Global Catastrophic Risks 2021:

Navigating the Complex Intersections

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Global Challenges Foundation

GLOBAL CHALLENGES FOUNDATION (GCF) ANNUAL REPORT: GCF & THOUGHT LEADERS SHARING WHAT YOU NEED TO KNOW ABOUT GLOBAL CATASTROPHIC RISKS IN 2021

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Dear reader,

It is now five years since the Global Challenges Foundation released its first annual report about global catastrophic risks, the most serious threats to humanity. Five years on, we are living through the worst pandemic in a century and face increasingly urgent warnings about our heating planet. Global cooperation is being put to the test as never before.

The pandemic, like nothing in our experience, highlights the need to better understand global risks so we can more effectively prepare for them. To that end, this year's report, *Global Catastrophic Risks 2021: Navigating the Complex Intersections*, includes a focus on the complex interconnectedness between different risks and the need to build more holistic global approaches to tackle them. Not the least with an estimated population growth combined with consumption and production patterns that continues to explore our common good.

When it comes to climate change, the most recent report from the Intergovernmental Panel on Climate Change (IPCC) has delivered a grim warning which UN Secretary-General António Guterres called a "code red for humanity." It found Earth is expected to hit the critical threshold of 1.5°C warming due to greenhouse gas emissions within the next 20 years. Even if we take drastic action to reduce emissions, a lot of the impact is likely already baked in, with drastic consequences for many people around the world. Glaciers will continue to shrink for decades or centuries and sea level will rise. The probability of low-likelihood, high impact outcomes increases - massive ice sheet loss, the collapse of forests, or even the breakdown of the circulatory system in the Atlantic Ocean that regulates much of the Northern Hemisphere's weather and climate.

▼The pandemic, like nothing in our experience, highlights the need to better understand global risks so we can more effectively prepare for them▼

As the impacts of man-made climate change and humanity's destruction of the natural environment worsen, so do the threats from future pandemics, especially zoonotic viruses that jump from animals to humans. A changing climate is also exacerbating conflict, food insecurity, refugee crises and extreme poverty.

All eyes are on the critical COP26 climate talks in Glasgow, Scotland – where effective global cooperation has never been more urgently needed. It is a positive sign that President Joe Biden has brought the United States back into the Paris Agreement, but the ravages of COVID-19 and the crisis in Afghanistan suggest the ability of the US to lead the world is still compromised.

While there have been effective global collaborations at the scientific level to tackle the pandemic, it has not, as hoped, heralded a new era of enlightened global cooperation. Rich countries are accused of "hoarding" vaccines at the expense of low income countries, risking prolonging the pandemic for years, with all the human and economic pain that this will cause.

This spiral needs to be broken. We have to be able to solve multiple global problems and create improvements in many policy areas at once. We need to review solutions from a multi-risk perspective, not from a single issue silo. And, like the scientists working hard to identify the 'Disease Y' that could cause the next pandemic, we need our eyes on the horizon for the next big threat to humanity. At the Global Challenges Foundation, we continue to bring together key thinkers to work on solutions to fill the gaps in our systems of global cooperation. The work of the Climate Governance Commission, a partnership supported by this foundation, has produced a report with feasible, high impact global governance solutions for urgent and effective action to limit global temperature rises to 1.5 degrees. Our Secretariat and representatives from the Climate Governance Commission will present the Commission's interim report at COP26.

We need our eyes on the horizon for the next big threat to humanity

Climate governance solutions will also be urgently discussed at this year's New Shape Forum, in Stockholm and online, between 12th-13th October. With key experts, we will explore thought-provoking governance solutions ranging from new institutions, such as a Global Environment Agency, with a mandate to make independent decisions, and a Global Resilience Council, to enhanced institutional approaches, such as how to better integrate climate in trade rules, to "bottom-up" pathways such as climate clubs, an international climate policy clearinghouse, and a Global Green Hydrogen Alliance.

More broadly, our series of reports, GCF Policy Outlook, brings policy perspectives from leading experts across the global catastrophic risks, including the latest thinking on risk drivers, the current gap in institutional management of these risks and policy solutions.

Like all concerned inhabitants of this planet, we hope COP26 will produce commitments to new and urgent climate action, from governments, companies and citizens. Either way, we will continue the work to encourage a proper understanding of global risks - and gather together the best thinking on solutions to their effective governance. I hope you find this report a useful resource and thought provoking reading.

Yours, Jens Orback

JENS ORBACK
Executive Director, Global Challenges Foundation

Approach

This report aims to present an overview of the global catastrophic risks that the world currently faces, based on consideration of certain crucial facts and the latest scientific research. It proposes to complement the World Economic Forum's Global Risks Report[1], which offers an up-to-date picture of global risks as perceived by leading political and economic actors. These two approaches are highly complementary: perception is a strong driver of collective action and decision-making, while a more focused examination of the risks themselves will guide better long-term strategy and support the design of more efficient governance models.

When preparing this report, we aimed to develop an approach that would reflect the best current understanding and be useful to decision-makers. We combined historical evidence and scientific data to decide which risks should be included in the report. For the sake of clarity, we identified ten key risks, which we then organised into three main categories: current risks from human action, natural catastrophes, and emerging risks. The reader should keep in mind, however, that many of those risks are closely interconnected, and their boundaries sometimes blur, as with climate change and ecological collapse, or as in the case of synthetic biology, which could be presented as a risk of its own, an additional risk factor in biological warfare, or a potential cause for engineered pandemics.

The report offers a description of the current risks, exploring what is at stake, what is known, and key factors affecting risk levels. Then, for each risk, the report considers current governance frameworks for mitigating the risks. Each section was prepared in collaboration with leading experts in the field.

CURRENT RISKS FROM HUMAN ACTION

Weapons of mass destruction – nuclear, chemical and biological warfare – catastrophic climate change and ecological collapse are all current risks that have arisen as a result of human activity. Although action on them is time sensitive, they are still within our control today.

NATURAL CATASTROPHES

Pandemics, asteroid impacts and supervolcanic eruptions are known to have caused massive destruction in the past. Though their occurrence is beyond human control to a large extent, our actions can significantly limit the scale of impact. This is especially true for pandemics, where the recent experience of COVID-19, Ebola and Zika outbreaks highlighted the challenges and opportunities of global cooperation.

EMERGING RISKS

Artificial intelligence might not seem like an immediate source of concern. However, we should remember that challenges widely recognised as the greatest today – climate change and nuclear weapons – were unknown only 100 years ago, and late response – as in the case of climate change – has increased the risk level considerably. Significant resources are devoted to further the potential of those technologies; in comparison, very little goes into mapping and managing the new dangers they bring. As we cannot expect the pace of technological development to be linear, and given our limited knowledge and resources, leading experts are pressing for action on those risks today[2].

Weapons of mass destruction

1. NUCLEAR WARFARE

On August 6, 1945, a nuclear bomb exploded in Hiroshima, killing some 70,000 people within the day. In total, almost a half of the city perished from the effects of the bomb, half in the heat, radiation, fires and building collapses following the blast, and another half before the end of the year from injuries and radiation, bringing the total number of deaths to some 150,000[1]. Since then, the world has lived in the shadow of a war unlike any other in history. Although the tension between nuclear states has diminished since the end of the Cold War and disarmament efforts have reduced arsenals, the prospect of a nuclear war remains present, and might be closer today than it was a decade ago[2]. Its immediate effect would be the catastrophic destruction of lives and cities, and debilitation, illness and deaths from radiation, but another concern is the risk that the dust released from nuclear explosions could plunge the planet into a mini ice-age[3], with dramatic ecological consequences, severe agricultural collapse, and a large proportion of the world population dying in a famine[4].

70,000

estimated number of deaths caused by the nuclear bomb in Hiroshima on August 6, 1945

2. BIOLOGICAL AND CHEMICAL WARFARE

Toxic chemicals or infectious micro-organisms have been used as weapons to harm or kill humans for millennia, from the ancient practice of poisoning an enemy's wells and throwing plague-infected bodies over the walls of cities under siege, to the horrifying usage of germ warfare during the Second World War in Asia, or the use of nerve gases in the Iran-Iraq War. Biological and chemical attacks not only cause sickness and death but also create panic.

Up to now, their destructive effect has been locally contained. However, new technological developments give cause for concern. In particular, developments in synthetic biology and genetic engineering make it possible to modify the characteristics of micro-organisms. New genetically engineered pathogens – released intentionally or inadvertently – might cause a pandemic of unprecedented proportions.

Reviewed by
KENNETTE BENEDICT

1. Nuclear warfare

HOW MUCH DO WE KNOW?

Depending on their yield, technical characteristics and mode of explosion, today's more powerful nuclear weapons will cause 80 to 95 per cent fatalities within a radius of 1 to 4 kilometres from their point of detonation, with very severe damage being felt for up to six times as far[5]. The largest arsenals are currently held by the United States and Russia who control approximately 6,500 warheads each[6]. Seven other states are known to possess nuclear weapons or are widely believed to possess them: the United Kingdom, France, China, India, Pakistan, North Korea and Israel[7]. Various scenarios of intentional use are currently imaginable but nuclear weapons could also be released by accident, triggering an inadvertent nuclear war – as has almost happened a number of times since 1945[8].

In addition to their destructive effect at the point of impact, nuclear explosions may cause what is known as a 'nuclear winter'[9], where clouds of dust and sulphates released by burning materials obscure the sun and cool the planet for months or years.

According to one model, an all-out exchange of 4,000 nuclear weapons, in addition to the enormous loss of lives and cities, would release 150 teragrams of smoke, leading to an 8 degree drop in global temperature for a period of four to five years[10], during which time growing food would be extremely difficult. This would likely initiate a period of chaos and violence, during which most of the surviving world population would die from hunger.

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WHAT ARE THE KEY FACTORS AFFECTING RISK LEVELS?

Continued efforts towards arsenal reduction will reduce the overall level of nuclear risk. Attention to geopolitical tensions and rising nationalism, along with continued efforts towards global conflict management, particularly among nuclear states, will reduce the underlying risk of an intentional nuclear war[11]. In addition, controlling and limiting horizontal proliferation[12] will limit the number of potential nuclear conflict scenarios and is highly likely to reduce the overall risk level.

The risk of accidental use depends largely on the systems in place to launch missiles and the growing threats of cyberattacks on command and control systems. Hundreds of nuclear weapons are currently in a state of high readiness and could be released within minutes of an order[13]. Building in longer decision-making time and broader consultation would reduce the risk of unauthorised launches or accidental launches based on misperception or false alarms.

Increased awareness and understanding of the grave effects that nuclear weapons have on human life, economic infrastructure, governance, social order and the global climate would motivate efforts to avoid such catastrophic harm to our societies[14].

Governance of nuclear warfare

Kennette Benedict, Senior Advisor, Bulletin of Atomic Scientists

States currently manage the risks of nuclear weapons through a range of measures that together have prevented the worldwide spread of these weapons of mass destruction but have not significantly reduced the risk of catastrophic use. In fact, recent changes to nuclear doctrine and planned development of new nuclear weapons by the United States, Russia, and other nuclear weapons states make it more likely that nuclear weapons will be used in military actions, or through miscalculation or accident, than at any time since the 1950s and the beginning of the Cold War.

The pillar of nuclear military strategy is deterrence, whereby nuclear-armed states threaten to retaliate against other states' use of nuclear weapons against them. This doctrine is considered by some to be an effective way of preventing nuclear war. The fact that no nuclear weapons have been used in any conflict since 1945, however, suggests that political restraint and a moral norm also may have played a role in discouraging their use.

At the same time that major powers relied on deterrence in their military doctrines, international cooperation, beginning with the 1963 US-Soviet treaty to ban atmospheric testing, along with subsequent US-Soviet/Russian bilateral treaties and agreements, has reduced and stabilised nuclear arsenals from a high of 68,000 in the late 1980s to about 14,000 today.

In addition, the 1970 Nuclear Non-proliferation Treaty (NPT) has prevented the development of nuclear weapons in all countries beyond the original five (United States, Soviet Union/Russia, United Kingdom, France and China) with the exception of India, Pakistan, North Korea and probably Israel. Altogether, some 25 governments have given up their nuclear weapons programmes, including South Africa, Libya, Belarus, Kazakhstan and Ukraine. Another 15, like Canada, Brazil and Argentina, have contemplated programmes but not embarked upon them, in keeping with their responsibilities under the NPT.

The UN Security Council, whose permanent members include the five recognised nuclear weapons states, enforces the Nuclear Non-proliferation Treaty in partnership with the International Atomic Energy Agency (IAEA). Although the IAEA was established primarily to promote and oversee the development of civilian nuclear power, it is entrusted with verifying adherence to the Treaty (under Article III). Parties to the Treaty regularly report to the IAEA about the means used to safeguard and secure enriched uranium and plutonium used in civilian power plants, as well as steps to prevent the use of these nuclear materials for bombs.

…planned development of new nuclear weapons by the United States and Russia make it more likely that nuclear weapons will be used in military actions…

Several states have not complied with their Nuclear Non-proliferation Treaty obligations and faced penalties from the international community. Iraq embarked on a nuclear weapons programme, but, after nuclear bomb technology was discovered in 1991, the weapons were destroyed by a special UN Security Council-mandated force. In the case of Iran, international economic sanctions were applied when suspicions arose about its possible pursuit of nuclear weapons. To prevent Iran from acquiring them, multilateral negotiations produced the 2015 Joint Comprehensive Plan of Action. It mandated reduction of the means to enrich uranium to a minimal level, allowing enrichment only to below weapons-grade.

