life and long-lasting consequences. Armed conflicts often lead to massive displacement of populations, significant loss of infrastructure and disruption of essential services such as health care and education. Moreover, international armed conflicts can exacerbate existing social, economic and political tensions, making it difficult for the affected regions to recover, even after hostilities cease. The potential for spillover effects, unintended consequences and the involvement of multiple parties in these conflicts increases the risk of further destabilization and the possibility of triggering additional and potentially more catastrophic hazards, such as a nuclear exchange leading to a nuclear winter.[52]

2.4.2. Environmental degradation from conflict

Environmental degradation from conflict, defined as the reduction of the environment's ability to meet social and ecological needs, can escalate dramatically during armed conflicts. Factors such as the type and tactics of weaponry used, conflict location, duration and pre-conflict environmental conditions can exacerbate land misuse, deforestation, pollution and loss of biodiversity.[53] These environmental hazards can perpetuate cycles of instability and tension. The impacts of conflict on the environment manifest directly, such as through targeted environmental destruction or contamination, and indirectly as populations overuse resources, or environmental governance structures fail.

This breakdown of governance and its long-term implications can be the most challenging to address, with, so far, poorly documented impacts on human life and health. Therefore, integrating environmental considerations into military and reconstruction programmes and enforcing international laws are crucial to mitigating environmental damage from conflict and facilitating peacebuilding.

2.5. Missing and underrepresented drivers of global risks

2.5.1. Climate change as an amplifier of hazards

Climate change is an overarching phenomenon that acts as an amplifying factor which can exacerbate many of the hazards and vulnerabilities previously mentioned in this report. Although excluded from much of the existential risk literature, due to it not being perceived as a direct hazard to the continued survival of humanity, climate change amplifies compounding and cascading risks. Climate change influences extreme weather events, disrupts food systems, erodes crucial infrastructure and increases the probability and severity of pandemics and volcanic eruptions. This makes system maintenance costlier and reduces the ability to address unrelated risks.[11,12,54–56] Consequently, its influence extends far beyond single hazard categories, interlinking numerous threats and exacerbating existing vulnerabilities (figure 3).

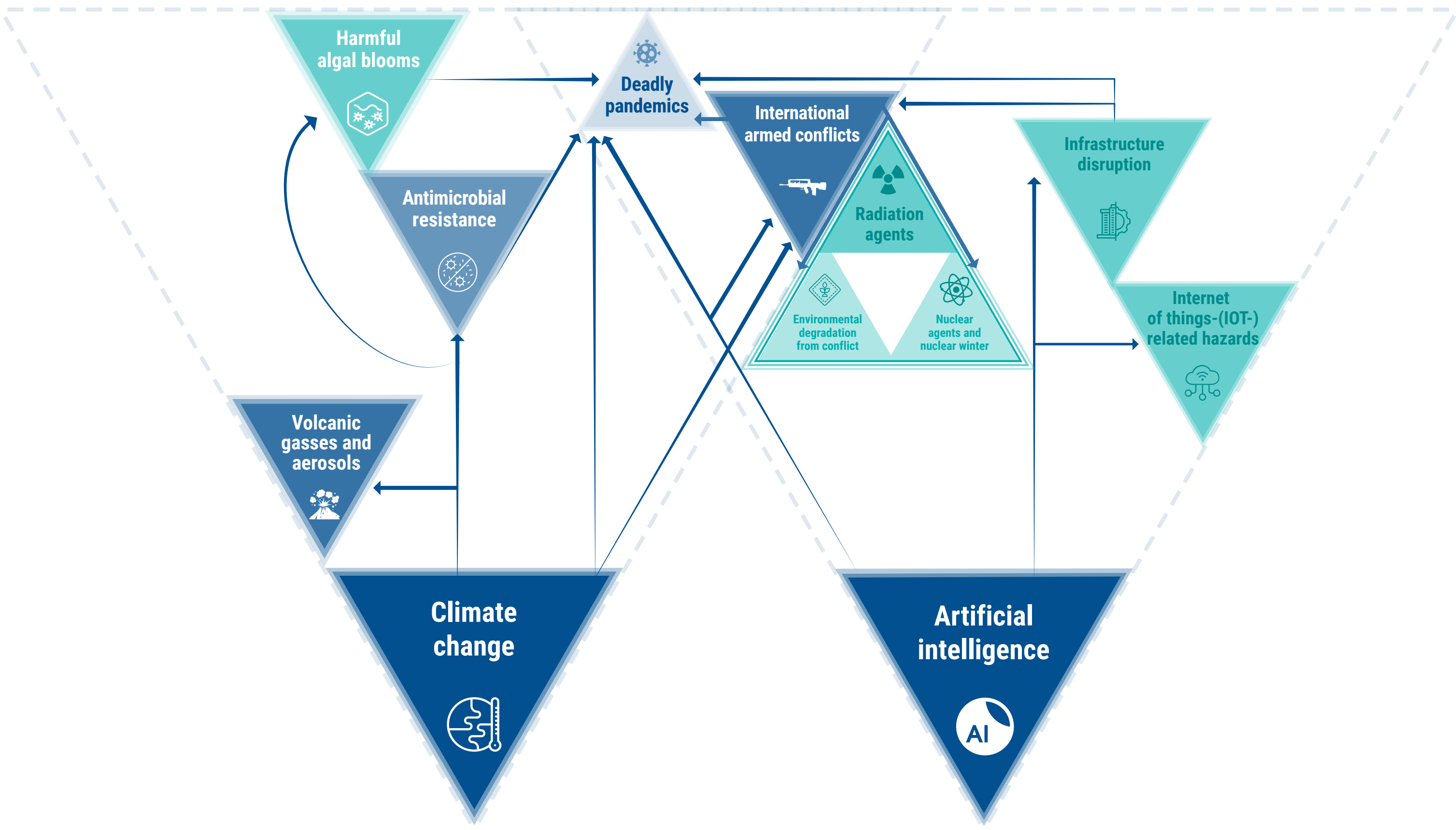
Recognizing climate change as a driver of many hazards, such as extreme weather events, is essential to understanding the complex relationships between these risks and their creation. Long-term climate feedbacks and interactions with anthropogenic climate change add to the complexity of the issue. By examining interconnected risks and common drivers of hazards, exposure and vulnerability, a better comprehension of the far-reaching implications of climate change on societies and ecosystems can be achieved. This comprehensive understanding enables the development of more holistic and effective strategies to mitigate the myriad risks associated with climate change.[57,58]

