Global
Challenges
Foundation

Global Challenges Quarterly Report

Global governance

in the age of disruptive technology

GLOBAL CHALLENGES QUARTERLY REPORT
GLOBAL GOVERNANCE IN THE AGE OF DISRUPTIVE TECHNOLOGY

Quarterly report team

Project leader: Carin Ism
Editor in chief: Julien Leyre
Project coordinator: Ben Rhee
Research: Waldemar Ingdahl
Art director: Elinor Hägg
Graphic design: Erik Johansson

Contributors

Marcella Atzori
Academic researcher, University College London; Blockchain Expert in the European Commission for industrial applications.

Liu Cixin
Science fiction writer, author of *The Three Body Problem*.

Jennifer Doudna
Professor, Departments of Chemistry & Molecular and Cell Biology, University of California, Berkeley.

William Hamilton
Founder, Mimerse.

Robin Hanson
Associate Professor, Department of Economics, George Mason University; Research Associate, Future of Humanity Institute, Oxford University.

Alex Leon
Junior Consultant, Open Data Institute.

Tasha McCauley
Board Member, GeoSim Systems.

Jay Naidoo
Board member, Mo Ibrahim Foundation.

David Orban
Advisor & Faculty, Singularity University; Founder and Managing Partner, Network Society Research.

Anna Scott
Head of Content, Open Data Institute.

Siim Sikkut
Chief Information Officer, Republic of Estonia.

Samuel Sternberg
Assistant Professor, Department of Biochemistry and Molecular Biophysics, Columbia University.

Pablo Suarez
Associate Director for Research and Innovation, Red Cross Red Crescent Climate Centre.

Chacko Thomas
Researcher, Climate and Environmental Governance Network (CEGNET), Australian National University.

Roey Tzezana
Researcher, Blavatnik Interdisciplinary Cyber Research Centre (ICRC), Tel Aviv University.

Peter Wells
Head of Policy, Open Data Institute.

Kok Yam Tan
Deputy Secretary (Smart Nation and Digital Government), Singapore Prime Minister's Office.

THE GLOBAL CHALLENGES FOUNDATION works to incite deeper understanding of the global risks that threaten humanity and catalyse ideas to tackle them. Rooted in a scientific analysis of risk, the Foundation brings together the brightest minds from academia, politics, business and civil society to forge transformative approaches to secure a better future for all.

The views expressed in this report are those of the authors. Their statements are not necessarily endorsed by the affiliated organisations or the Global Challenges Foundation.

Contents

MATS ANDERSSON

Vice-chairman, Global Challenges Foundation, Former CEO, Fourth Swedish National Pension Fund, co-founder Portfolio Decarbonization Coalition.

Preface

The Global Challenges Foundation, since its inception, has worked with leading researchers to compile and share knowledge of risks on a magnitude such that they threaten the existence of more than a billion people. Our mission, however, combines awareness-raising with an effort to identify which model for global governance can better mitigate or – in the best case – eliminate these threats.

In November 2016, the Global Challenges Foundation cast a wide net to find the best ideas for an update to the current global governance system by launching the five million dollar New Shape Prize. In total, we received 2,702 models for improved global cooperation around these issues, coming from 122 countries. The evaluation and assessment of proposals is currently underway, involving more than a hundred leading experts.

Our competition guidelines called for models that could be implemented within the foreseeable future. As such, it is necessary to be on the lookout for technological disruptions that can and will change both the shape of human society and the landscape of global governance and cooperation as we know it. The present report brings together visionaries from around the world to share their perspective on the possibilities and risks associated with those technologies, and their potential impact on global governance.

The development and governance of new technologies currently lie primarily within the tech industry itself. Many of our authors, therefore, come from an industry background. Their perspectives complement those of expert advisors and public servants involved in cutting-edge initiatives harnessing new technologies for better governance, as well as key figures from civil society. For the first time, we are also including a perspective from the arts, featuring a piece from one of China's most respected science fiction authors.

Technology's crucial role in driving forward the creation of the UN is undeniable. It was the development of a new technology – the nuclear bomb – that, in many accounts, brought "the good news of damnation": the insight that humanity had developed the capacity to self-destruct catalysed a collective understanding that global cooperation was necessary in order to achieve existential security.

From railways to aviation and from the first cable laid across the Atlantic to the connected networks of the

Internet, technological innovation has made our world considerably smaller. Recent developments in transport and communication have created pathways for empathizing and communicating across borders to a degree which would have seemed utopian seven decades ago, when the UN itself was designed. Technology has brought nations together: research on nuclear fusion has gathered scientists from around the world to develop an energy source which could come to benefit all. Today, renewed incentives to collaborate are likely to stem from what is, perhaps, the most promising technology that our world has ever seen: artificial intelligence, which offers significant hope for unprecedented prosperity, but also poses one of the greatest threats to humanity.