As part of an unravelling of nuclear governance, however, the United States pulled out of the JCPOA in 2017, and Iran has increased production of enriched uranium beyond that stipulated in the agreement. A new United States administration is now engaged in multi-state talks to negotiate a new plan that prevents Iran's enrichment of fuel to weapons grade in exchange for economic sanctions relief. Even more consequential, however, the United States and Russia withdrew from the 1987 Intermediate Range Nuclear Forces Treaty that banned a class of missiles with nuclear weapons capability. The only remaining bilateral arms agreement between the United States and Russia is New START, now extended to 2026, a treaty that places a cap on US and Russian arsenals with provisions for robust inspections. Even with these limits, however, Russia and the United States have each declared their intentions to use nuclear weapons even if nuclear weapons are not used against them first. These actions, along with North Korea's continued production of nuclear weapons, despite international economic sanctions, suggest that the norms of restraint may not be as strong as in the past. In fact, a new nuclear arms race is underway among all of the nuclear weapon's states that reinforces the perceived utility of nuclear weapons in war-fighting and increases the risk that these weapons will be used.

This new arms race underscores the difficulties of enforcing the NPT when countries do not wish to cooperate. The original treaty suggested a bargain whereby states without nuclear weapons would not acquire them, would have access to civilian nuclear power, and, in exchange, the states with nuclear weapons pledged to disarm when conditions warranted. Many believed that the end of the Cold War was such a time, and, while nuclear arsenals have radically decreased in Russia and the United States, the recent reversal in doctrine and rhetoric suggest that these and other nuclear weapons states have no intention at present of eliminating their nuclear arsenals.

Even as formal treaties and informal norms of restraint are eroding, non-nuclear weapons states introduced a UN treaty banning all nuclear weapons. One hundred and thirty-five of the 193 member countries participated in negotiating the treaty that prohibits developing, manufacturing, possessing, or stockpiling nuclear weapons, as well as threatening their use. While there is no verification regime established with this treaty, all signatories must adhere to IAEA safeguards. As of June 2021, 86 countries have signed the treaty and 54 have ratified it, adapting their national legislation to comply with its provisions. With 50 ratifications, the treaty entered into force on January 22, 2021. Not since the Nuclear Non-proliferation Treaty of 1970 have states taken such dramatic and collective action to prohibit possession of nuclear arsenals.

Unfortunately, re-emerging nationalism is spurring the nine nuclear weapons states – none of which participated in or voted on the UN ban treaty – to modernise and increase arsenals, and to lower the threshold to use their nuclear weapons. These actions reinforce beliefs about the purported utility of nuclear weapons, undermine international cooperative efforts to reduce the risks and seriously increase the probability of catastrophic nuclear war.

Reviewed by
ANGELA KANE

2. Biological and chemical warfare

HOW MUCH DO WE KNOW?

Unlike nuclear weapons, which require rare materials and complex engineering, biological and chemical weapons can be developed at a comparatively low cost[15], placing them within the reach of most or all states as well as organised non-state actors. Chemical and biological weapons carry various levels of risk. Toxic chemicals could be aerosolised or placed into water supplies, eventually contaminating an entire region. Biological weapons possess greater catastrophic potential, as released bioengineered pathogens might spread worldwide, causing a pandemic.

Recent developments in synthetic biology and genetic engineering are of particular concern[16]. The normal evolution of most highly lethal pathogens ensures that they will fail to spread far before killing their host. Technology, however, has the potential to break this correlation, creating both highly lethal and highly infectious agents[17]. Such pathogens could be released accidentally from a lab, or intentionally released in large population centres[18]. Current trends towards more open knowledge sharing can both contribute to, and mitigate, such risks. The COVID-19 pandemic – while not an engineered pathogen release – has shown us the existential and economic consequences such a pandemic can cause.

WHAT ARE KEY FACTORS AFFECTING RISK LEVELS?

- Global frameworks controlling research on chemical or biological weapons, including revised strategic trade controls on potentially sensitive dual-purpose goods, technology and materials; biological and chemical safety and security measures; and an ongoing commitment and capacity to enforce disarmament and arms control conventions[19].
- The unknown number of laboratories researching potential pandemic pathogens for military or civilian purposes, along with the public availability of dangerous information circulating for scientific purposes[20].
- Further developments in synthetic biology and genetic engineering lowering skill levels and costs to modify existing pathogens or to develop new pathogens[21].
- COVID-19 has shown that states lack meaningful health preparedness to address biological threats. Only rapid medical countermeasures will effectively tackle any potential outbreak of a pathogen release or even a pandemic in order to avoid massive harm to populations.

Unlike nuclear weapons, which require rare materials and complex engineering, biological and chemical weapons can be developed at a comparatively low cost

CHEMICAL WEAPONS: AN UNRAVELLING CONSENSUS?

Deadly agents like sulphur mustard were used during and between the World Wars, but the horrific results of such attacks eventually led to a global consensus to ban toxic chemical weapons, the most widely-used and easily proliferated weapon of mass destruction[22].

This consensus, however, represented by the near-universal 1993 Chemical Weapons Convention (CWC) is under strain. The Syrian Civil War has resulted in well-documented and indiscriminate uses of various deadly toxic chemicals against the civilian population, including children – dying from the deadly nerve agent Sarin (or a 'sarin-like' compound). Though the risk may always exist from easily available dual-use chemicals, and from terrorists like the Aum Shinrikyo (now know as Aleph), which perpetrated the Tokyo attack in 1995, there is a global risk that the hard-won consensus on banning state use of toxic chemicals will be further weakened[23].

The international community has established a number of investigative bodies to uncover the facts and determine responsibility, yet attribution is contested and until now, no person or entities has been brought to justice. The danger is that the weakening consensus could lead to the devastating use of more advanced toxic chemical weapons of mass destruction in any potential large-scale conflict in the future. It could also cause long-term changes in how states understand the development, evaluation and use of 'non-standard chemical substances' (substances other than deadly substances like sarin) for domestic riot control, counter-terrorism operations, international peacekeeping, and as a mechanism to maintain a standby offensive chemical weapons capability.

Biological and chemical weapons are banned by two international treaties: the Biological Weapons Convention (BWC) of 1975, with 183 State Parties, and the Chemical Weapons Convention (CWC) of 1997, with 189 State Parties. In both cases, dual-use creates a particular difficulty: the same chemicals and biological agents can be applied for beneficial purposes or serve as the core components of deadly weapons.

1975
Biological Weapons Convention (BWC)

1997
Chemical Weapons Convention (CWC)

The CWC, negotiated with the participation of the chemical industry, defines a chemical weapon by its intended purpose, rather than lethality or quantity. It allows for stringent verification of compliance: acceding to the CWC means mandatory destruction of all declared chemical weapons as well as their production sites – to be subsequently verified by appointed inspectors.

The BWC is less prescriptive, which results in ambiguities and loopholes. Research is permitted under the Convention, but it is difficult to tell the difference between legitimate and potentially harmful biological research. States are required to "destroy or to divert to peaceful purposes" their biological weapons, but no agreed definition of a biological weapon exists. In addition, there is no secretariat to monitor and enforce implementation, except for a small administrative support unit in Geneva. No mechanism exists to verify destruction or diversion. No international database exists to monitor and track commitments to improve biosafety and bio-security related assistance. Efforts have failed since 1991 to include legally-binding verification procedures in the BWC. Some lesser steps have been taken, including confidence-building measures on which State Parties are to report each April, and management standards on biosafety and biosecurity. However, implementation is voluntary and the vast majority of State Parties do not submit declarations on their activities and facilities.

Under the BWC, complaints can be lodged with the UN Security Council – which can investigate them – but no complaint has ever been made and enforcement mechanisms do not exist. The CWC includes a provision for "challenge inspections" in case of suspected chemical weapons use – but again, it has never been invoked, not even in the case of Syria, though doubts about a chemical weapons programme are regularly debated at the Security Council. For over seven years, regular visits by the OPCW "Declaration Assessment Team" have not been able to clarify discrepancies and determine if Syria's declaration is accurate and complete, and monthly reporting to the UN Security Council continues. In April 2021, the Conference of States Parties to the CWC took the unprecedented step of suspending certain right and privileges of the Syrian Arab Republic.

The repeated use of chemical weapons and the high concern about biosecurity have led to increased focus on the UN Secretary-General's Mechanism for Investigation of Alleged Use of Chemical and Biological Weapons, concluded in 1988.

In case of alleged use of chemical or biological weapons, investigations can be requested as happened in Syria in 2013, with mandatory reporting to the Security Council.

Only four UN countries are not State Parties to the CWC (Egypt, Israel, North Korea and South Sudan). The highest concern among those is North Korea, said to possess large quantities of chemical weapons that could be sold or traded to unscrupulous non-State actors. The existence of large stocks remains a risk, and the largest possessors of chemical weapons, Russia and the United States, had requested extensions of the deadlines imposed by the Organisation for the Prohibition of Chemical Weapons. While Russia announced in late 2017 that it had destroyed its large chemical arsenal, the United States has not been able to complete the destruction, due to the cost and environmental challenges of chemical disposal.

In the 56 years since the BWC was negotiated, rapid advances in biotechnology have been made, which challenge our current governance models. The pharmaceutical and medical industries possess the tools and knowledge to develop biological weapons; the internet spreads this know-how to those who might use it for nefarious purposes. Biological threats do not respect borders and, as global travel increases, could quickly have a regional or even global impact. Terrorists could contaminate the water supply or release deadly bacteria, but it is also possible that the lack of lab safety could result in the inadvertent release of a virus or disease. The first step towards a solution would be to acknowledge the seriousness of the situation and create public health entities to handle any potential outbreak. But leadership is also needed to place this issue at the right place on the global agenda. This could come from the UN Security Council, the G7 or the G20, coalitions of government and industry bodies, civil society groups, or one or more nations acting as global champions.

Only four UN countries are not State Parties to the Chemical Weapons Convention

Reviewed by
DR JOANA CASTRO PEREIRA

Catastrophic climate change

WHAT IS AT STAKE?

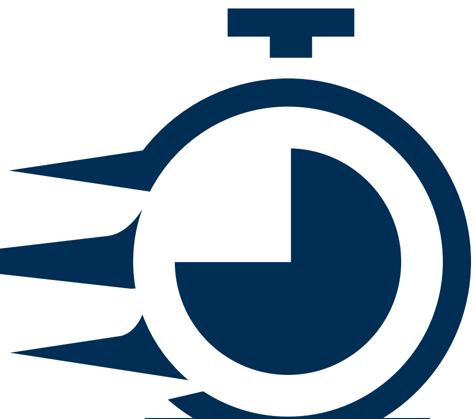
Catastrophic climate change has been associated with an increase in global average temperature of >3 °C[1]. This level of global warming would probably imply a serious shift in global climate patterns, unprecedented loss of landmass creating large flows of climate refugees, significant risks to regional and global food security, a combination of high temperature and humidity jeopardising normal human activities, and massive species extinctions having adverse cascading effects on ecosystem functioning and services critical for sustaining humanity[2].

Catastrophic climate change would be triggered by crossing one or more tipping points of the Earth's climate system. Decision-makers have tended to assume that tipping points are of low probability and poorly understood, in spite of growing evidence that these tipping points may be more likely than previously thought, have high impacts and interact in complex and dangerous ways, threatening long-term irreversible changes[3]. Political discussions about climate change rarely acknowledge catastrophic climate risk[4].

HOW MUCH DO WE KNOW?

The Earth's climate is impacted by the concentration of certain gases in the atmosphere known as greenhouse gases, the most important being carbon dioxide and methane. As a result of human activity since the Industrial Revolution, the atmospheric concentrations of greenhouse gases – generally expressed as the number of greenhouse gas molecules per million or ppm – have risen consistently, from 280 ppm at the dawn of the Industrial Revolution to 410 ppm in 2019. Current carbon dioxide levels are the highest in at least 800,000 years[5].

Climate change is accelerating and its impacts increasing. Human actions are estimated to be causing the planet's climate to change 170 times faster than natural forces. Despite a La Niña cooling event, 2020 was one of the three warmest years on record; 2011-2020 is the warmest decade recorded. Extreme weather, ice loss, sea level rise and ocean heat and acidification are accelerating[7]. Human activities have caused approximately 1.2°C of global warming above pre-industrial levels[8]; under current policies, global temperatures are expected to reach nearly 2.9°C by 2100.

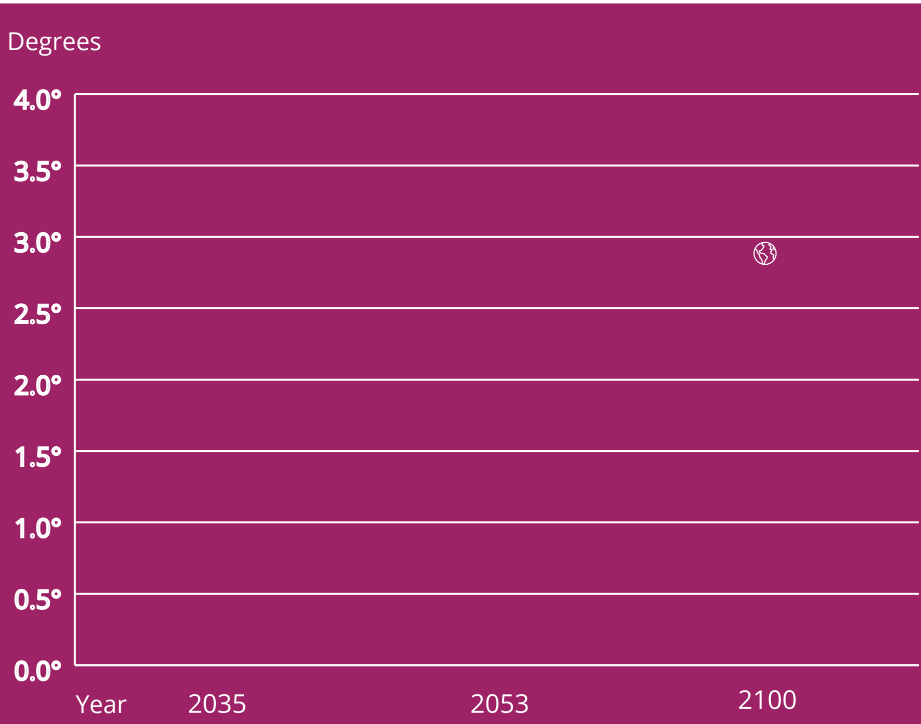


Human actions are estimated to be causing the planet's climate to change 170 times faster than natural forces.