2.5.2. Artificial intelligence as a transformative process

While acknowledging that AI presents opportunities for positive applications, the development of AI and its capabilities creates risks. AI is transformative due to its nature as a general-purpose technology, and thereby could magnify hazards, exposures and vulnerabilities in various sectors,[14,59] especially as capacity to understand, audit and regulate AI systems lag behind technological developments. It has the potential to induce radical, irreversible changes in welfare, wealth and inequality.[60] With the increasing power of AI systems, such as OpenAI's ChatGPT and DeepMind's Gato, concerns emerge regarding their potential to reinforce biases or spread false information. Moreover, powerful AI systems such as Microsoft's Bing Chat could interfere with the agency of vulnerable users. The increased use of AI and related technologies in decision-making raise major questions around control and alignment with human values. Future goal-oriented systems with more advanced capabilities might even develop self-improving capacities or a drive for self-preservation, in order to achieve autonomously evolved, opaque objectives.[61] As a result, AI's transformative nature amplifies risks across numerous domains, exacerbating inequities and challenges faced by societies, as well as posing an existential risk in and of itself.[7]

Transformative AI could exacerbate numerous types of hazards, from armed conflict and nuclear wars to pandemics, making it a primary driver of existential risk and global catastrophic risk (figure 3.) in particular, in the case of advanced AI systems having control over significant resources, critical infrastructure and military systems. As AI systems become more advanced and autonomous, they may enable and entice State and non-State actors to deploy lethal autonomous weapons, AI-enhanced propaganda and surveillance, and AI-enhanced cyberwarfare.[31,62] Additionally, AI-driven decision-making processes may inadvertently escalate geopolitical tensions (potentially increasing the risk of major conflict and use of weapons of mass destruction) or fail to identify emerging threats, such as the outbreak of new pandemics.[63,64] Furthermore, the potential misuse of AI in biotechnology research could lead to the creation of more potent and deadly pathogens, heightening the risk of engineered pandemics.[62,65–68] The transformative nature of AI not only amplifies existing hazards, but also introduces new complexities and uncertainties, making it a significant contributor to global catastrophic and existential risks. The value misalignment of AI (when AI systems fail to adequately follow the imperfectly conveyed goals of their creators) also poses challenges for societal resilience, necessitating the addressing of specification, robustness, assurance and interpretability to prevent catastrophic outcomes.[69] The potential for disastrous AI deployments across all sectors of human activity emphasizes the importance of understanding and mitigating the transformative threats posed by AI.

Figure 3. Interactions between hazards with escalation potential discussed in this briefing note




Credit: Pexels/Bruno Thethe

03

CHARACTERISTICS SHARED BY HAZARDS AND DRIVERS WITH ESCALATION POTENTIAL

- Exponential growth and self-propagation over both short and long time frames
- A global geographical scope
- Severe, fatal and rapid cascading impacts across multiple ecosystems and geographies, public and private sectors
- Irreversible systemic shifts in socioeconomic systems
- Bypass established response and recovery capacity
- Trust and cooperation erosion
- Uncertainty and complexity
- Shared ownership between governments
- Technological origins
- Emerging and development-driven

Credit: Unsplash/Laboratory Institute,
Artificial intelligence and human combined

3. CHARACTERISTICS SHARED BY HAZARDS AND DRIVERS WITH ESCALATION POTENTIAL

Hazards with escalation potential – whether reported by the literature or the expert survey – share common characteristics. These common characteristics should mean that governance can be designed and organized around their impacts and implications and could thus adapt to new potential hazards which, even if difficult to predict, will likely share the same characteristics. This helps delineate strategies to mitigate worst-case scenarios.

3.1. Exponential growth and self-propagation over both short and long time frames

Hazards with escalation potential grow in exponential spurts and self-propagate over varying time frames, leading to rapidly escalating consequences. For example, global pandemics can spread rapidly, infecting and affecting a large number of people in a short period. The exponential growth of a viral outbreak can quickly overwhelm health-care systems and lead to widespread illness and death.

3.2. A global geographical scope

Hazards with escalation potential have a global geographical scope, affecting multiple continents simultaneously, often by affecting multiple global critical systems, functions and infrastructure at once. Climate change, for instance, is a global phenomenon that impacts ecosystems, economies and societies worldwide. Rising temperatures, more frequent and severe extreme weather events, and sea level rise are just a few examples of climate change's far-reaching consequences.

3.3. Severe, fatal and rapid cascading impacts across multiple ecosystems and geographies, public and private sectors

Hazards with escalation potential trigger severe, rapid cascading impacts across various sectors, ecosystems and geographies, causing fatal consequences for people and infrastructure. For example, a large magnitude volcanic eruption could lead to widespread destruction not only in the immediate vicinity but also through the release of ash and gas that can disrupt global climate patterns, carrying adverse consequences to global food production and trade and transportation networks.

3.4. Irreversible systemic shifts in socioeconomic systems

Hazards with escalation potential cause irreversible systemic shifts in socioeconomic systems, dramatically altering the way societies function. International armed conflicts, for example, can lead to the destruction of infrastructure, a loss of life and displacement of populations, resulting in lasting economic, social and political upheaval.

3.5. Bypass established response and recovery capacity

Hazards with escalation potential can overwhelm established coping, response and recovery capacities, making it difficult for societies to effectively mitigate their impacts. An example is the collapse of infrastructure systems, such as energy grids or transportation networks, which can disrupt essential services, hinder emergency response efforts and impede economic recovery.

3.6. Trust and cooperation erosion

Hazards with escalation potential erode the trust and multinational cooperation needed to contain their impacts. For example, IoT-related hazards, such as data breaches or cyberattacks, can erode trust and cooperation by compromising the confidentiality, integrity and availability of data or services. This could lead to a loss of sensitive information, operational disruption and damage to the reputation of governments and organizations involved, thereby undermining mutual trust and willingness to collaborate. Misinformation may also play a role in undermining trust and cooperation to address a range of global catastrophic risks. The erosion of global capacity to take collective action is identified as one of the key pathways to escalation by preventing effective preparedness, and coordinated response.