Existing institutions have proven insufficient to tackle the pressing dangers that humanity faces. The most telling example may be the more than twenty years that have passed since the global community announced that climate change was a threat to civilization. In theory, we have been able to combat this threat during all this time – but carbon emissions today are higher than ever.

Stating that the world has changed radically through technological advancements in the last 70 years sounds like a cliché – and yet, our global institutions have changed very little in that time, though many new tools are at our disposal. As we anticipate the outcome from the New Shape Prize, we chose to develop a report where we would examine how those new tools might affect our global institutions – and consider which ones hold the most promise to make our governance systems more effective, preemptive and just.

The compilation of texts presented here is naturally far from exhaustive. We do, however, hope to see more frequent cross-pollination between governance and technology, to better identify both directions for improvements and new challenges to prepare for. The conversation started in this report will come live at the New York Times Climate Tech conference in Silicon Valley and at a broadcasted session in Davos, which will be shared on our website in January. Lastly, we hope that some of the ideas planted here will stimulate new conversation at the New Shape Forum in May 2018.

Mats Andersson
Vice-chairman, Global Challenges Foundation, Former CEO, Fourth Swedish National Pension Fund, co-founder Portfolio Decarbonization Coalition

Executive summary

Julien Leyre, Global Challenges Foundation.

Disruptive technologies can affect societies in unexpected manners. The thirteen pieces in this report explore the intersection of innovation and global governance. They describe some of the new challenges to global collaboration presented by recent technological developments, and offer a set of visionary perspectives on the ways that emerging technologies could provide a new basis for our global institutions.

As a first step towards better understanding how technological development may hinder or improve global governance, this report opens with a survey of experts from around the world, conducted by Roey Tzezana, researcher at the Blavatnik Interdisciplinary Cyber Research Centre (ICRC) in Tel Aviv University. The results of this survey show a high level of optimism. Among eleven disruptive technologies presented in total to the experts, only two were identified as more likely to hinder global governance: autonomous robots and genetic modification. On the positive side, clean and abundant energy was seen as the most likely to improve global governance, followed by big data, digital governance systems, and biometric identification.

Science fiction has been an important vehicle for anticipating technological developments, including some of the most disruptive – therefore, we turned to this field to consider the ways that technology may impact on global governance. The second piece in this report offers an interview with Liu Cixin, China's most respected science fiction writer, author of the world-acclaimed best-seller *The Three Body Problem*, where the United Nations feature prominently. With information technology making the world smaller, global cooperation is becoming increasingly important – particularly as the development path of rising nations may conflict with the values of the dominant West. Virtual reality, AI and 3D printing will all play a role in the future of global cooperation – but in the eyes of Liu Cixin, the technology most likely to unify the planet will be spatial exploration.

Genetic modification is the object of the third piece in our report, *Preparing for the global ramifications of gene-editing technology*, authored

by Samuel Sternberg from Columbia University and Jennifer Doudna, Professor at the University of California Berkeley, and one of the leading figures behind what has been called 'the CRISPR Revolution'. When a technology is so radical that it might alter the very building blocks of life, it also forces us to think about our common human condition on a new basis. CRISPR now places the power to easily rewrite the genetic code of living organisms – including humans – into the hands of scientists worldwide. What type of oversight is required for this technology to deliver on its immense potential to improve the human condition? Scientific, regulatory and governmental agencies are starting to get involved at the national level. However, as this piece articulates, discussions and guidelines must extend beyond national boundaries, to support transnational policy diffusion and strengthen cooperation on a global scale.

Among the various innovations emerging at the intersection of governance and technological development, one may revolutionize the very core of the governance process: artificial intelligence based on machine learning used to support decision making processes. This is the topic of *Machine learning for better governance* by Kok Yam Tan, Deputy Secretary in the Smart Nation and Digital Government Office in the Singapore Prime Minister's Office. Artificial intelligence could overcome the biases and limitations of the human mind, and offer a radical new way to address highly complex problems such as climate change. Cities offer a good testing ground for this technology, and Singapore has made some early inroads. However, to harness the full possibilities of machine learning, insists the author, we must invest in the know-how to deal confidently with questions of ethics and risk management, and how to align artificial intelligence with societal values.

Over the last 20 years, Estonia transformed into one of the most digital countries in the world. What could our global governance institutions learn from this experience? This is what Siim Sikkut, Chief Information Officer for the Republic of Estonia, proposes to address in *Digital Lessons from e-Estonia and applications to the global level*. The three pillars of 'e-Estonia' have been the development of a strong digital identity, interoperability systems, and a decisive embrace of change. These could offer promising pathways for more effective global governance systems.

Trust is a crucial piece of the global governance puzzle. A new technology which is currently the object of many discussions, the blockchain, may offer new ways of negotiating trust on a global scale. A large proportion of

international aid money is currently lost to corruption or inefficient intermediaries. The blockchain could offer a solution to this challenge. This is the vision put forward in *Promoting sustainable development at the global level through the blockchain technology* by Marcella Atzori, researcher at University College London and Blockchain advisor with the European Commission. By design, the blockchain supports transparent and auditable transactions, and provides a way to automate the execution of agreements based on mutual satisfaction. If institutions were willing to embrace this technology, the blockchain could therefore radically transform funding models for international organizations – and herald a new paradigm for global resource transfer.