Current pledges and targets under the Paris Climate Agreement put the world on track to warm by approximately 2.4°C by the end of the century. Full implementation of the net zero targets announced or considered but not yet submitted to the United Nations Framework Convention on Climate Change (UNFCCC) by the US, China and other countries would still lead to global warming of 2 °C by 2100 – well above the agreement's 1.5 °C aspirational temperature goal[9].

Climate change is a non-linear phenomenon where tipping points play a determining role[12]. When warming rises above a certain level, self-reinforcing feedback loops set in and the concentration of greenhouse gases increases rapidly. Although precise thresholds and exact scenarios remain very uncertain, we know that the level of risk increases with the rise in temperature. The latest science suggests that tipping points could be exceeded even between 1.5°C and 2°C[13]. For example, at 2 °C of warming there is a 10-35% chance that the Arctic becomes largely ice-free in summer[14].

▼...exceeding tipping points in one system can increase the risk of crossing them in others▼



Under current policies, global temperatures are expected to reach nearly 2.9°C by 2100.

Scientists recently found that 45 per cent of all potential ecological collapses are interrelated and could reinforce one another[15]; in other words, 'exceeding tipping points in one system can increase the risk of crossing them in others'[16].

Limiting the Earth's temperature rise to 1.5 °C is thus not only crucial for saving the majority of the world's plant and animal species[17] as well as safeguarding low-lying island states from sea level rise and the poorest countries from climate extremes[18], but also a precautionary step to prevent triggering climate tipping points.

According to the 2018 special report by the Intergovernmental Panel on Climate Change of the United Nations, the remaining carbon budget, to stand a reasonable chance (66%) of limiting warming to 1.5 °C would be depleted by around 2030[20]. The panel's conclusions were, however, criticised for being too conservative[21]. Considering, for example, an upper estimate of a wide range of potential Earth system feedbacks, humanity might have already exceeded the remaining budget to limit warming to 1.5 °C, (66% probability)[22]. Moreover, mitigation pathways compatible with 1.5 °C imply the deployment of negative emissions technologies (e.g., bioenergy production with carbon capture and storage)[23] policy are currently far from ideal[24].

CLIMATE TIPPING POINTS

The Earth's climate system is formed by large-scale components characterised by a threshold behaviour known as tipping elements. Put another way, climate tipping elements are supra-regional constituents of the Earth's climate system that may pass a tipping point[25]. The Greenland ice sheet and the Amazon rainforest are examples of tipping elements. A tipping point is 'a threshold at which small quantitative changes in the system trigger a non-linear change process that is driven by system-internal feedback mechanisms and inevitably leads to a qualitative different state of the system, which is often irreversible'[26].

WHAT ARE KEY FACTORS AFFECTING RISK LEVELS?

Climate change is a highly complex phenomenon affected by many factors. We may divide them into four categories to better discern the various areas where action is possible.

First, the risk is directly related to the release of greenhouse gases in the atmosphere through human activity. Carbon dioxide mainly results from the burning of fossil fuels for energy and transport. In turn, this is a factor in population growth and unsustainable production and consumption models[27].

As to methane emissions, they largely relate to large-scale animal farming, driven by demand for meat, dairy and wool[28].

Second, some ecosystems store large amounts of carbon, particularly forests and coastal marine ecosystems and their destruction could result in the large-scale release of greenhouse gases into the atmosphere[29].

The third factor is our capacity for global coordination to reduce emissions. This may be positively impacted by a better understanding of tail-end climate risk and climate tipping points, increasing the sense of urgency and prompting faster action[30].

Finally, the risk of catastrophic climate change is increased by insufficient knowledge and understanding of impacts and vulnerability, in turn affecting our ability to build resilience. The complex and interrelated nature of global catastrophic risk suggests an integrated research agenda to address related challenges and dilemmas – such as the use of solar radiation management techniques (namely, stratospheric aerosol injection) to reduce the risk of catastrophic climate change, which might harm in other ways[28] – and ensure human development and the protection of the non-human living beings that enable life on the planet to thrive[31].

Photo Mandy Beerley on Unsplash

▼The risk of catastrophic climate change is increased by insufficient knowledge and understanding of impacts and vulnerability, in turn affecting our ability to build resilience▼

The impact of the COVID-19 pandemic on CO_2 EMISSIONS

According to a 2021 report by the International Energy Agency[29], in 2020 primary energy demand dropped by approximately 4% and global energy-related CO2 emissions fell by 5.8%. The unprecedented reduction in oil demand during 2020 (8.6%) – mostly associated with the drop in road transport and aviation activity – accounted for over half of the reduction in global emissions. In turn, low-carbon fuels and technologies accelerated their expansion; rising from 27% in 2019 to 29% in 2020, the share of renewables in the global energy mix reached the highest annual increase ever recorded. The COVID-19 pandemic resulted in a decline in emissions of nearly 2,000 million tonnes of CO2 – in absolute terms, the largest-ever decline in global emissions[30].

However, as the pandemic is brought under control and the global economy begins to stir, emissions are on the rise again. By the end of 2020, global emissions were 2% higher than they were December 2019. In China, emissions increased by 7% in December 2020 compared with a year earlier; in India, emissions rose above 2019 levels in September; the same happened in Brazil in the later months of 2020; in the US, by the end of 2020 emissions were approaching the same level seen in December 2019. Unless structural changes are made during 2021 as part of the governments' efforts to boost their economies, emissions will most likely increase significantly throughout the year. A global energy transition is needed[31].

▼…global warming makes conditions more favourable to the spread of some infectious diseases and air pollution makes people more vulnerable to infection▼

CLIMATE CHANGE, BIODIVERSITY LOSS AND HUMAN HEALTH

The COVID-19 global health crisis urges us to rethink our relationship to nature and the non-human species with which we share the planet. The coronavirus has been attributed to anthropogenic interferences on the natural world such as deforestation, a major contributor to climate change, encroachment on animal habitats, and biodiversity loss, which is also driven among other factors[38] by climate change. The crisis is a reminder of our enmeshment in a more-than-human world[39]. It also calls our attention to the critical links between climate change and biodiversity loss, and their impacts on human health.

By eroding wild spaces largely for agriculture and changing the climate – thus forcing animals to find food and shelter close to people or migrate to the poles to escape heat which creates new opportunities for pathogens to get into new hosts - and by trading and consuming wild animals, we increase the likelihood that zoonotic viruses will jump to humans.

Moreover, and although there is no direct evidence that climate change is influencing the spread of the new coronavirus, we know that global warming makes conditions more favourable to the spread of some infectious diseases and that air pollution makes people more vulnerable to infection[40]. We also know that when biodiversity declines, the species that thrive are the ones that are best at transmitting diseases e.g., bats and rats[41]. As current species extinction rates have no parallel in human history[42], there are strong reasons for concern. Finally, attention is also needed on the thawing of the Arctic's permafrost as a result of global warming and the possibility that viruses and bacteria once buried in the region are released[43].

Future policies must thus integrate climate, biodiversity and health considerations as well as the needs and rights of the non-human living beings with which we share the Earth.

Governance of catastrophic climate change

Dr Joana Castro Pereira, Postdoctoral Researcher at Portuguese Institute of International Relations, NOVA University of Lisbon

The challenge of climate change has been defined as a 'super-wicked' problem. It is intricately linked to everything else – energy, land use, food, water, transportation, trade, development, housing, investment, security, etc.[44] Solving it requires tremendous, unprecedented collective action by countries with heterogeneous interests, priorities and circumstances [45], where powerful forces pushing for environmentally destructive development have prevailed thus far[46]. The sharing of responsibility in mitigating climate change has thus been a central challenge in international negotiations[47].

The Paris Climate Agreement, signed in 2015 and in force since November 2016, avoids the critical issues of the allocation of responsibilities for safeguarding the climate and fairness of each country's mitigation efforts[48]. In addition, it fails to include:

- Dates by which countries must reach a global peaking of emissions
- Legal obligations determining concrete mitigation actions
- Means for coordinating the countries' contributions[49]
- Solid mechanisms for monitoring the implementation of national pledges and supporting the mitigation efforts of developing countries
- Tools to punish the parties that do not comply with its provisions, and any references to the end of fossil fuel subsidies[50].

Moreover, the rules already established for operationalising the agreement provide very few obligations for countries to implement ambitious climate action at the domestic level. Other important guidelines remain undefined as parties have not reached consensus yet. These include rules to develop a global carbon trading system and how to channel new financial resources for helping countries already facing the adverse impacts of climate change[51].

In spite of the devastating fires, storms, social protests and climate strikes that swept the world in 2019, the last Conference of the Parties of the United Nations Framework Convention on Climate Change ended in failure. Countries such as Brazil, Australia and Saudi Arabia, 'invigorated by the US withdrawal from the Paris agreement and rising nationalism at home (...) defended loopholes and opposed commitments to enhance climate action'[52]. The next paragraphs highlight some of them.

The fact that the US re-joined the Paris Climate Agreement in 2021, and the new climate targets and commitments announced during the Leaders' Summit on Climate convened by President Joe Biden in April, brought new hope that catastrophic climate change might be avoided and helped build momentum for the decisive COP26, which will take place in November this year. Nevertheless, the world is still far from the level of ambition required to ensure a safe climate. Additionally, '[c]ommitting to intentions, targets and promises can no longer be enough. (...)[; we need to focus on] concrete results (...)[. We need a] "climate accountability summit", where showcasing results towards fulfilling the Paris Agreement are centre stage'[10]. Yet accountability is a sensitive issue.

It appears highly unlikely that the international community will be able to prevent global warming from exceeding 1.5 °C. In this context, we need to prepare for dealing with the consequences of an increasingly unstable ecological environment and mitigating the risk of a climate catastrophe. There are, however, a number of limitations and obstacles that challenge our ability to do so[53].

The first is the fact that our brain is wired to process linear correlations, not sudden, rapid and exponential changes; our cognitive expectations are failed by the uncertainty and non-linearity of socio-ecological systems[54]. In addition, our political-legal system was developed to address structured, short-term, direct cause and effect issues (the exact opposite of the climate issue); our institutions provide simple solutions with immediate effects[55].

Moreover, managing catastrophic risks requires proactivity to anticipate emerging threats, mobilise support for action against possible future harm and provide responses that are sufficiently correct the first time, as those risks offer little or no opportunity for learning from experience and revising policies. Nevertheless, in addition to the fact that few existing institutions are capable of acting in this manner, there is the risk that such a proactive approach translates into oppressive behaviours and security measures[56].

The second is the possibility of creating a new risk through efforts to prevent another[57], e.g., large-scale deployment of bioenergy with carbon capture and storage to help prevent catastrophic climate change, which would erode natural habitats and cause the loss of biodiversity, thus increasing the risk of ecological collapse.

Third, mitigating the risk of a climate catastrophe requires that current generations resist short-term individual benefits with the aim of improving the far future of human civilisation. Many people lack motivation to help the far future[58].

Fourth, there tends to be a general distrust in human agency in the face of high-magnitude situations that demobilises people. In addition, people tend to experience strong, mobilising feelings about recent, visible events, and develop feelings of compassion especially when a subject is given a face; as societies have never lived a global climate catastrophe and nature is a vast and blurred subject, public and political concern for that possibility is low[59]. It remains to be seen whether the COVID-19 pandemic will make people more open to considering abrupt, high-impact situations.

More research is needed to increase our understanding of catastrophic climate risk, better reach the public and pressure political actors to act.

…our political-legal system was developed to address structured, short-term, direct cause and effect issues – the exact opposite of the climate issue

Managing catastrophic risks requires proactivity to anticipate emerging threats

Photo Sippakorn Yamkasikorn on Unsplash

Reviewed by
PHILIP OSANO

Ecological collapse

WHAT IS AT STAKE?

Ecosystems are the foundation for human life. They perform a range of functions, generally referred to as environmental services, without which human societies and economies would not operate at their current level[1]. We depend on the services they provide for air, water, food and fiber, shelter and energy. Ecosystems can tolerate a measure of impact from human use and recover after a period of time with minimal negative effects – an attribute generally known as resilience – but beyond a certain threshold, or "tipping point", sudden and radical disruption occurs), which may lead to "ecosystem collapse"[2]. Under such conditions, soil quality, freshwater supplies and biodiversity diminish drastically, while agricultural capacity plummets and daily human living conditions deteriorate significantly[3].

Although little studied, new evidence is emerging on "ecosystem collapse" due to among other factors, human pressure, and climate impact[4]. Local ecological collapse may have caused the end of a civilization on Easter Island[5].