3.7. Uncertainty and complexity

Uncertainty and complexity are inherent to hazards with escalation potential, particularly regarding the detail, speed and location of the points of failure associated with their impacts. AI, for instance, can introduce unforeseen consequences as systems become increasingly autonomous, making it difficult to predict and manage potential hazards.

3.8. Shared ownership between governments

Hazards with escalation potential result in transboundary impacts, leading to the need for shared ownership between governments and cooperation. An example is the international efforts required to address climate change, as the consequences and thus mitigation efforts often extend beyond national borders, necessitating international cooperation and coordination.

3.9. Technological origins

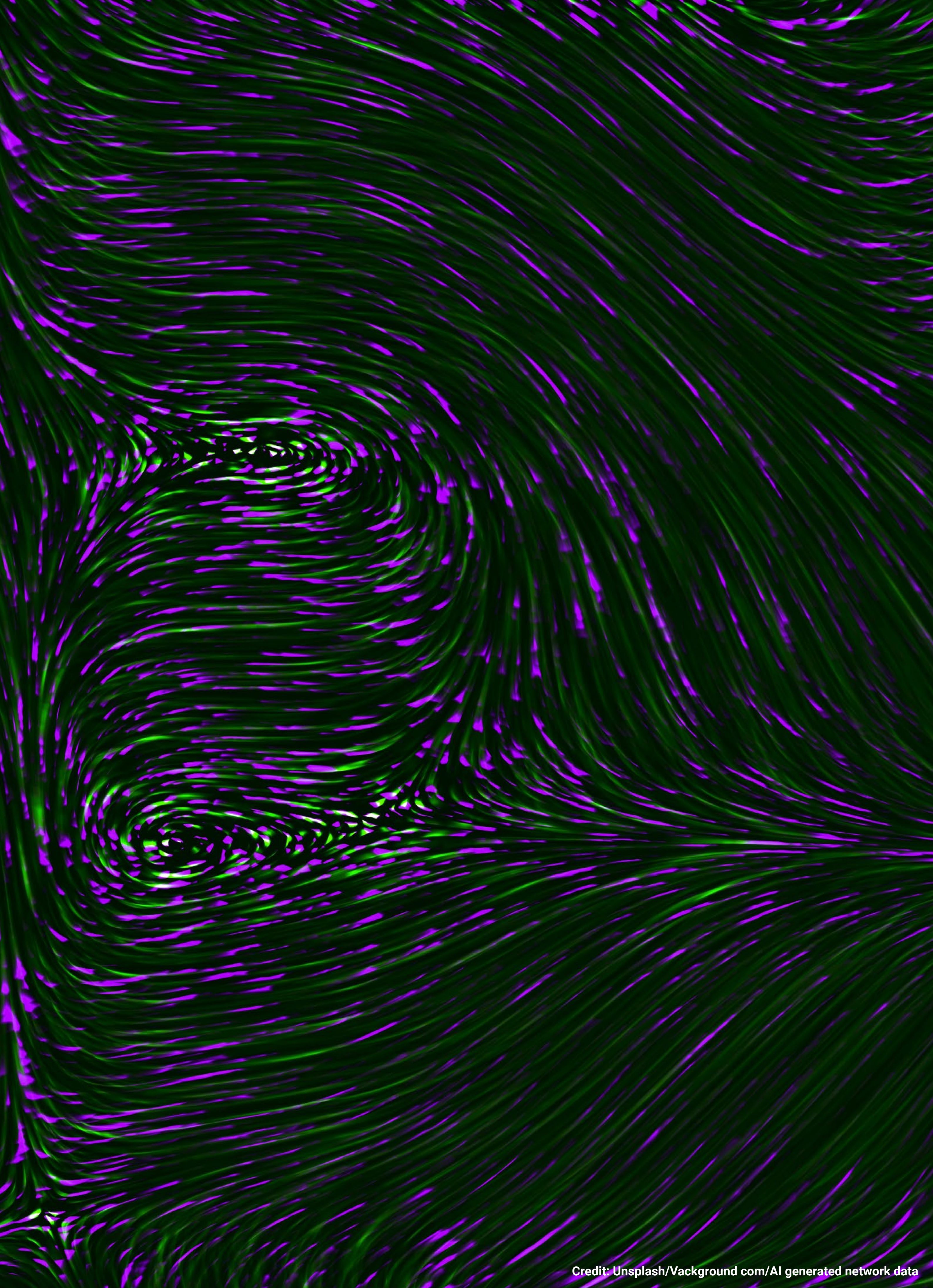
Hazards with escalation potential, albeit not all of them, can have technological origins or be accelerated by activities in the private sector and financial investments. For example, nuclear agents and nuclear winter, as well as radiation agents, have technological origins as they primarily result from human-engineered nuclear technology, such as nuclear weapons or nuclear power plants, which can cause radiation hazards due to accidents, misuse or intentional destructive acts. Infrastructure disruption and IoT-related hazards are also technologically rooted, stemming from the growing reliance on digital and interconnected systems that can be vulnerable to physical damage, cyberattacks or systemic failures.

3.10. Emerging and development-driven

Many hazards with escalation potential have not manifested in the past or are the direct consequences of human decisions in ongoing technological developments in the private sector or by financial institutions. For example, engineered pandemics resulting from biotech advances exemplify this characteristic, as rapid progress in biotechnology allows for the manipulation of pathogens on an unprecedented scale.

04

IS CURRENT RISK GOVERNANCE FIT FOR PURPOSE?


Credit: Unsplash/Vackground com/AI generated network data

4. IS CURRENT RISK GOVERNANCE FIT FOR PURPOSE?

Ten governance challenges result from the characteristics of hazards with escalation potential (table 2). Addressing these challenges is important in order to ensure national and international risk governance is fit for purpose to address worst-case scenarios.[70,71]

Each challenge is illustrated with examples of disasters related to hazards with limited escalation potential. Such hazards did have either global or severe consequences but never to the extent of a global catastrophe. However, historical precedents help illustrate the governance challenges and further highlight the crucial importance of improving governance for worst-case scenarios.

Table 2. Governance challenges in the face of hazards with escalation potential

Hazard characteristic	Key governance challenge	Example disaster highlighting the challenge
Exponential growth and self-propagation over both short and long time frames	Inadequate preparedness	2014–2016 West African Ebola outbreak
A global geographical scope	Limited geographical reach	2019–Present COVID-19 pandemic
Severe, fatal and rapid cascading impacts across multiple ecosystems and geographies, public and private sectors	Ineffective coordination	2011 Fukushima nuclear disaster
Irreversible systemic shifts in socioeconomic systems	Systemic rigidity	2007–2008 global financial crisis
Bypass established response and recovery capacity	Overwhelmed capacities	2005 Hurricane Katrina
Trust and cooperation erosion	Fragile cooperation	1947–1991 Cold War
Uncertainty and complexity	Uncertainty management	2010 Deepwater Horizon oil spill

Hazard characteristic	Key governance challenge	Example disaster highlighting the challenge
Shared ownership between governments	Shared responsibility	2015–2016 European migrant crisis
Technological origins	Pace mismatch	2011 H5N1 avian influenza research
Emerging and development-driven	Lack of anticipation	1986 Chernobyl nuclear disaster

1. Inadequate preparedness:

National and international risk governance structures often lack the capacity and flexibility to adapt to the rapidly evolving consequences of hazards with escalation potential that exhibit exponential growth and self-replication. Crisis response planning and resource allocation tend to be reactive rather than proactive, leading to delayed action and an inability to keep pace with the rate of hazard escalation. Existing governance mechanisms may be overwhelmed by the speed and scope of such threats, hindering their ability to address the cascading effects.

For example, the West African Ebola outbreak (2014–2016) revealed the inadequacy of national and international preparedness to address rapidly escalating hazards. The World Health Organization and affected countries were slow to recognize and respond to the outbreak, leading to more than 28,000 cases and over 11,000 deaths. A World Health Organization report acknowledged that the organization's response was hindered by weak surveillance and response systems, limited resources and a lack of coordination among stakeholders.[72]

2. Limited geographical reach:

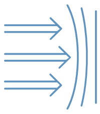
National and international risk governance structures can only act on limited geographical scope, focusing on addressing hazards within their own borders or silos. This approach is inadequate for hazards with a global geographical scope, which require coordinated international efforts. Current governance systems may struggle to facilitate the necessary collaboration and resource-sharing to address far-reaching threats, leading to fragmented and inefficient responses.

For example, the COVID-19 pandemic exposed the limitations of national and international risk governance structures with a limited scope, as they struggled to respond effectively to a hazard that transcended borders and affected the entire world. The initial stages of the pandemic saw countries focusing on their individual responses, often implementing travel restrictions and lockdown measures independently. This lack of information-sharing impeded the global containment effort and contributed to the rapid spread of the virus. The pandemic highlighted the need for improved international cooperation and coordination to address hazards with global implications.[25]

3. Ineffective coordination:

Risk governance systems may lack the coordination and communication channels necessary to address the interconnectedness of hazards with escalation potential and their cascading impacts. The inability to manage multisectoral dependencies and coordinate effective responses across sectors and geographies can lead to disjointed and inefficient mitigation efforts, exacerbating the overall impact of these hazards.

For example, the 2011 Fukushima nuclear disaster was triggered by the Tōhoku earthquake and tsunami in Japan. The disaster exposed the significant challenges to coordination among Japanese regulatory agencies, the plant operator and the government. An independent investigation concluded that the disaster was human-made, with failures in communication and information-sharing exacerbating the crisis.[73]



4. Systemic rigidity:

National and international risk governance structures are vulnerable to irreversible systemic shifts in socioeconomic systems caused by hazards with escalation potential. These structures tend to be entrenched in existing systems and may lack the flexibility needed to navigate the new dynamics and challenges presented by systemic changes, and thus predict them. As a result, traditional governance mechanisms may be ill-equipped to anticipate and address the long-term consequences of hazards with escalation potential.

For example, the response of the United States Government to the onset of the financial crisis in 2007 provides a stark example of the rigidity and lack of flexibility that can characterize governmental systems.[74] Despite clear signs of instability in the housing market and subsequent banking sector strain, regulatory agencies and policymakers largely maintained their existing stances and failed to take preemptive actions that could have mitigated the extent of the crisis.

5. Overwhelmed capacities:

Risk governance structures are often designed to address hazards within a certain range of severity and may not be equipped to handle hazards with escalation potential that exceed these thresholds. As a result, established coping, response and recovery capacities may be overwhelmed and rendered ineffective, leaving societies vulnerable to the impacts of such hazards.

Hurricane Katrina (2005) overwhelmed the capacities of local, state and federal risk governance structures in the United States. The disaster led to the deaths of more than 1,200 people and caused widespread damage. Inadequate preparedness, poor communication and insufficient resources contributed to the ineffective response, leaving many communities devastated.[75]

6. Fragile cooperation:

National and international risk governance structures can be undermined by eroding trust and cooperation among nations when dealing with hazards with escalation potential. The competitive nature and uncertainty of geopolitics weaken cooperation, making global stability highly dependent on whether States and international organizations continue to communicate and collaborate.

The Cold War exemplifies how trust and cooperation erosion can undermine national and international risk governance. The period was marked by an arms race between the United States and the Soviet Union, with both sides competing for global influence. The lack of trust and cooperation hindered collaborative efforts to address shared threats, such as nuclear proliferation and environmental degradation.

7. Uncertainty management:

Risk governance structures often struggle to address the uncertainty and complexity associated with hazards with escalation potential. Traditional risk assessment and management approaches may be insufficient for understanding and responding to the unpredictable nature of these threats, leaving societies vulnerable to the impacts of unforeseen consequences and cascading failures.

For example, the Deepwater Horizon oil spill in the Gulf of Mexico (2010) illustrates the challenge of managing uncertainty. After the offshore drilling rig explosion, BP and governing authorities faced significant uncertainty regarding the scale of the spill, the best solution to stop the leak, and the long-term impact. Initial underestimations complicated response efforts and planning; the set of unsuccessful methods exemplify the difficulty of making decisions under pressure and with incomplete information.[76,77]

8. Shared responsibility:

National and international risk governance structures can be inadequate in addressing hazards with escalation potential with shared ownership between governments. The lack of clear roles and responsibilities, coupled with bureaucratic and political barriers, may hinder the development and implementation of coordinated strategies, reducing the overall effectiveness of governance efforts.