More recently, ecological collapse in and around the Aral Sea has had dramatic social and economic consequences for the region[6], although timely intervention has led to some marked recovery[7]. Ecological changes in Lake Chad has not only destroyed livelihoods with dramatic impact on people and ecosystem of the region; the diminishing water resources and the decline in the lake's ecosystem leads to severe health and economic impacts for the populations around Lake Chad, and has affected fishing communities and pastoralists, and generated resource-based conflicts[8].

In today's highly connected world, local disruptions may sometimes also lead to unintended ecological effects on other far flung areas. This might escalate into the rapid collapse of most ecosystems across the Earth[9]. And with no time for effective recovery – and amplified by climate change impacts[10]- drastically compromising the planet's capacity to sustainably support a large and growing human population.

▾...compromising the planet's capacity to sustainably support a large and growing human population▾

HOW MUCH DO WE KNOW?

Ecosystems are complex entities, which consist of a community of living organisms in their non-living environment, linked together through flows of energy and nutrients. The behaviour of an ecosystem is relatively stable over time, but when the balance between some of its elements is altered beyond a certain threshold, it can experience a non-linear, possibly catastrophic transformation[11].

Human-induced factors that affect ecosystem vitality may be classified in the following manner:

- changes in the balance of local biodiversity caused by human intervention, in particular as a result of introducing new species or overharvesting of plants and animals[12]
- alteration of the chemical balance in the environment – soil, water and air - due to pollution[13]
- modifications in the local temperatures and water cycle because of climate change[14]
- habitat loss, whether through destruction or ecosystem fragmentation in terrestrial and water/sea systems[15].

Scholars describe the current historical moment as the start of a new geological era, called the Anthropocene , where humans as the predominant agent of change at the planetary level change the nature of nature itself[16]. Since the mid-1950s, many elements that ensure the habitability of the planet, whether greenhouse gas concentration, forested areas or the health of marine ecosystems, have been degrading at an accelerating pace[17].

In 2009, an international group of experts identified nine interconnected planetary boundaries that underpin the stability of the global ecosystem, allowing human civilization to thrive. It is argued that humanity has exceeded the safe limits for the planetary boundaries and are now operating in a high-risk zone for biosphere integrity and biogeochemical flows, and are very likely to exceed all the nine boundaries, and move beyond the safe operating ecological space where humanity has thrived[18].

New evidence suggests that changing course to stop the pervasive human-driven decline of life on Earth requires transformative change[19].

WHAT ARE KEY FACTORS AFFECTING RISK LEVELS?

The development and adoption of new technologies or production models that are less resource-intensive and/or less polluting could reduce the risk of biodiversity loss and ecological collapse, as would a shift towards more sustainable lifestyles, more specifically changing consumption patterns, possibly accompanied by behaviour change[20].

It is estimated that environmental services, should their contribution to human well-being be calculated, would be worth more than twice as much as the entire global GDP[21]. Integrating the valuation of ecosystems into economic decision making, reviewing our measures of economic success, and employing robust environmental accounting systems across businesses and national economies would contribute to reducing the risk[22].

Global governance mechanisms to conserve ecosystems and reduce pollution, in particular more integrated approaches between the global governance of ecosystems and economics and trade, are of particular importance, as many ecosystems do not overlap with national boundaries, and trade is an important driver of ecosystem collapse[23].

ECOSYSTEM COLLAPSE IN AUSTRALIA AND TERRESTRIAL ANTARCTICA

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A recent study assessed evidence of collapse in 19 ecosystem (both terrestrial and marine) that cover approximately 1.5% of the Earths surface extending from northern Australia to coastal Antarctica, looking at environmental changes over the past 30 years[24]. The study applied four criteria to assess collapse (abrupt, smooth, stepped and fluctuating), and found evidence of local collapse for all the 19 ecosystems studied, although none has collapsed across the entire distribution. The collapses were as a result of ecosystems experiencing multiple pressures simultaneously, including, pressures from global climate change (such as temperature rise, altered precipitation and ocean acidification), and pressures arising from regional human impacts (such as habitat loss, pollution and water extraction) acting together to erode biodiversity. To deal with this challenge of ecosystem collapse, the authors recommend a three-step approach of promoting awareness of ecosystem values, anticipation of pressures, and taking action to manage the impacts through recovery, restoration, renovation and adapting to the changes.

Governance of ecological collapse

Contemporary ecological risks are increasingly global in scale, scope, and impact with strong levels of interconnection not only across the borders of nations, but across continents[1]. Action to address them, however, has to be taken at both global and national level. The environment is a classic common good: all benefit from healthy ecosystems and a pollution-free planet, while extraction of natural resources and pollution by some compromise the benefit for many.

A number of international institutions oversee monitoring, assessment, and reporting on problem identification and implementation; they set standards, policies, and laws; and they support the development of institutional capacity to address existing and emerging problems at the national level. Governments crafted the institutional architecture for managing global ecological risks in the 1970s with the creation of the anchor institution for the global environment: the United Nations Environment Program (UNEP). Global environmental conventions, also known as treaties or agreements, are the main international legal instrument for promoting collective action toward managing ecological risk and staying within the safe planetary operating space. Their number and membership have increased dramatically.

About a dozen international treaties deal with global issues including climate change, land-system change, biosphere change, and chemicals and waste. These include the UN conventions on climate change, biodiversity, migratory species, trade in endangered species, desertification, persistent organic pollutants, among others[2]. The expectation is that when countries implement their obligations under the treaties, the problems will be managed and ultimately resolved. At the national level, governments have established ministries and authorities to deal with environmental concerns, advocate for ecologically informed decision making, and improve national capacity.

States voluntarily create international agreements to govern their relations through legal responsibilities. There is, however, no overarching judicial system or a coercive penal system that could ensure effective enforcement of the agreements that deal with environmental issues. Breaches cannot be sanctioned. Compliance and implementation have to be enticed rather than coerced. Environmental agreements such as the 2015 Paris Agreement, for example, are explicitly non-punitive: countries face no penalties for not meeting their commitments. Rather, they are facilitative, as international institutions commit to support compliance and implementation. The United Nations General Assembly Resolution 72/277 on *"Towards a Global Pact for the Environment"*, seeks to explore how to strengthen the implementation of international environmental law, and international environmental governance[3].

The environment is a classic common good... extraction of natural resources and pollution by some compromise the benefit for many

Additionally, through the United Nations Convention on Biological Diversity (CBD), UN member states are working on a post-2020 global biodiversity framework to be adopted at the 15th Conference of Parties (CoP) to the CBD. The framework builds on the Strategic Plan for Biodiversity 2011-2020 and sets out an ambitious plan to implement broad-based action to bring about a transformation in society's relationship with biodiversity and to ensure that, by 2050, the shared vision of living in harmony with nature is fulfilled. The framework aims to galvanise urgent and transformative action by governments and all of society, including indigenous peoples and local communities, civil society and businesses, to achieve the outcomes it sets out in its vision, mission, goals and targets, and thereby contribute to the objectives of the Convention on Biological Diversity and other biodiversity related multilateral agreements, processes and instruments.

Importantly, many countries are implementing their obligations. The Environmental Conventions Index developed by the team at the Center for Governance and Sustainability at the University of Massachusetts Boston measures the implementation of global environmental conventions. The Index is a composite score based on the national reports that member states submit to each convention secretariat and illustrates trends across countries, within countries (across issues and over time), and across the conventions. It highlights the leaders and the laggards and raises questions about the determinants of implementation[4]. Availability of data, comprehensive regulations, national capacities, cooperation, and funding emerge as important factors.

Reporting is the fundamental mechanism to entice and monitor implementation. National reports on progress in achieving global commitments are part of every agreement.

Reporting, however, is a challenge because of low capacity and poor data in countries, an inadequate reporting system that does not always cover the comprehensive nature of the issues, and lack of analysis of and feedback on submitted reports. It is notable, however, that the complexity of the reporting process is not necessarily a deterrent to reporting compliance. The Ramsar Convention on wetlands, for example, requires countries to report on over 100 indicators and has among the highest reporting rates with member states reporting at close to 90% of the time.

Enforcement mechanisms do not guarantee that international commitments will be implemented, and much less that problems will be solved. Countries, however, care about reputation and can be influenced by ratings and rankings, an approach to global performance assessment that has come to be known as scorecard diplomacy.[5] This form of soft power can shape national policies and outcomes as it goes beyond 'naming and shaming' to 'naming and acclaiming'. It outlines actions that could lead to better ranking and enables learning across peers. Scorecard diplomacy has proven effective in national governance, corruption, human trafficking, environmental democracy, and environmental performance[6].

Since the 2015 Paris Agreement, the progress on global efforts to address climate change have been slow, despite the growing threat that climate change and other human activities risk triggering biosphere tipping points across a range of ecosystems and scales[7]. Companies, cities, and countries must raise their ambition to significantly take actions to reduce greenhouse gas emissions to below the 1.5 degree target and lead the transformation to a low carbon economy, which many see as desirable, inevitable, and irrevocable.

Photo Matt Howard on Unsplash

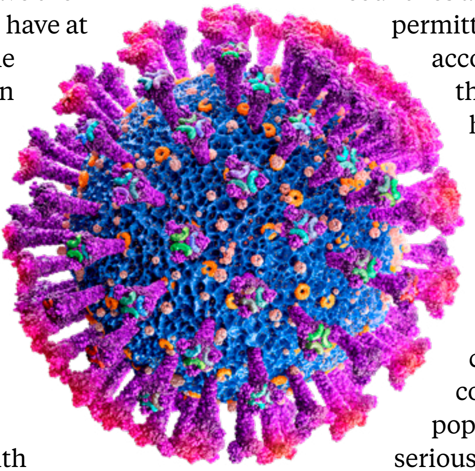
Since the 2015 Paris Agreement, the progress on global efforts to address climate change have been slow, despite the growing threat that climate change and other human activities risk triggering biosphere tipping points across a range of ecosystems and scales

Reviewed by
PROFESSOR DAVID L. HEYMANN

Pandemics

COVID-19 (SARS-COV-2)

After a year and a half of varied national response and remarkable accomplishments in research and development the world is learning to live with COVID-19, and converting pandemic response to control as it becomes more and more evident that SARS CoV2 is becoming endemic like the four other endemic human coronaviruses. These four endemic coronaviruses, like SARS CoV2, have their origin in the animal kingdom and have at some time in the past breeched the species barrier and entered human populations – populations that have learned to live with them as their epidemiology has evolved.



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But fortunately, though SARS CoV2 is more virulent than the other four human coronaviruses, there is an astounding array of vaccines, diagnostic tests and medicines that will help us live with this virus thanks to the unprecedented speed with which these tools have been developed, studied and licensed. One of the major concerns now is whether the tools we have will continue to be effective because SARS CoV2, like other RNA viruses, is unstable and mutates as it replicates in humans. Some mutations of SARS CoV2 have been shown to increase its ability to spread from person to person if the opportunity for transmission is created. The question remains as to whether the mutated variants of SARS CoV2 will escape the protective effect of the vaccines we have today, whether the many diagnostic tests will continue to identify infection, and whether SARS CoV2 will become more virulent.

The world has learned much about pandemics from the example of COVID-19. Countries that reacted more rapidly when the World Health Organization provided initial information on 5 January 2020 have been able to maintain low levels of hospital burden and mortality, and many were countries that had previous outbreaks of SARS and MERS coronaviruses that emerged in 2003 and 2012 respectively. These countries also had strong health systems that permitted them to control outbreaks and accommodate the surge of patients in their health facilities, while ensuring healthcare for others who had non-COVID related illness.

The rest of the world has also learned that robust and resilient health facilities are required to respond to the surge of patients caused by a pandemic, and all countries have seen that healthy populations are best able to resist serious illness when infected with newly emerged viruses.

We have also seen the cost to economies of a pandemic, increased by the response actions by governments that have taken on the function of risk assessment and responded in a manner that requires populations to protect themselves and others by being confined to their homes. The challenge now for many governments is to transfer these tasks to the population so that they are able to do their own risk assessment and management – protecting themselves and protecting others as they do for other infectious diseases.

WHAT IS AT STAKE?

In the 5th and 14th centuries, Plague epidemics spread internationally and killed approximately 15% of the global population over the course of a few decades. Systematic vaccination campaigns have allowed us to eradicate two diseases that had affected humanity for centuries, Smallpox in humans and Rinderpest in animals, and two more diseases – Guinea Worm and Polio – are close to being eradicated. Progress in vaccine development has permitted us to control other infectious diseases such as diphtheria, tetanus, whooping cough and polio; public health and sanitation have reduced the prevalence and impact of yet other infectious diseases such as Typhus and Cholera; and antimicrobial medicines have helped cure or control infections such tuberculosis, AIDS and malaria. But there is a serious risk that the emergence of yet another new infectious disease in humans will cause a major outbreak or pandemic, with high mortality and rapid spread in our densely populated, urbanised and highly interconnected world. And there is also a major risk that the antibiotics and other antimicrobial drugs on which we depend will become ineffective because of misuse, causing outbreaks of resistant infections that spread first in communities and then within countries and across international borders.

And developments in synthetic biology continue to raise concern among certain scientists and governments that a micro-organism will one day be engineered in such a way that its release in the population– whether by malice or accident - could cause an epidemic or pandemic. The best means to mitigate such an event is to develop health systems that have the capacity to deal with events such as the COVID-19 pandemic that we are witnessing today.

HOW MUCH DO WE KNOW?

Catastrophic pandemics – diseases with high lethality that spread globally such as COVID-19 – are extremely disruptive, and have been infrequent in the past. Outbreaks of lethal diseases that remain locally contained or pandemics with less acute effects on human health are more common, but they can also have significant disruptive effects.