For example, the European migrant crisis (2016–2016) revealed the challenges of shared responsibility between governments. The crisis saw more than 1 million displaced persons entering Europe in search of safety and a better life. The lack of a coordinated European response led to individual countries implementing their own policies, often shifting the burden of responsibility onto neighbouring countries.[78]

9. Pace mismatch:

Risk governance structures may struggle to address hazards with escalation potential with technological origins due to the rapid pace of innovation and the cross-disciplinary nature of these threats. Current governance mechanisms may not keep pace with technological advancements and may lack the expertise needed to effectively regulate and manage the risks associated with emerging technologies.

For example, the controversy surrounding the H5N1 avian influenza research in 2011 highlights the limitations of risk governance structures in addressing biotechnology hazards, specifically in the context of potentially dangerous pathogens.[79] In this case, two research groups independently created lab-engineered H5N1 influenza strains that were more transmissible among mammals than the naturally occurring virus. These studies raised serious biosecurity concerns, as the accidental release or misuse of such engineered pathogens could lead to a deadly pandemic. The incident sparked a heated debate among the scientific community, policymakers and biosecurity experts about the need for robust technology governance to balance the benefits of scientific research with the potential risks posed by the manipulation of pathogens.

10. Lack of anticipation:

Risk governance structures often fail to address emerging and development-driven hazards with escalation potential, as they tend to focus on known and historical threats.[80] This reactive approach leaves societies vulnerable to novel hazards and unforeseen consequences arising from rapid technological advancements. Anticipatory governance, which involves proactive identification, assessment and management of potential risks, is essential for addressing these emerging threats. However, national and international risk governance structures often lack the necessary foresight, flexibility and capacity to implement anticipatory governance effectively, leaving societies exposed to the potential impacts of development-driven hazards.

For example, the Chernobyl nuclear disaster in 1986, one of the most devastating nuclear accidents in history, showcased the lack of anticipation in national and international risk governance structures.[81] The explosion at the Chernobyl Nuclear Power Plant in the former Soviet Union (now Ukraine) resulted from a combination of design flaws, human error and inadequate safety regulations. The disaster led to widespread radioactive contamination, long-term health consequences and significant environmental damage. The Chernobyl incident highlighted the need for improved anticipatory governance in the nuclear energy sector, including the development of more robust safety protocols, effective risk assessment and stronger regulatory oversight to prevent similar catastrophes in the future.

05

SO WHAT?

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5.1. Implications for hazard and risk understanding

From the above hazards with escalation potential, their characteristics and governance challenges, we can distil the following implications for hazard and risk understanding and modelling.

1. First, not all hazards have the potential to become existential or catastrophic risks.

A more focused approach to risk reduction and prevention strategies could concentrate the field, resources and efforts on the most critical threats. The hazards' common characteristics suggest that successful risk reduction measures for one risk may be transferable to others, further enhancing the effectiveness of prevention and disaster risk reduction initiatives. A focus on realistic worst-case scenarios increases resilience to all disasters, including the most likely ones.

2. Second, learning from large-scale disasters such as the Ebola outbreak or the COVID-19 pandemic is crucial to better understanding hazard escalation and its implications.

Studying these events can provide valuable insights into how impacts spread and reveal potential vulnerabilities in current systems. This knowledge can then be used to improve preparedness and response strategies, as well as to identify areas where improvements in infrastructure, public health and governance are needed.

3. Third, improved comprehension of hazard escalation characteristics can also contribute to more accurate risk modelling.

Modellers often seek trends and inflection points based on sensitive variables, and so examining these characteristics in that context could lead to a better understanding of risk. This enhanced understanding could then result in more effective prevention strategies, providing policymakers and stakeholders with the necessary information to make informed decisions.

4. Fourth, a deeper understanding of hazard escalation can reveal potential circuit-breaker actions that may slow or halt the exponential growth of disasters

Identifying and implementing these measures can mitigate the severity of future events, ultimately saving lives, preserving resources and minimizing the impacts of hazards with escalation potential on societies worldwide.

5.2. Implications for risk governance at the national and international levels

From the above extreme hazards and characteristics, we can distil the following implications for risk governance at the national and international levels.

1. First, the global scope of hazards with escalation potential necessitates governance at both national and international levels,

as no single institution possesses the legitimacy to act independently on a global scale. Additionally, the technological origins and societal implications of these hazards call for strong collaboration between public and private sectors to address potential risks effectively. The capacity of these hazards to trigger cascading impacts across various sectors demands a multisectoral governance approach. Furthermore, the emerging and uncertain nature of hazards with escalation potential requires adaptive governance mechanisms capable of evolving with changing circumstances. The severity of such hazards underscores the need for proactive, preventative and preparedness measures.

2. Second, the global risk governance community's definition of a large-scale event inadequately considers global catastrophic or existential risks.

This discrepancy is mirrored in the mapping of duty bearers and the scale of preparedness for such risks. In light of emerging trends such as climate change, and an increasingly interconnected world, joint analysis and planning across duty bearers to address these gaps should be considered a priority. Because of their scale, global catastrophic and existential risks must likely be addressed by central parts of governments rather than become an additional burden on emergency and disaster management authorities. Additionally, the inequality in terms of risk governance capacity among different countries requires capacity-building instruments to strengthen practices where necessary.

3. Third, understanding escalation potentials can contribute to the development of better standard operating procedures for duty bearer organizations,

enabling them to take appropriate action to prevent exponential escalation. This knowledge can help mitigate the impact of hazards with escalation potential and ensure that responses are timely and effective.

4. Fourth, while risk assessments prioritize the most likely and frequent events, governments and duty bearer organizations must focus on hazards with the greatest escalation potential.

By incorporating actions to halt escalation into their ongoing disaster risk reduction efforts, they can proactively address these hazards. This approach can be integrated with existing contingency planning exercises, ensuring that plans are linked to current mechanisms and systems, and are periodically tested to maintain their efficacy.

Credit: Pexels/Mark Mccammon

ENDNOTE REFERENCES

[1] Murray, Virginia, and others (2021). *Hazard Information Profiles. Supplement to : UNDRR-ISC Hazard Definition & Classification Review - Technical Report*. Geneva, Switzerland: United Nations Office for Disaster Risk Reduction; Paris: International Science Council. https://undrr.org/publication/hazard-information-profiles-hips.

[2] Independent Group of Scientists appointed by the Secretary-General (2019). *Global Sustainable Development Report 2019: The Future Is Now – Science for Achieving Sustainable Development*. United Nations publication. https://sustainabledevelopment.un.org/content/documents/24797GSDR_report_2019.pdf.

[3] Sillmann, Jana, and others (2022). *Briefing Note: Systemic Risk*. Geneva, Switzerland: United Nations Office for Disaster Risk Reduction; Paris: International Science Council. https://www.undrr.org/publication/briefing-note-systemic-risk.

[4] International Risk Governance Center (2018). *Guidelines for the Governance of Systemic Risks*. Lausanne, Switzerland. https://infoscience.epfl.ch/record/257279.

[5] United Nations Office for Disaster Risk Reduction (2022). Global Assessment Report on Disaster Risk Reduction 2022: Our World at Risk: Transforming Governance for a Resilient Future. Geneva, Switzerland. https://www.undrr.org/gar/gar2022-our-world-risk-gar.

[6] Avin, Shahar, and others (2018). Classifying global catastrophic risks. *Futures*, vol. 102, pp. 20–26. https://doi.org/10.1016/j.futures.2018.02.001.

[7] Stauffer, Maxime, and others (2023). *Existential Risk and Rapid Technological Change - Advancing Risk-Informed Development | Midterm Review of the Sendai Framework*. Geneva, Switzerland: United Nations Office for Disaster Risk Reduction. https://www.undrr.org/publication/thematic-study-existential-risk-and-rapid-technological-change-advancing-risk-informed.

[8] United Nations (2021). Our Common Agenda: Report of the Secretary-General. https://www.un.org/en/content/common-agenda-report/.

[9] Schoch-Spana, Monica, and others (2017). Global catastrophic biological risks: toward a working definition. *Health Security*, vol. 15, No. 4 (August), pp. 323–328. https://doi.org/10.1089/hs.2017.0038.

[10] Cotton-Barratt, Owen, and others (2016). *Global Catastrophic Risks 2016*. Stockholm: Global Challenges Foundation. https://globalchallenges.org/library/global-catastrophic-risks-2016/.

[11] Beard, S.J., and others (2021). Assessing climate change's contribution to global catastrophic risk. *Futures*, vol. 127, 102673. https://doi.org/10.1016/j.futures.2020.102673.

[12] Kemp, Luke, and others (2022). Climate endgame: Exploring catastrophic climate change scenarios. *PNAS*, vol. 119, No. 34 (August). https://doi.org/10.1073/pnas.2108146119.

[13] Farquhar, Sebastian, and others (2017). *Existential Risk: Diplomacy and Governance*. Oxford, United Kingdom: Global Priorities Project. https://www.fhi.ox.ac.uk/xrisk-diplomacy/.

[14] Gruetzemacher, Ross, and Jess Whittlestone (2022). The transformative potential of artificial intelligence. *Futures*, vol. 135. https://doi.org/10.1016/j.futures.2021.102884.

[15] Beard, Simon, Thomas Rowe and James Fox (2020). An analysis and evaluation of methods currently used to quantify the likelihood of existential hazards. *Futures*, vol. 115. https://doi.org/10.1016/j.futures.2019.102469.

[16] United Nations Office for Disaster Risk Reduction (2023). Sendai Framework Terminology on Disaster Risk Reduction. Available at https://www.undrr.org/terminology. Accessed 22 June 2023.

[17] United Nations Office for Disaster Risk Reduction and International Science Council (2020). *Hazard Definition and Classification Review (Technical Report)*. Geneva, Switzerland; Paris. https://www.undrr.org/publication/hazard-definition-and-classification-review-technical-report.

[18] Baum, Seth (2023). Assessing natural global catastrophic risks. *Natural Hazards*, vol. 115, pp. 2699–2719. https://doi.org/10.1007/s11069-022-05660-w.

[19] Blong, Russell (2021). Four global catastrophic risks – a personal view. *Frontiers Earth Science*, vol. 9. https://doi.org/10.3389/feart.2021.740695.

[20] Cassidy, Michael, and Lara Mani (2022). Huge volcanic eruptions: time to prepare. *Nature*, vol. 608, pp. 469–471. https://doi.org/10.1038/d41586-022-02177-x.

[21] Denkenberger, David C., and Robert W. Blair Jr. (2018). Interventions that may prevent or mollify supervolcanic eruptions. *Futures*, vol. 102, pp. 51–62. https://doi.org/10.1016/j.futures.2018.01.002.

[22] Mani, Lara, Douglas Erwin and Lindley Johnson (forthcoming). Natural global catastrophic risks. In *The Era of Global Risk: An Introduction to Existential Risk Studies*, SJ Beard, and others, eds. Cambridge, United Kingdom: Open Book Publishers.

[23] Mani, Lara, Asaf Tzachor and Paul Cole (2021). Global catastrophic risk from lower magnitude volcanic eruptions. *Nature Communications*, vol. 12, No. 4756. https://doi.org/10.1038/s41467-021-25021-8.

[24] Connell, Nancy D. (2017). The challenge of global catastrophic biological risks. *Health Security*, vol. 15, No. 4 (August), pp. 345–346. https://doi.org/10.1089/hs.2017.0056.

[25] Liu, Hin-Yan, Kristian Lauta and Matthijs Maas (2020). Apocalypse now?: Initial lessons from the Covid-19 pandemic for the governance of existential and global catastrophic risks. *Journal of International Humanitarian Legal Studies*, vol. 11, No. 2 (December), pp. 295–310. https://doi.org/10.1163/18781527-01102004.

[26] Baum, Seth, Robert de Neufville and Anthony Barrett (2018). *A Model for the Probability of Nuclear War.* Washington, D.C.: Global Catastrophic Risk Institute. https://gcrinstitute.org/a-model-for-the-probability-of-nuclear-war/.

[27] Baum, Seth, and Anthony Barrett (2018). *A Model for the Impacts of Nuclear War.* Washington, D.C.: Global Catastrophic Risk Institute. https://gcrinstitute.org/a-model-for-the-impacts-of-nuclear-war/.

[28] Scouras, James (2019). Nuclear war as a global catastrophic risk. *Journal of Benefit-Cost Analysis*, vol. 10, No. 2 (Summer), pp. 274–295. https://doi.org/10.1017/bca.2019.16.

[29] Askell, Amanda, Miles Brundage and Gillian Hadfield (2019). The role of cooperation in responsible AI development. *arXiv preprint arXiv:1907.04534*. https://doi.org/10.48550/arXiv.1907.04534.