There is also a major risk that the antibiotics and other antimicrobial drugs on which we depend will become ineffective

Outbreaks occur when a micro-organism – virus, bacteria, parasite, etc. – is able to spread across the population. At times and under certain conditions, such as failure of water or sanitation systems, an outbreak is caused by a micro-organism known to be circulating at low levels in human populations. At other times, an outbreak is caused by a micro-organism that has crossed the animal/human species barrier to infect humans, and spreads to new and more densely populated areas. Those micro-organisms that replicate in the respiratory system, especially the passages of the nose, are easiest to transmit from person to person directly and can cause explosive outbreaks. If mutation occurs in a micro-organism as it replicates, or when it combines with genetic material from another micro-organism, virulence can increase or decrease. Mutation can also cause a micro-organism to transmit more or less easily from human to human.

Photo by John Cameron on Unsplash

WHAT ARE KEY FACTORS AFFECTING RISK LEVELS?

New micro-organisms affecting humans are more likely to arise when environments with high levels of biodiversity are disrupted, and when humans or domesticated animals come into close contact with other animal species that serve as reservoirs for micro-organisms not present in human populations. Experts now consider this is likely to be the way that the HIV/AIDS epidemic started - HIV/AIDS is now endemic in human populations, and its origin is thought to have been a single event when a retrovirus in non-human primates infected a human somewhere on the African continent. From this person chains of transmission of HIV began and they were eventually amplified into the HIV/AIDS pandemic when conditions were right.

Infections are easier to contain when they occur among small populations with limited external contacts. Conversely, dense urbanisation and global interconnection strongly increase the risk of an infectious disease spreading internationally.

The broad adoption of hygiene and infection control practices in health facilities can have a significant effect in reducing the local and cross-border spread of an infection. This is especially true in health facilities where infection prevention and control through handwashing and other infection control measures can prevent transmission from amplifying into an outbreak. And the capacity to monitor a disease and deploy very rapid containment early in the process can have a large impact on the final number of deaths as well.

RISK SCENARIOS

In February 2003, an elderly woman infected by the SARS virus travelled from Hong Kong to Toronto. SARS is a highly infectious and often fatal pulmonary disease that emerged in the Pearl River Delta, in China. The infected woman died soon afterwards in Toronto, after inadvertently infecting over forty people, resulting in a localised outbreak. One of those persons infected in Canada went on a plane to the Philippines, where another outbreak occurred. Meanwhile, from Hong Kong, the virus had also spread to Singapore, where it likewise caused an outbreak.

The outbreaks that occurred around the world were eventually contained, after infecting over 8,000 people, of whom 774 died, through concerted public health action coordinated by the WHO. Severe social and economic disruption occurred, and a similar scenario with only minor variations – a few more international contacts, a slightly longer incubation period for the virus, or a few more days of delay in deploying strict containment measures, could have a similar or even more serious outcome.

In late 2013, in Guinea in West Africa an initial infection with the Ebola virus is thought possibly to have occurred directly from a bat in nature to a child living in the tropical rain forest of Guinea. Small chains of transmission are thought to have occurred from this infected person, and transmission is thought to have been amplified in health care settings with weak infection prevention and control measures. Health workers became infected as well, and they served as the entry point of the virus into their families and their communities from where it spread across international borders to neighbouring countries. Over 28,000 persons were reported to have been infected during this outbreak in Guinea, Liberia and Sierra Leone, with over 11,000 deaths.

Infected persons from West Africa travelled to countries in Europe and North America for care, and rigorous infection prevention and control practices in health facilities in these countries prevented spread within health facilities and into communities.

It is estimated that in addition to tragic loss of life from Ebola in West Africa, there was a reported increase in death from common infections such as malaria and measles because of the failure of health systems to accommodate needs of those with endemic infections.

Photo by JC Gellidon on Unsplash

RISK FACTORS[2]

Three main factors determine the potential danger of an outbreak:

1. Virulence: the ability of a micro-organism to damage human tissues and cause illness and death.

2. Infection risk: the probability that a micro-organism will spread in a population. One key factor is the means of transmission – whether by blood, bodily fluids, direct contact with a lesion such as a skin ulcer, or by aerosol in the air; another is the level of immunity in the population; and a third is whether population behaviour creates a risk of transmssion.

3. Incubation period: the time between infection and appearance of the first symptom(s). A longer incubation period could result in a micro-organism spreading unwittingly, as in the case of HIV. Conversely, a shorter incubation period, if the infection is highly lethal, is less likely to be transmitted unwittingly, and can cause considerable disruption of social, economic and medical systems in a very short period of time.

Ebola is a highly lethal infection with a short incubation period but a relatively low infection rate, which explains why most Ebola outbreaks to date have been localised.

New developments in synthetic biology, however, raise concern among certain scientists that an engineered micro-organism both highly virulent and with a high infection rate could be released in the population – whether by malice or accident – and cause an unprecedented outbreak, possibly leading to the international spread of a highly lethal infectious disease.

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ANTIBIOTICS AND BACTERIA

Antibiotics have saved millions of lives and dramatically increased life spans since they were introduced in the 1940s, allowing us to contain most bacterial infections and diseases. However, more recently, as a result of random mutations, improper use of antibiotics among humans and animals, and the buildup effects of evolution, some strains of bacteria have become resistant to traditional antibiotics. These 'superbugs' require alternative medications with more damaging side effects or, in the worst cases, can no longer be treated effectively. Antibiotic-resistant bacteria currently kill an estimated 700,000 people. That number is predicted to reach 10 million by 2050 if efforts are not made to curtail resistance or develop new antibiotics.

▼Under the International Health Regulations, countries are required to strengthen core capacities in public health that are deemed necessary for rapid detection of, and response to, a disease outbreak▼

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Governance of pandemics

David Heymann, Head and Senior Fellow, Centre on Global Health Security, Chatham House, Professor of Infectious Disease Epidemiology, London School of Hygiene & Tropical Medicine

The World Health Organization (WHO), established in 1948 as a specialised agency of the United Nations, is currently the global body in charge of governing the risk of pandemics. It does this mainly through a governance mechanism called the International Health Regulations (IHR), the goal of which is to stop public health events that have the potential to spread internationally with minimal interference of travel and trade. The IHR first came into force in 1969, with an initial focus on four infectious diseases – Cholera, Plague, Yellow Fever and Smallpox.

Revised in 2005, the IHR now acknowledges that many more diseases than the four originally covered may spread internationally, and that many cannot be stopped at international borders, as was demonstrated by the spread of HIV in the 1980s and SARS in 2003. Emphasis is therefore placed now on the requirement that countries rapidly detect and respond to outbreaks and other public health events with potential to spread internationally. The revised version of the IHR also includes a global safety mechanism that calls for collaborative action should a public health event be assessed as at risk of spreading internationally.

The governance of pandemics typically involves collaboration between the WHO, ministries of health and public health institutions. Some nations have established national public health institutes the role of which is to monitor public health events.

Alexandros Michailidis / Shutterstock.com

Some of those, including the US CDC and Public Health England, and a federation of national public health institutes (IANPHI), provide support to lower- and middle-income countries, helping them strengthen their capacity to better detect and respond to public health events. When an outbreak occurs, other national institutions, hospitals in particular, play a major role in early detection and containment.

The IHR are a binding agreement under international law, and as such provide a framework for national legislation and responsible national and international action. But like all international law and treaties, there is no enforcement mechanism. Under the IHR, countries are required to strengthen eight core capacities in public health that are deemed necessary for rapid detection of and response to a disease outbreak. Each year countries are required to do a self-assessment of their core public health capacity, and to report the outcome of their assessment to the WHO.

However, there is no sanction for non-reporting, and many countries do not report. As part of the IHR (2005) Monitoring and Evaluation Framework, the Joint External Evaluation (JEE) was developed as a mechanism where a country's core capacity in public health is assessed by a group of international experts. All countries may request such an evaluation through the WHO on a voluntary basis. The tool was made available in 2016 and to date, over 79 countries have done so.

The revised IHR provides a decision tree which can be used by countries to determine whether a public health event in their country has the potential for international spread, and should therefore be reported as a potential public health emergency of international importance (PHEIC). The WHO Director General then conducts a risk assessment.

For this, the Director General can ask for a recommendation from an emergency committee set up under the auspices of the IHR, and/or from other experts from around the world. If the Director General decides that the event is a PHEIC, the WHO must provide emergency recommendations aimed at curbing international spread, and review those recommendations every three months until the PHEIC has been declared over.

After the Ebola outbreak in West Africa, an external review of the revised IHR was conducted, and a second review was conducted during the COVID-19 pandemic. Recommendations from that review are now being considered by the World Health Assembly of the WHO.

Creator: Antoine Tardy Credit: WHO/Antoine Tardy Copyright: WHO/Antoine Tardy

Asteroid impact

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ROMANA KOFLER

WHAT IS AT STAKE?

The largest near-Earth asteroids (> 1 km diameter) have the potential to cause geologic and climate effects on a global scale, disrupting human civilization, and perhaps even resulting in extinction of the species. Smaller NEOs in the 140m to 1 km size range could cause regional up to continental devastation, potentially killing hundreds of millions. Impactors in the 50 to 140-meter diameter range are a local threat if they hit in a populated region and have the potential to destroy city-sized areas. NEOs in the 20 to 50 m diameter range are generally disintegrated in Earth's atmosphere but can cause localised blast and impact effects.

HOW MUCH DO WE KNOW?

Surveys of the NEO population on-going since the 1990s have discovered more than 26,000 NEOs of all sizes as of June 2021. A new record 2,959 NEOs of all sizes were discovered in 2020. The current surveys have discovered more than 96% of the population of NEOs larger than 1 km in diameter – 889 individual asteroids. In the United States, NASA's Planetary Defense Program has a Congressionally directed objective to discover at least 90% of potentially hazardous asteroids 140 meters and larger in size. As of 1 June 2021, 9,663 NEOs larger than 140 m have been discovered. This is estimated to be approximately 39% of the total population of NEOs this size or larger.

Credit: DART Credit_NASA_Johns Hopkins APL_Steve Gribben

Smaller asteroids are also continually being discovered, with the reservoir of NEOs with diameters between 50 and 140 metres expected to be approximately 300,000, making these the more likely impact threat in the near term. Impactors of these sizes are expected to have an average frequency of one per ~1000 years. The Tunguska event (1908) is believed to have been an impactor in the lower end of this size range. The total number of NEOs larger than 10m could be as high as 50-100 Million.

WHAT ARE KEY FACTORS AFFECTING RISK LEVELS?

The assessment of the risk presented by an NEO is related to the probability of impact with Earth, the size and composition of the asteroid, and where on Earth the impact occurs. Beyond discovery of NEOs, the risk assessment for a NEO with the potential to impact Earth requires an observational assessment programme to refine knowledge of the orbit and to characterise the size and composition of the asteroid. This could include specialised ground and space-based observations, or a spacecraft reconnaissance mission to the asteroid. Accurate orbital knowledge is required to establish the "impact corridor" – the areas on Earth where, given uncertainties in the orbital knowledge, the impact is most likely to occur. The impact location and potential severity of damage will determine the risk level, and the required governmental response, either in terms of disaster preparedness or potential asteroid deflection attempt.

The recent sample return missions to the asteroids Ruygu (Hayabusa2) and Bennu (OSIRES-REx) contribute considerable to our knowledge of these NEOs. The main objectives of these missions were scientific, but the characterisation of natural parameters of these objects is also important for planning of potential future Planetary Defence missions.

In the event of a credible impact threat prediction, warnings will be issued by the IAWN if the object is assessed to be larger than 10 meters in size. If the object is larger than about 50 m and the impact probability is larger than 1% within the next 50 years, the SMPAG would start to assess in-space mitigation options and implementation plans for consideration by the Member States. With vigilance and sufficient warning, an asteroid impact is a devastating natural disaster that can be prevented.