[30] Baum, Seth, and others (2020). *Lessons for Artificial Intelligence from Other Global Risks*. Boca Raton, United States: CRC Press. https://papers.ssrn.com/abstract=3609295.

[31] Brundage, Miles, and others (2018). *The Malicious Uses of Artificial Intelligence: Forecasting, Prevention, and Mitigation*. Cambridge, United Kingdom: University of Cambridge. https://doi.org/10.17863/CAM.22520.

[32] Everitt, Tom, Gary Lea and Marcus Hutter (2018). AGI safety literature review. In *Proceedings of the Twenty-Seventh International Joint Conference on Artificial Intelligence,* Lang, Jérôme, ed. Washington, D.C.: AAAI Press. https://doi.org/10.24963/ijcai.2018/768.

[33] Gabriel, Iason (2020). Artificial intelligence, values and alignment. *Minds and Machines*, vol. 30, pp. 411–437. https://doi.org/10.1007/s11023-020-09539-2.

[34] Omohundro, Stephen M. (2008). The basic AI drives. In *Artificial General Intelligence, 2008: Proceedings of the First AGI Conference*, Wang, Pei, Ben Goertzel, and Stan Franklin, eds. Amsterdam: IOS Press. https://dl.acm.org/doi/10.5555/1566174.1566226.

[35] Sotala, Kaj, and Roman V. Yampolskiy (2015). Corrigendum: Responses to catastrophic AGI risk: a survey. *Physica Scripta*, vol. 90, No. 6. https://doi.org/10.1088/0031-8949/90/6/069501.

[36] Zwetsloot, Remco, and Allan Dafoe (2019). Thinking about risks from AI: Accidents, misuse and structure. *Lawfare*, 11 February. https://www.lawfareblog.com/thinking-about-risks-ai-accidents-misuse-and-structure.

[37] Baum, Seth, and Itsuki C. Handoh (2014). Integrating the planetary boundaries and global catastrophic risk paradigms. *Ecological Economics*, vol. 107, pp. 13–21. https://doi.org/10.1016/j.ecolecon.2014.07.024.

[38] Holt, Lauren A. (2021). Why shouldn't we cut the human-biosphere umbilical cord? *Futures*, vol. 133, 102821. https://doi.org/10.1016/j.futures.2021.102821.

[39] Kareiva, Peter, and Valerie Carranza (2018). Existential risk due to ecosystem collapse: Nature strikes back. *Futures*, vol. 102, pp. 39–50. https://doi.org/10.1016/j.futures.2018.01.001.

[40] Xu, Yangyang, and Veerabhadran Ramanathan (2017). Well below 2 °C: Mitigation strategies for avoiding dangerous to catastrophic climate changes. *PNAS*, vol. 114, pp. 10315–10323. https://doi.org/10.1073/pnas.1618481114.

[41] Puma, Michael, Souyoung Chon and Y. Wada (2015). Exploring the potential impacts of historic volcanic eruptions on the contemporary global food system. *Past Global Changes Magazine*, vol. 23, No. 2, pp. 66–67. https://doi.org/10.22498/pages.23.2.66.

[42] World Health Organization (2019). Antimicrobial resistance, 23 July. https://www.who.int/health-topics/antimicrobial-resistance.

[43] Infectious Diseases Society of America (2011). Combating antimicrobial resistance: policy recommendations to save lives. *Clinical Infectious Diseases*, vol. 52, No. 5, pp. S397–S428. https://doi.org/10.1093/cid/cir153.

[44] Murray, Christopher J.L., and others (2022). Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. *The Lancet*, vol. 399, No. 10325 (January), pp. 629–655. https://doi.org/10.1016/S0140-6736(21)02724-0.

[45] NOAA (2016). What is a harmful algal bloom?, 27 April. https://www.noaa.gov/what-is-harmful-algal-bloom.

[46] Cordell, Dana, and Stuart White (2014). Life's bottleneck: sustaining the world's phosphorus for a food secure future. *Annual Review of Environment and Resources*, vol. 39 (October), pp. 161–188. https://doi.org/10.1146/annurev-environ-010213-113300.

[47] Anderson, Donald M. (2009). Approaches to monitoring, control and management of harmful algal blooms (HABs). *Ocean & Coastal Management*, vol. 52, No. 7, pp. 342–347. https://doi.org/10.1016/j.ocecoaman.2009.04.006.

[48] Xia, Lili, and others (2022). Global food insecurity and famine from reduced crop, marine fishery and livestock production due to climate disruption from nuclear war soot injection. *Nature Food*, vol. 3, pp. 586–596. https://doi.org/10.1038/s43016-022-00573-0.

[49] Pentreath, Richard J. (2002). Radiation protection of people and the environment: developing a common approach. *Journal of Radiological Protection*, vol. 22, No. 45. https://doi.org/10.1088/0952-4746/22/1/304.

[50] Çetinkaya, Egemen K., and others (2013). Modelling communication network challenges for future Internet resilience, survivability, and disruption tolerance: a simulation-based approach. *Telecommunication Systems*, vol. 52, pp. 751–766. https://doi.org/10.1007/s11235-011-9575-4.

[51] Cihan, Ataç, and Sedat Akleylek (2019). A survey on security threats and solutions in the age of IoT. *Avrupa Bilim ve Teknoloji Dergisi*, No. 15, pp. 36–42. https://doi.org/10.31590/ejosat.494066.

[52] Clauset, Aaron (2018). Trends and fluctuations in the severity of interstate wars. *Science Advances*, vol. 4, No. 2 (February). https://doi.org/10.1126/sciadv.aao3580.

[53] Biswas, Asit K. (2000). Scientific assessment of the long-term environmental consequences of war. In *The Environmental Consequences of War: Legal, Economic, and Scientific Perspectives*, Carl E. Bruch, and Jay E. Austin, eds. Cambridge, United Kingdom: Cambridge University Press. https://doi.org/10.1017/CBO9780511522321.017.

[54] Intergovernmental Panel on Climate Change (2023). *AR6 Synthesis Report: Climate Change 2023*. Geneva, Switzerland. https://www.ipcc.ch/report/sixth-assessment-report-cycle/.

[55] Aubry, Thomas J., and others (2021). Climate change modulates the stratospheric volcanic sulfate aerosol lifecycle and radiative forcing from tropical eruptions. *Nature Communications*, vol. 12, No. 4708. https://doi.org/10.1038/s41467-021-24943-7.