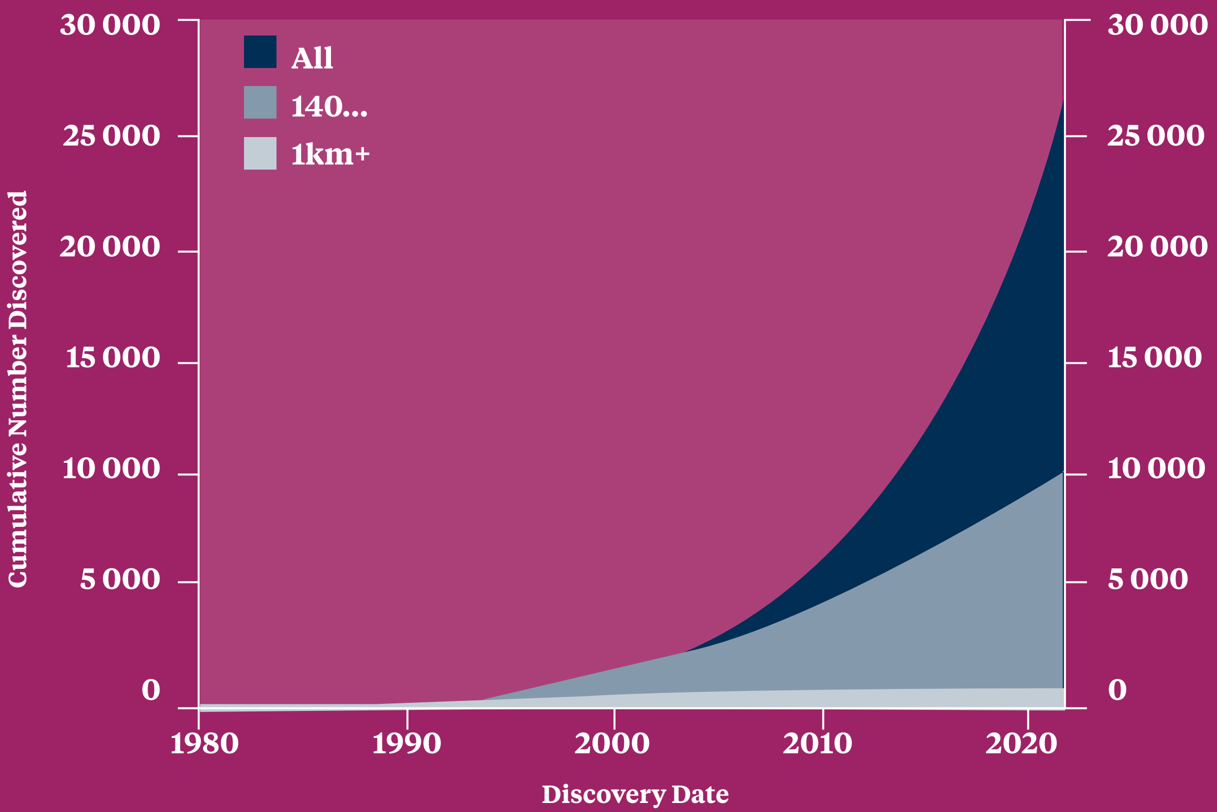
At the end of 2021 the DART impactor will be launched by NASA. DART will impact Dimorphos, the smaller 160 m companion of the 780 m large Didymos, in early fall 2022. It will test the capabilities to deflect an asteroid by a high velocity impact of the spacecraft. A few years later ESA will launch the HERA spacecraft to study the impact effects in detail. If successful, these missions will demonstrate that an impact can be avoided by active measures if the object is discovered soon enough.

SMPAG plans to perform exercises to test their function and coordination for realistic impact threats. These exercises should also clarify the working procedure, form of recommendations and flow of information. They should also identify missing technologies and other potential deficiencies in the field of space-based NEO mitigation.


Credit/source: Shutterstock

Near-earth asteroids discovered

Most recent discovery: 01-Jun-2021



NEAs:		**PHAs:**	
25998	all	2181	all
9663	>140m	158	>1km
889	>1km		
		NECs:	114

https://cneos.jpl.nasa.gov/stats/

Alan Chamberlin (JPL/Caltech)

Governance of asteroid impact

Gerhard Drolshagen, University of Oldenburg and the European Space Agency

Lindley Johnson, NASA Planetary Defense Officer and Program Executive of the Planetary Defense Coordination Office

Romana Kofler, United Nations Office for Outer Space Affairs

The issue of near-Earth objects (NEOs) has long been on the agenda of the Committee on the Peaceful Uses of Outer Space (COPUOS), the primary United Nations body for coordinating and facilitating international cooperation in space activities, established in 1959 by the UN General Assembly and supported by the Office for Outer Space Affairs (UNOOSA)[1]. In the last year several important events have contributed to our understanding of NEOs and to a better preparedness in case of a real impact threat.

The International Asteroid Warning Network (IAWN) and the Space Mission Planning Advisory Group (SMPAG) provide mechanisms at the global level to address the global challenge posed by NEOs, including detection, tracking and impact risk assessment and, subsequently, planetary defence measures like civil protection or asteroid deflection.

UNOOSA, through the IAWN and SMPAG, facilitates the dissemination of information related to NEOs to UN Member States. Important linkages are being made with civil protection communities, including through UNOOSA's UN-SPIDER programme and its global network of Regional Support Offices (RSOs).

IAWN and SMPAG - global mechanisms for coordinating action in the area of planetary defence

The IAWN links together the institutions that are already performing many of the proposed functions, including: discovering, monitoring and physically characterising the potentially hazardous NEO population. One of its purposes is to maintain an internationally recognised clearing house for the receipt, acknowledgment and processing of all NEO observations. IAWN recommends policies regarding criteria and thresholds for notification of an emerging impact threat.

IAWN also assists Governments in the analysis of impact consequences and in the planning for mitigation responses, using well-defined communication plans and protocols **(see iawn.net)**. As of June 2021, there are thirty-two official signatories to the IAWN Statement of Intent.

The SMPAG, (pronounced "same page") is composed of Member States with space agencies or inter-governmental entities that coordinate and fund space activities and are capable of contributing to or carrying out a space-based NEO mitigation campaign. In the event of a credible impact warning by the IAWN, the SMPAG would assess and propose through their member Governments space-based mitigation options and implementation plans for consideration by the Member States.

SMPAG currently has 19 members and 6 permanent observers, with UNOOSA acting as its secretariat. In 2016, SMPAG established the Ad-Hoc Working Group on Legal Issues to address possible legal questions related to the work of SMPAG. This group published a report entitled ´Planetary Defence Legal Overview and Assessment´ (see smpag.net under ´Documents and presentations´).

International Asteroid Day

As part of the effort to raise awareness about this topic, the UN General Assembly proclaimed in resolution ***A/71/492*** that International Asteroid Day would be observed annually on 30 June to raise public awareness of the asteroid impact hazard. 30 June is the anniversary of the Tunguska impact over Siberia in what is now the Russian Federation, which occurred on 30 June 1908. That event was Earth's largest confirmed asteroid impact in recorded history, devastating over 2,000 square kilometres of forest.

2021 International Planetary Defense Conference (PDC)

As the key biannual global conference that brings together key experts in this area, the 7th International IAA (International Academy of Astronautics) PDC was hosted by UNOOSA from 26th to 30th April 2021 as a virtual conference that attracted a wide audience, with more than 700 participants from all over the globe. Highlight presentations included results from the sample return space missions Hayabusa2 (lead by JAXA) and OSIRIS-REx (lead by NASA) and the latest status information on the upcoming missions DART and HERA which will demonstrate the capability to deflect an asteroid by the kinetic impactor technique. The 2021 PDC also included a number of dedicated panels on different aspects of Planetary Defence. In a panel with Heads and Representatives of Space Agencies, 11 high ranked officials (from AEB, AEM, Austrian Space Agency FFG, CNSA, ESA, KASI, NASA) gave statements and expressed their support for international collaboration on Planetary Defence issues.

As in previous PDCs, a hypothetical asteroid impact scenario was part of the Conference. This time the scenario included a hypothetical impactor of approximately 100 m in size discovered only six months before impact. Due to the imposed short warning time, a space mission for deflection was not possible. The main emphasis of this exercise was an assessment of impact effects and the role, interaction and mitigation measures from civil protection agencies. Several disaster management representatives from both national, regional and intergovernmental levels (Copernicus EMS, ERCC, FEMA, UN-SPIDER, UNOSAT) were engaged in discussing practical solutions to this hypothetical asteroid scenario that was initially predicted to pose a threat to most parts of Earth and eventually impacted the border areas of Austria, Czech Republic and Germany. The next PDC will be held in 2023 and hosted again by UNOOSA in Vienna as an in-person or hybrid meeting.

Presentations and recordings of the 7th IAA PDC 2021 are available *here*.

Reviewed by
STEPHEN SPARKS

Supervolcanic eruption

The eruption of the Toba supervolcano in Indonesia, around 74,000 years ago, ejected billions of tonnes of dust and sulphates into the atmosphere[1]. Experts estimate that it caused a global cooling of 3-5°C for several years and led to devastating loss of plant and animal life[2]. Some have argued that Toba caused the greatest mass extinction in human history, bringing our species to the brink of extinction[3]. Supervolcanic eruptions are events in which at least 400 km^3 of bulk material is expelled. Eruptions of such magnitude may happen at any time in the future, with catastrophic consequences.

HOW MUCH DO WE KNOW?

In order to assess the likelihood of supervolcanic eruptions, we have to rely on a relatively limited set of past observations, which makes any estimates very uncertain[4]. Existing data suggest that a supervolcanic eruption will occur every 17,000[5] years on average – with the last known event occurring 26,500 years ago in New Zealand[6]. We are currently unable to anticipate volcanic eruptions beyond a few weeks or months in advance, but scientists are monitoring a number of areas, including Yellowstone in the US[7], which have been identified as potential sites of a future supervolcanic eruption. The impact of a supervolcanic eruption is directly connected to the quantities of materials ejected by the volcano.

Super-volcanic eruptions are events in which at least 400 km3 of bulk material is expelled. Eruptions of such magnitude may happen at any time in the future...

Dust and ashes will kill human populations nearby and devastate local agricultural activity. In addition, the release of sulphate and ashes in the atmosphere will affect the amount of solar energy reaching the surface of the planet and may lead to temporary global cooling[8] and severe environmental effects[9].

What are key factors affecting risk levels?

- There is no current prospect of reducing the probability of a supervolcanic risk, but there may be ways to mitigate its impact[10].
- Improvements in our ability to identify volcanoes with potential for future super-eruptions – and to predict eruptions – will help us to prepare and ensure that food stockpiles are available to mitigate a temporary collapse of agricultural systems.
- Resilience building, particularly the potential to rely on food sources less dependent on sunlight – including mushrooms, insects and bacteria – could significantly reduce the death rate among humans[11].

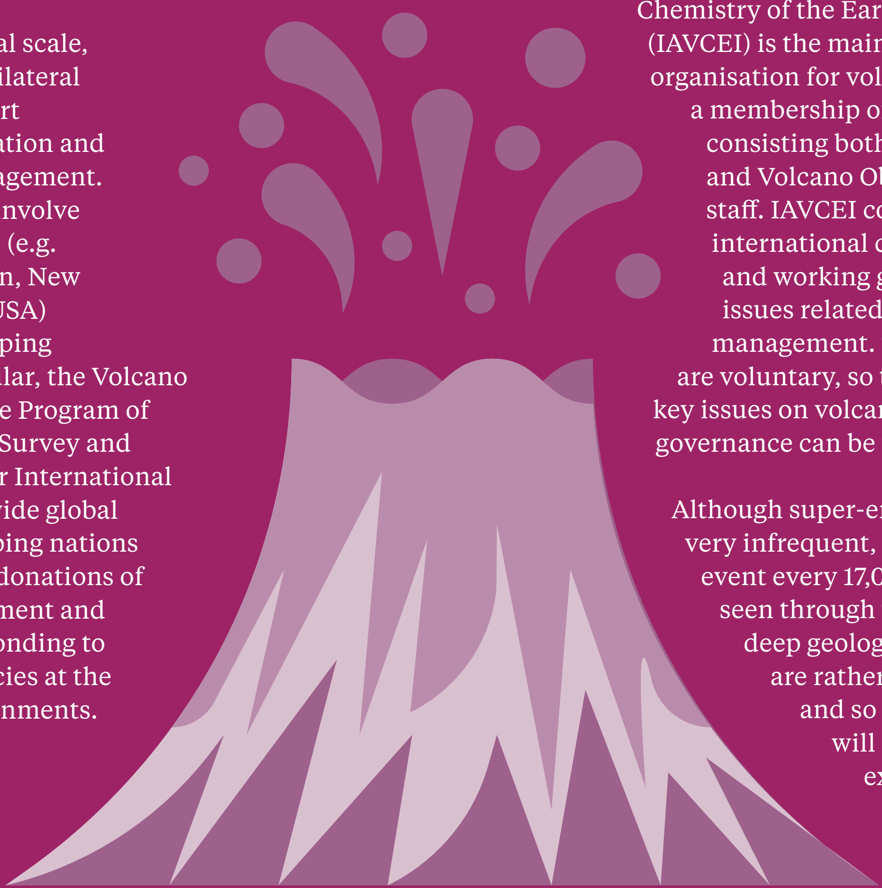
Resilience building, particularly the potential to rely on food sources less dependent on sunlight... could significantly reduce the death rate among humans

Governance of supervolcanic eruption

Stephen Sparks, Professor, School of Earth Sciences, University of Bristol

Monitoring volcanoes is largely a responsibility of national institutions that operate Volcano Observatories, and work with political authorities, civil protection agencies and communities to manage the risk. Over the past century, these institutions have been set up in many countries to monitor either a single volcano or multiple volcanoes: the World Organisation of Volcano Observatories lists 80 Volcano Observatories in 33 countries and regions, and plays a coordinating role among them. In countries with infrequent eruptions and no Volcano Observatory, national institutions responsible for natural hazards would be responsible for monitoring the risk.

On an international scale, bilateral and multilateral agreements support scientific investigation and volcanic risk management. These commonly involve developed nations (e.g. France, Italy, Japan, New Zealand, UK and USA) supporting developing nations. In particular, the Volcano Disaster Assistance Program of the US Geological Survey and the U.S. Agency for International Development provide global support to developing nations through training, donations of monitoring equipment and assistance in responding to volcanic emergencies at the invitation of governments.



In addition, an international network of nine Volcanic Ash Advisory Centres issues warnings of volcanic ash eruptions into the atmosphere to protect aviation, with world-wide coverage. Apart from those, there is no organisation or institution that has a mandate to manage volcanic risk on a global scale.

More informal global coordination is achieved through voluntary international and regional organisations, networks and projects that coordinate the sharing of scientific knowledge, technical expertise and best practice. The International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) is the main scientific organisation for volcanology with a membership of over 1000, consisting both of academics and Volcano Observatory staff. IAVCEI co-ordinates international commissions and working groups on many issues related to volcanic risk management. These activities are voluntary, so the coverage of key issues on volcanic risk and its governance can be uneven.

Although super-eruptions are very infrequent, (an estimated event every 17,000 years), seen through the lens of deep geological time they are rather common, and so humanity will eventually experience one.

Volcanoes with potential for future super-eruptions either have a past record of super-eruptions or have been long dormant. Known sites include volcanoes in the USA, Japan, New Zealand, Turkey and several South American countries, but identifying potential future sites of eruptions with no previous record is significantly more challenging.

The existing system provides an effective, though imperfect, structure to manage local volcanic risk. Depending on the magnitude of the event, the system is likely to come under pressure and prove inadequate in the event of a catastrophic eruption with global reach. No organisation has a specific mandate to address risk from super-eruptions. If one occurred in a populated location, we could anticipate an immediate major humanitarian crisis, with overwhelmed institutions and services, and long-term effects on the environment, climate, critical infrastructure, food security and global trade. Developing a global response plan under the auspices of a UN agency and IAVCEI would be a good start to improve governance of this global risk.

A recent synthesis of global volcanic risk and its governance can be found in endnote 17 for this section.

VOLCANIC ERUPTIONS

Volcanic eruptions are measured through a magnitude scale, a logarithmic scale, ranging from 0 to 9, where each unit increase indicates an eruption 10 times greater in erupted mass[12]. At the top of the scale, supervolcanic eruptions (M 8) release more than 400 km3 of magma. By comparison, the largest volcano eruption recorded in human history, the 1815 Tambora eruption in Indonesia, had a magnitude of about 7:41 km^3 of magma expelled[13], claiming over 70,000 lives[14]. When Mount Vesuvius erupted in 79 AD, devastating the Roman cities of Pompeii and Herculaneum, it released approximately 4 km^3 of magma, placing it at magnitude 6[15]. More recently, the May 1980 eruption of Mount St. Helens in Washington, USA, with just over 0.5km^3 released, was a magnitude 5.1[16].

VEI = Volcanic Explosivity Index

> **Although super-eruptions are very infrequent, seen through the lens of deep geological time they are rather common**

Reviewed by
ARIEL CONN

Artificial Intelligence

WHAT IS AT STAKE?

Human intelligence has led to the greatest triumphs of humanity, but it is also behind some of history's greatest catastrophes. So, what happens if we create artificial intelligence (AI) that's significantly smarter than any person? Will it help us reach even greater heights or will it trigger, as some experts worry, the greatest catastrophe of all: human extinction?

Today's artificial intelligence systems already outperform humans in the tasks they were trained for, especially when it comes to the speed with which they act. In just a matter of seconds, an AI system can play the winning move in Chess or Go, translate an article, or plot a route to a given destination while taking into account current traffic patterns.

Though a human requires more time to do any of these, a key aspect of human intelligence is that we can perform all of these tasks. We have what's known as general intelligence. While AI systems can only perform the tasks they were trained to do, a human can learn from context and experience and develop new skills or solve novel problems.

Many experts worry that if an AI system achieves human-level general intelligence, it will quickly surpass us, just as AI systems have done with their narrow tasks. At that point, we don't know what the AI will do.

WHY IS THIS A RISK?

First, it's important to note that experts are not worried that an AI will suddenly become psychopathic and begin randomly hurting or killing people. Instead, experts worry that an AI programme will either be intentionally misused to cause harm, or it will be far too competent at completing a task that turned out to be poorly defined.

Just looking at some of the problems caused by narrow AI programmes today can give us at least some sense of the problems an even more intelligent system could cause. We've already seen that recommendation algorithms on social media can be used to help spread fake news and upend democracy. Yet even as AI researchers race to find ways to prevent the spread of fake news, they worry the problem will soon worsen with the rise of Deepfakes – in which AI programmes modify what's seen or heard in a video without the viewer recognising it's been doctored.

At the same time, AI systems that were deployed with the best of intentions to identify images, parse through job applications, or minimise mindless tasks have instead inadvertently reinforced institutional racism, put jobs at risk, and exacerbated inequality.

It's not hard to imagine how much worse these problems could get with advanced AI systems functioning across many platforms or falling into the hands of terrorists or despots.

WHAT DO WE KNOW?

Though science fiction often portrays artificial intelligence systems as humanoid robots, the AI systems we interact with in our daily lives are typically algorithms running in the background of some programme we're using. They work so seamlessly that people outside of the AI world often don't even realise they've just interacted with artificial intelligence.

For now, these programmes can only perform those narrow tasks. But it is widely accepted that we will be able to create AI systems capable of performing most tasks, as well as a human, at some point. According to the median surveyed expert, there is a roughly 50 per cent chance of such AI by 2050 – with at least a five per cent chance of super-intelligent AI within two years after human-level AI, and a 50 per cent chance within thirty years[1]. The long-term social impact of human-level AI and beyond, however, is unclear, with extreme uncertainty surrounding experts' estimates.

No "off" switch

It's tempting to say that if an AGI system starts behaving badly, we'll just turn it off. But again, we need only look at some of today's problems to see this is unrealistic.

Consider the efforts to stop fake news. Fake news is often spread across social media by recommendation algorithms that are powered by artificial intelligence. Yet the platforms use these same algorithms to share accurate news and personal stories that users are likely to appreciate.

"Turning off" fake news without negatively impacting the spread of real information (or even legitimate advertising, as annoying as many of us might find it) is challenging. It's unlikely that social media platforms would choose to switch themselves off entirely to fix the problem, and it's likely that fake news would simply pop up on another platform anyway

As artificial intelligence becomes more advanced and ubiquitous, similar challenges will arise. Turning off an AGI in the future could become akin to turning off the Internet today.

Credit/source: Shutterstock

AI in the fight against COVID-19: lessons learned

If AI poses such a threat to humanity, why develop it? Most AI researchers go into the field precisely because the technology promises to do so much good. As COVID-19 swept across the world in spring of 2020, AI researchers immediately began developing algorithms, models, and programs to help medical professionals in variety of ways.

Thousands of papers were published on *COVID applications of AI*, covering prediction and tracking, contact tracing, monitoring outbreaks and individual cases, early diagnosis, assisting healthcare professionals, and more. Some AI applications were so helpful that the US Food and Drug Administration issued a handful of *Emergency Use Authorizations* to implement the programmes as quickly as possible. Meanwhile, in the UK, *the ISARIC4C study* is using big data to predict which patients have greater risk of becoming seriously ill.

However, most AI work failed to meet medical standards. For example, *one review* found that "almost all published prediction models are poorly reported, and at high risk of bias such that their reported predictive performance is probably optimistic." More recently, a study in *Nature Machine Learning* found that over 300 papers that tried applying AI to identify COVID-19 via chest x-rays were ultimately insufficient for clinical use.

The World Health Organization partnered with the medical publication, the BMJ, to identify *best practices and lessons learned from using AI* for research, diagnosis, and treatment of COVID-19. They found issues with discrimination, bias, and ethics, with two of the five review papers specifically addressing concerns that the AI applications exacerbated inequality.

In September of 2020, The BMJ, Nature Medicine, and The Lancet co-published AI-specific updates to their guidelines for clinical trial *reports and protocols* for intervention. New tools like this will help AI researchers improve their reporting and develop better, more reproducible studies and ensure that AI continues to advance medicine.

Photo by Dollar Gill on Unsplash

Most AI work failed to meet medical standards...the AI applications exacerbated inequality

WHAT ARE KEY FACTORS IMPACTING RISK LEVELS?

AI risk is still emerging today but could rapidly accelerate if sudden technological breakthroughs left inadequate time for social and political institutions to adjust risk management mechanisms. If AI development gets automated, in particular, new capabilities might evolve extremely quickly.

Risks can be exacerbated by geopolitical tensions leading to an AI weapons race, AI development races that cut corners on safety, or ineffective governance of powerful AI.

The level of AI risk will partly depend on the possibility of aligning the goals of advanced AI with human values – which will require more precise specification of human values and/or novel methods by which AIs can effectively learn and retain those values.

The current quest for Artificial General Intelligence (AGI) builds on the capacity for a system to automate predictive analysis – a process generally described as machine learning. One important element of machine learning is the use of neural networks: systems that involve a large number of processors operating in parallel and arranged in tiers.

The first tier receives a raw input; each successive tier receives the output from the tier preceding it. Neural networks adapt and modify themselves autonomously, according to initial training and input of data, in ways that are typically not transparent to the engineers developing them.

If researchers one day succeed in building a human-level AGI, it will probably include expert systems, natural language processing and machine vision as well as mimicking cognitive functions that we today associate with a human mind, e.g., learning, reasoning, problem solving, and self-correction. However, the underlying mechanisms may differ considerably from those happening in the human brain just as the workings of today's airplanes differ from those of birds[3].

Risks can be exacerbated by geopolitical tensions leading to an AI weapons race, AI development races that cut corners on safety, or ineffective governance of powerful AI

Governance of Artificial Intelligence

Ariel Conn, Founder and President, Magnitude 10 Consulting

In recent years, the risks of artificial intelligence have become much more tangible, with real-world threats appearing regularly in news articles. The most well-known problems surround Facebook, with the Cambridge Analytica scandal and the use of AI and fake news to interfere with elections. But countless AI issues and concerns have graced the covers of prominent news sites, leading the public and government officials alike to consider the development of AI with more scrutiny.

In the Fall of 2019, researchers published a *Global Landscape of AI Ethics*[6], in which they "identified 84 documents containing ethical principles or guidelines for AI," 88 per cent of which were released after 2016. These documents were written by some of the world's most prominent companies and organisations, including groups like *Google*, *SAP*, *the European Commission's High Level Expert Group on Artificial Intelligence,* the *OECD*, *IEEE's Ethically Aligned Design*, the *UK House of Lords*, the *US Department of Defense* (the latter adopted AI principles after the Landscape paper was published), and many more.

The Landscape paper found "eleven overarching ethical values and principles have emerged": "transparency, justice and fairness, non-maleficence, responsibility, privacy, beneficence, freedom and autonomy, trust, dignity, sustainability, and solidarity."

To address these issues, some non-governmental groups, like *AI Now*, have been tracking problems that are already cropping up with AI, including bias, racism, discrimination, violations of human rights, job loss and more. Meanwhile, other groups have focused on emphasising and supporting AI developed for good, including the *United Nations AI for Good Global Summit* and the nascent $1,000,000 *AAAI Squirrel AI Award for Artificial Intelligence for the Benefit of Humanity*.

However, in all cases, these efforts have been little more than advisory, offering guidelines and suggestions rather than concrete laws and regulations. This situation has proven woefully insufficient in recent months as companies like Google have garnered *negative public attention* for their struggles to address ethics and discrimination, even within their own organisation. Yet for now, companies and countries continue to be expected to develop AI for good with little real oversight or direction.

AUTONOMOUS WEAPONS

Autonomous weapons systems are generally considered to be weapons that could select and engage a target, without a person overseeing the decision-making process.

The idea of such weaponry has triggered intense ethical and legal debates around the world, as people try to determine the extent to which an algorithm can (or should) decide who lives, who dies, and how. Though fully autonomous weapons don't exist yet, weapons with increasingly autonomous and intelligent functions made headlines in 2020 and 2021, and many experts are concerned these systems will be used without sufficient ethical and legal guidelines and norms.

Recently, the International Committee of the Red Cross *recommended* "that States adopt new legally binding rules," providing three specific suggestions for aspects of autonomy that should be ruled out or regulated. Leadership at the Brookings Institution has also *suggested* that developing global treaties will be easier to do now, "before AI capabilities are *fully fielded* and embedded in military planning."

However, though member states of the United Nations Convention on Conventional Weapons have considered this question for nearly a decade, they have yet to find consensus on legal definitions or on regulations regarding the development and use of such weapons.

Autonomous weapons pose another threat too: if countries race to develop more powerful autonomous weapons, they could inadvertently find themselves in a race for advanced AI more generally. In such a situation, developers may cut corners or get sloppy in their efforts to be the first to create something new, and the resulting artificial intelligence systems are more likely to behave unpredictably or cause problems in some way.

Autonomous weapons pose another threat too: if countries race to develop more powerful autonomous weapons, they could inadvertently find themselves in a race for advanced AI...

Planning ahead to avert catastrophe - an examination of the next global risks

Global Challenges Foundation

Reviewed by
MARK PEARCE*

Reviewed by
FELIX RYDE*

Will we survive the nearby formation of a black hole?

The night sky may appear to be a tranquil place, but, in reality, cataclysmic events occur continuously throughout the Cosmos. Among the most extreme of these are gamma-ray bursts (GRB) – created when old stars collapse to form black holes[1]. The amount of energy released is prodigious. In no more than a few minutes, an amount of energy equivalent to that released by the Sun through-out its 10-billion-year lifetime is expelled in concentrated beams of high energy radiation called gamma-rays. What would happen to the Earth if it was hit by such a powerful beam of radiation?

Direct damage would be limited, as the Earth's protective atmosphere would greatly attenuate the GRB beam. A brief pulse of dangerous ultraviolet (UV) radiation would reach the Earth's surface, but its transient nature would prevent widespread damage. The GRB beam would, however, catastrophically damage the stratosphere, eventually resulting in surface-level devastation[2,3]. The primary destructive effect is caused by gamma-rays ionising and dissociating nitrogen and oxygen molecules in the stratosphere, creating ozone-destroying nitrogen compounds. The ensuing demise of the ozone layer would result in elevated levels of solar UV radiation reaching the ground during a number of years. UV radiation damages DNA, resulting in destruction of lifeforms, e.g., through developmental abnormalities and cancer. Surface marine life, such as the plankton crucial to the food chain and global oxygen production, would also be threatened. A secondary factor is that the smog-like nitrous oxide gas produced in the stratosphere would reduce the amount of visible sunlight reaching the Earth's surface.