[56] Jehn, Florian U., and others (2021). Betting on the best case: higher end warming is underrepresented in research. *Environmental Research Letters*, vol. 16, No. 8 (July). https://doi.org/10.1088/1748-9326/ac13ef.

[57] Armstrong McKay, David. I., and others (2022). Exceeding 1.5°C global warming could trigger multiple climate tipping points. *Science*, vol. 377, No. 6611 (September). https://doi.org/10.1126/science.abn7950.

[58] Rockström, Johan, and others (2023). Safe and just Earth system boundaries. *Nature*. https://doi.org/10.1038/s41586-023-06083-8.

[59] Dafoe, Allan (2018). *AI Governance: A Research Agenda*. Oxford, United Kingdom: Centre for the Governance of AI, Future of Humanity Institute, and University of Oxford. https://uploads-ssl.webflow.com/614b70a71b9f71c9c240c7a7/61d48553bf2faf58c3900bd2GovAI-Research-Agenda.pdf.

[60] Roser, Max (2022). The brief history of artificial intelligence: The world has changed fast – what might be next? *Our World in Data*, 6 December. https://ourworldindata.org/brief-history-of-ai.

[61] Tamkin, Alex, and others (2021). *Understanding the Capabilities, Limitations, and Societal Impact of Large Language Models*. New York, United States: arXiv. https://doi.org/10.48550/arXiv.2102.02503.

[62] Urbina, Fabio, and others (2022). Dual use of artificial-intelligence-powered drug discovery. *Nature Machine Intelligence*, vol. 4, pp. 189–191. https://doi.org/10.1038/s42256-022-00465-9.

[63] Avin, Shahar, and Amadae, S.M. (2019). Autonomy and machine learning at the interface of nuclear weapons, computers and people. In *The Impact of Artificial Intelligence on Strategic Stability and Nuclear Risk: Euro-Atlantic Perspectives*, Vincent Boulanin, ed. Stockholm: Stockholm International Peace Research Institute. https://doi.org/10.17863/CAM.44758.

[64] Maas, Matthijs. M., Kayla Lucero-Matteucci and Di Cooke (2022). Military artificial intelligence as contributor to global catastrophic risk. In *The Era of Global Risk: An Introduction to Existential Risk Studies* (forthcoming), SJ Beard, and others, eds. Cambridge, United Kingdom: Open Book Publishers. https://doi.org/10.2139/ssrn.4115010.

[65] Esvelt, Kevin M. (2018). Inoculating science against potential pandemics and information hazards. *PLOS Pathogens*, vol. 14, No. e1007286. https://doi.org/10.1371/journal.ppat.1007286.

[66] Callaway, Ewen (2020). 'It will change everything': DeepMind's AI makes gigantic leap in solving protein structures. *Nature*, 30 November. https://www.nature.com/articles/d41586-020-03348-4.

[67] Shankar, Sadasivan, and Richard N. Zare (2022). The perils of machine learning in designing new chemicals and materials. *Nature Machine Intelligence*, vol. 4, pp. 314–315. https://doi.org/10.1038/s42256-022-00481-9.

[68] Tumpey, Terrence M., and others (2005). Characterization of the reconstructed 1918 Spanish influenza pandemic virus. *Science*, vol. 310, No. 5745, pp. 77–80. https://doi.org/10.1126/science.1119392.

[69] Rudner, Tim G.J., and Helen Toner (2021). *Key Concepts in AI Safety: An Overview*. Washington, D.C.: Center for Security and Emerging Technology. https://cset.georgetown.edu/publication/key-concepts-in-ai-safety-an-overview/.

[70] Epstein, Graham, and others (2015). Institutional fit and the sustainability of social–ecological systems. *Current Opinion in Environmental Sustainability*, vol. 14, pp. 34–40. https://doi.org/10.1016/j.cosust.2015.03.005.

[71] Stauffer, Maxime, and others (2023). The FAIR Framework - A future-proofing methodology. *Simon Institute*, 26 April. https://www.simoninstitute.ch/blog/post/the-fair-framework-a-future-proofing-methodology/.

[72] World Health Organization (2016). Ebola outbreak 2014-2016 - West Africa. https://www.who.int/emergencies/situations/ebola-outbreak-2014-2016-West-Africa.

[73] National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission (2011). *The Official Report of the Fukushima Nuclear Accident Independent Investigation Commission*. Tokyo. https://warp.da.ndl.go.jp/info:ndljp/pid/3856371/naiic.go.jp/en/report/.

[74] United States of America, Government Accountability Office (2013). *Financial Regulatory Reform: Financial Crisis Losses and Potential Impacts of the Dodd-Frank Act.* Washington, D.C. https://www.gao.gov/products/gao-13-180.

[75] Congleton, Roger D. (2006). The story of Katrina: New Orleans and the political economy of catastrophe. *Public Choice*, vol. 127, pp. 5–30. https://doi.org/10.1007/s11127-006-7729-9.

[76] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling (2011). *Deep Water: The Gulf Oil Disaster and the Future of Offshore Drilling: Report to the President.* Washington, D.C. https://www.govinfo.gov/app/details/GPO-OILCOMMISSION.

[77] Summerhayes, Colin (2011). Deep water – The gulf oil disaster and the future of offshore drilling. *Underwater Technologies*, vol. 30, No. 2 (November), pp. 113–115. https://doi.org/10.3723/ut.30.113.

[78] Metsola, Robert, and Kashetu Kyenge (2016). *Report on the Situation in the Mediterranean and the Need for a Holistic EU Approach to Migration.* Brussels: European Parliament. https://www.europarl.europa.eu/doceo/document/A-8-2016-0066_EN.html.

[79] Morens, David M., Kanta Subbarao and Jeffery Taubenberger (2012). Engineering H5N1 avian influenza viruses to study human adaptation. *Nature*, vol. 486, pp. 335–340. https://doi.org/10.1038/nature11170.

[81] International Risk Governance Council (2015). *IRGC Guidelines for Emerging Risk Governance: Guidance for the Governance of Unfamiliar Risks.* Lausanne, Switzerland. https://doi.org/10.5075/epfl-irgc-228053.

[82] McCall, Chris (2016). Chernobyl disaster 30 years on: lessons not learned. *The Lancet*, vol. 387, pp. 1707–1708. https://doi.org/10.1016/S0140-6736(16)30304-X.