Although the reduction is expected to be small (per cent-level), and only last for a few years, an extinction-level global cooling episode may result if the climate system is already at a tipping-point.

What is the chance of a GRB threatening life on Earth? All bursts observed thus far have occurred well outside of our galaxy. Consequently, the gamma-ray beam is weak and has little effect, if any, on the Earth's atmosphere. However, during the past 500 million years, it is likely that a bright GRB occurred as close as ten thousand light years from the Earth. It has been proposed that such a GRB triggered the Ordovician mass extinction, which occurred 440 million years ago, resulting in the second largest loss of biodiversity in history[4]. This is supported by the observation that deep sea life was less affected, presumably due to the UV absorbing properties of water. Moreover, the sudden ice age connected to the Ordovician period is a feasible consequence of the GRB-induced smog.

Understanding the risk posed by GRBs is made possible through curiosity-driven research, where a deeper understanding of the world is sought without a particular application in mind. Tantalisingly, this leads to an improved understanding of habitable zones in galaxies in general, informing searches for extra-terrestrial life[5]. Only 10% of all galaxies might be hospitable to life. The low-density regions on the outskirts of galaxies are favoured, since conditions are not conducive for a GRB to form. Reassuringly, the solar system is located in just such an environment[6].

*Mark Pearce photo credit: Jenny Jansson Pearce
*Felix Ryde photo credit: Jann Lipka

Reviewed by
BEN SNODIN

Risks and opportunities from mature nanotechnology

While the products of present-day nanotechnology research pose risks for society, these do not currently constitute global catastrophic risks. However, nanotechnology research may eventually allow us to arrange matter with atomic resolution, with tremendous specificity and flexibility, and at very low cost[1]. This technology, which for the purposes of this article I'll call "mature nanotechnology", could be a general-purpose technology comparable to the steam engine or electricity, with profound and wide-ranging implications. We should be hopeful that this technology would lead to great material wealth for the whole of society, but we must also consider the dangers that the technology could imply.

OPPORTUNITIES

Mature nanotechnology could imply new, highly effective medical interventions, for example through the use of nano- or micro-scale autonomous drones delivering targeted interventions within the body.

Technological solutions from mature nanotechnology might also allow us to reduce or eliminate some sources of global catastrophic risk. Cheap and atomically precise fabrication might enable the manufacture of extremely high-performance solar panels and carbon capture and storage devices, allowing us to tackle and perhaps ultimately solve climate change. It could also provide us with powerful tools for reducing bio risk,, such as ubiquitous bio surveillance for early detection of dangerous pathogens. On a grander scale, perhaps the availability of cheap, high-performance materials and abundant energy would eventually allow us to settle the stars, which could increase our resilience against civilisation-scale risks.

RISKS

Such a powerful technology could, however, also enable new sources of global catastrophic risk.

Mature nanotechnology could enable ultra-powerful surveillance, for example by enabling the ubiquitous presence of tiny autonomous drones continuously reporting on individuals' activities. In an extreme scenario, this capability could lock in an existing global totalitarian regime, constituting a severe global catastrophe.

The technology could also allow states to develop high-precision and possibly non-lethal weapons, further boosting state control. Perhaps even more worryingly, mature nanotechnology might make it easy for individual actors to manufacture highly destructive weapons; to get some feel for this scenario, picture a world where nuclear weapons or dangerous pathogens can be manufactured with everyday household materials[2].

> **Mature nanotechnology could enable ultra-powerful surveillance...**

Mature nanotechnology might also provide routes for accelerated development of artificial intelligence (and perhaps Artificial General Intelligence) and its associated risks by enabling cheap and highly advanced neurotechnology and computers, providing insights for artificial intelligence research and better hardware for existing computer algorithms.

POLICY

The transformative implications described above are very speculative; and it appears likely that they are at least decades away, if they ever materialise. However, it seems prudent to be prepared for unexpectedly rapid progress in nanotechnology R&D, just as we should be prepared for other low probability, very high impact events. To this end, international arms control institutions should ensure they have access to sufficient scientific expertise to keep them apprised of risks from emerging technologies, including those from advanced nanotechnology.

Technological solutions from mature nanotechnology might also allow us to reduce or eliminate some sources of global catastrophic risk

Photo by American Public Power Association on Unsplaw

Reviewed by
NICKLAS BERILD LUNDBLAD

Quantum computing

While great progress has been made in quantum computing research, we are at least 5 to 10 years away from any real world applications of quantum computing. We can, however, already now sketch out the risks that will be associated with such real world applications.

Technological risks can be divided into risks that have to do with access to these technologies, use of them and any unintended effects they may carry.

De Wolf (2017)[1] has suggested that quantum computing is likely to impact three different areas - cryptography, optimisation and simulation. If we look at these three we can construct a set of risks that need to be addressed as quantum computing improves.

First, access to quantum computation will allow an actor to break today's cryptographic systems and optimise far better. The simulation of quantum systems matter less in this category, but the two first present real risks. The reason for this may not be immediately obvious, but has to do with the possible technological asymmetry that arises if one actor has access to the technology and others don't. Today's quantum computing research is concentrated to the US, and to a few companies that also hold the majority of the patents.

There is a real chance that the US will achieve a sustainable technological advantage here.

Such an advantage could trigger a pre-emptive attack from other countries that fear that with this technological advantage, the US will also achieve military advantages that present an unacceptable threat to these other countries.

Asymmetric access to technologies that shift the power balance by an order of magnitude creates incentives for preventive moves.

If we look at the use of the technology, the most obvious risk is that our cryptographic systems are built around problems that are easy to construct but hard to solve, such as factoring problems. Quantum computing could, theoretically, make such problems easy to solve and the mere existence of such technologies would undermine trust in the security systems that have been deployed in the last several decades.

We should not overstate this risk, however, since the technology would not immediately make it easier to mass-decrypt communications - the challenge is rather that we would know which transactions we could trust and which transactions that could have been corrupted.

In optimisation the ability of some actors to optimise faster and better than others could drive inequality through network effects and scale advantages.

If a few companies manage to optimise far better than others, their ability to free up resources, learn and then use those improvements to create an accelerating improvement spiral would place them beyond competition.

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Navigating the complex intersections of diverse global catastrophic risks

Throughout the past century, leading nations have taken impressive steps to confront global catastrophic risks, creating multilateral governance institutions to mitigate the looming possibilities of nuclear war, climate change, global pandemics, and ecological collapse. Despite achieving significant progress to collaborate on these critical issues, the practice of multilateralism has been rigidly siloed for decades, with stakeholders addressing different existential risks in separate domains of collective action.

Today, global catastrophic risks overlap in critical ways, exacerbating their technical, economic, societal, and ethical implications at the global, regional, national, and individual levels. Such overlaps produce distinct converging risks that typically go unaddressed due to the lack of flexible mechanisms within existing institutions and the absence of a holistic approach to collective action in general. To add to this complexity, a set of rapidly advancing technologies are generating new types of global catastrophic risks and many more areas of overlap: synthetic biology, artificial intelligence, and autonomous systems. Unlike in the past, it is the private sector rather than governments that are the driving forces behind these military-relevant technologies. Existing multilateral governance institutions were not designed to adapt effectively to emerging risks within their own domain, let alone to address emerging and converging risks across multiple private and public domains. At the Converging Risks Lab, an institute of the Council on Strategic Risks, we aim to investigate these innumerable pathways and develop risk-reducing ideas.

To illustrate the intersections of global catastrophic risks in this paper, we examine the linkages between ecological disruption, climate change, global pandemics, and nuclear war.

Despite the cascading effects of ecological disruption, world leaders have paid far less attention to the rapid, novel, and human-caused transformations of multiple Earth systems over the past decades than to climate change or the risk of nuclear war. As a result of lacking mitigation efforts, our planet now teeters on the verge of ecological collapse. Ongoing damage to the Earth's biosphere threatens to usher in new patterns of disturbance and amplify chaos for people and societies worldwide, straining and sometimes overwhelming countries' response capacities[1]. As one of many examples, illegal logging not only serves to fund violent conflicts in many regions of the world, it eliminates the carbon-reducing potential of large swaths of forest land, causes further biodiversity loss, and contributes to population migration in response to lost natural resources. Whilst the effects of climate change can also exacerbate trends in ecological disruption, both result in heightened regional instability, leading to a rise in conflict over issues such as mass migration, limited water and natural resources, and diminishing food supplies.


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Among its many negative impacts, ecological disruption, especially when intensified by climate change, has the potential to produce global pandemics even more devastating than COVID-19. Over the past two decades, the number of emerging infectious diseases as a result of zoonotic crossover from animals to humans have been on the rise--SARS, H1N1 (Avian flu), MERS, Chikungunya, Zika, and now COVID-19. Although the coronavirus responsible for COVID-19 is highly transmissible and has led to millions of deaths around the world, it has a comparatively low mortality rate relative to other recent disease outbreaks. For example, MERS, also caused by a coronavirus, generated a case fatality rate of 34 per cent[2].

Ecological disruption can be directly linked to global pandemics in multiple ways. One such pathway centers on the conversion of wildlife ecosystems to farmland, increasing the exposure of regional populations to spillover of novel diseases carried by animals and insects. Disease outbreaks that spiral out of control and become a global pandemic have the potential to overwhelm public health capacity, undermine the economic and political stability of affected regions, and diminish public trust in governments for maintaining law and order. These dynamics lead to an increase in the risk of regional and international conflict.

Whilst climate change and ecological disruption set the stage for potential conflict, nuclear energy production, increasingly considered as a way of reducing fossil fuel consumption, may exacerbate the proliferation of nuclear weapons and thereby increase the risk of nuclear war. To mitigate the effects of climate change, more countries are turning to nuclear energy as an alternative source for producing electricity, and some are pursuing a comprehensive nuclear fuel cycle approach, which would leverage technologies that could also be used to develop nuclear weapons.

Today, global catastrophic risks overlap in critical ways, exacerbating their technical, economic, societal, and ethical implications at the global, regional, national, and individual levels

At the same time, nuclear armed nations entangled in geopolitical crises are themselves experiencing extreme climate change impacts--exacerbating national and regional tensions. As such, in some cases, climate change can combine with other issues such as political instability and lead to a greater risk of nuclear conflict over the long-term. Climate change and ecological disruption also raise the risk of nuclear war among existing nuclear weapons states. In regions with pre-existing fissures, there is always a chance that a conflict sparked in part by drought, dwindling food supplies, and cross-border migration could escalate to a nuclear confrontation, including by misinterpretations that these conditions worsen.

Although global catastrophic risks are addressed by multilateral governance, a systemic and dangerous gap exists in collective action for mitigating the complex intersections across these risks and for managing the impact of disruptive technologies largely coming out of the private sector. For this reason, world leaders urgently need to reimagine multilateralism through a converging risks lens and work to prevent global catastrophic risks as part of an interconnected system rather than in separate silos of governance undertaken by nation-states. Given that setting up new governance institutions requires much time and political will, there are three interim steps that world leaders could take today.

…it is critical that our global governance mechanisms and organisations incorporate the increasingly intersectional nature of global catastrophic risks

First, world leaders should create a global forum for a broad range of stakeholders to discuss the complex intersections of global catastrophic risks and feed the outcomes of such discussions into relevant multilateral governance institutions for climate change, infectious disease, nuclear weapons, and biological weapons. To save on time and effort, they could initially turn to an existing platform for resolving international conflicts across public and private stakeholders such as the World Economic Forum (WEF). In collaboration with the private sector, world leaders could convene such a discussion at the next annual meeting and explore how to institutionalise the goal of collaborating to prevent global catastrophic risks.

Second, to frame the above discussion on global catastrophic risks, organisers should consider developing scenarios and exercises to familiarise diverse organisations and world leaders with complex convergences. In many cases, governments and response teams are ill-equipped to manage emergencies involving intersections across several different risks because they lack sufficient understanding and awareness. By identifying blindspots and flashpoints as well as incorporating predictive technical analysis, participating nations would be able to establish safety nets ahead of time. These experiences would bolster crisis prevention and response capabilities in regions where there is increased probability of converging risks. There is established precedent for conducting exercises at a high level.

For example, at the 2014 Nuclear Security Summit in the Hague, Netherlands, world leaders participated in a table-top exercise in which they responded to the threat of a radiological device.

Third, within the different multilateral governance institutions, world leaders should expand multilateral efforts that address the complex intersections of global catastrophic risks. For example, to mitigate converging risks related to nuclear weapons and climate change, countries should consider actions such as: doubling the IAEA budget; expanding nuclear safety and security cooperation; capping and eliminating tactical and low yield nuclear weapons; and integrating extreme climate forecasting into nuclear energy plans. CSR has published multiple briefers highlighting the ways in which countries such as Egypt,Turkey, India, the Philippines, and the U.S. can harness policy action to minimise these threats.

To confront the links between climate change, ecological collapse, and global pandemics, countries should consider: ratifying the UN Convention on Biological Diversity and the Law of the Sea; integrating ecological disruption into climate change mitigation mechanisms; addressing the ecological-biological nexus by enhancing monitoring, understanding of pathogen space and pathogen early warning; and elevating wildlife tracking as a national security threat.

Addressing complex, converging risks at the global level is by no means an easy task.

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Endnotes

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3. See more at https://councilonstrategicrisks.org/the-climate-nuclear-security-project-cnsp/ for country specific briefers

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