The following piece, *Blockchain technology and decentralized governance*, by David Orban, Advisor and Faculty at the Singularity University, explores another set of possibilities offered by blockchain technology. In a context of exponential change, old centralized models of governance may be outdated. Opportunity may come from a new trend towards decentralization, which allows organizations facing global challenges to trial a range of novel solutions adapted to local contexts. In this perspective, suggests David Orban, the United Nations could operate as a platform, offering a neutral interface to facilitate interactions among a broad range of stakeholders. To bring this vision to life, the author argues that the best vehicle would be an independent UN Labs that harnesses the potential of blockchain technology to support better global data flows and catalize the development of decentralized solutions to global challenges.

One of the recurring keywords in all discussions about new technologies is 'data'. Today, we can gather and aggregate data more easily than ever before, but how can we best harness the potential of this data to improve the lives of people and address the world's most pressing challenges? This is the question addressed in *Global challenges call for better data infrastructure* by three contributors from the Open Data Institute, Peter Wells, Anna Scott and Alex Leon. Building appropriate systems will require efforts on four fronts: strengthening data infrastructure, but also making more data open, promoting data skills and fostering innovation. Global governance institutions, argue the authors, have a crucial role to play in supporting better access to and use of data, and addressing new challenges around ethics, engagement and equity.

The potential offered by data depends in large part on our capacity to effectively gather and aggregate it on a large scale. The Internet of

Things is an emerging network where integrated sensors, communicating through the Internet, generate diverse, granular and real-time data. This technology could revolutionize the way that we monitor the economy and our environment, and respond to risks and challenges, as Australian National University researcher Chacko Thomas explains in *The Internet of Things – coordinating data for better environmental management and reporting*. What steps do we need to take so that the Internet of Things can effectively support evidence-based and data-driven decision making to benefit humanity? Four areas require particular attention. We must build understanding of this new paradigm, including its limitations; we must shift our discourse from 'Big' to 'Smart' data; we must embrace open data; and we must unify data standards around the world.

New technologies allow us to gather more data than ever before. However, what use is all this data if decision makers cannot access its meaning? This is the provocation offered by Tasha McCauley – Board Member at GeoSim, a start-up exploring revolutionary ways of visualising cities in 3D – in *Making big data intuitive – the challenge of representation*. The information revolution is not just about aggregating more information, but also creating better ways of visualizing it. Recent advances make it possible to create virtual models of entire cities and run accurate simulations of future scenarios, giving experts and non-experts a visceral experience of potential catastrophes such as major floods. This could create a powerful drive towards action and support better decision making on the most pressing global challenges – but only if institutional practice starts embracing the possibilities offered by these new modes of data visualization.

Developments in data visualization are closely connected to the coming of age of a new form of experience described in *Governance in the age of Virtual Reality – from data to experience*, by William Hamilton, formerly with Stockholm University and Founder of Mimerse, a start-up building virtual reality experiences to better manage and treat mental health. Virtual reality is an immersive technology that produces the illusion of real presence in a virtual environment – allowing users, rather than receive information, to take part in a mediated experience. What should decision makers know about an innovation that, with large investments from major industry players, will become commonplace in the coming decades? The technology is about to radically change the way we conduct meetings and conceive of interpersonal relationships. Soon, articulates the author, fully virtual

summits will be commonplace, and the perspectives gained from immersive VR experiences could be harnessed to make decision making processes at major governance events more conscientious and collaborative.

When we think of new technology, we primarily think about hardware and lines of code. But these developments, in turn, open and encourage new ways of seeing the world, new ways of interacting, and new practices which, in themselves, can be revolutionary. Pablo Suarez, associate director for Research and Innovation at the Red Cross Red Crescent Climate Centre, describes the potential of such new practices in *Rethinking the future of governance through games*. At major governance events, current modes of interaction are far from optimal. As long as series of unidirectional statements followed by insufficient Q&A prevail, can we expect any genuine change? Serious gameplay, uniquely conducive to systems thinking, could provide a precious alternative. Games have already been harnessed in a range of development projects, and resulted in major breakthroughs. Games, argues the author, have the power to reveal systemic shortcomings in current frameworks. If they were to be more systematically deployed, they could deepen the role of citizens in day-to-day governance mechanisms, and even improve the workings of major UN bodies. They could trigger new ways of approaching unfamiliar problems, and harness the power of creative thinking to develop new solutions for the world's greatest challenges.

Change in practice and social innovation is also the topic of the following piece: in *Decision markets for global governance*, Robin Hanson, from the Future of Humanity Institute, puts forward an innovative proposal for improving global governance systems. At present, it is hard for ordinary world citizens to judge the quality of global governance choices. It would be feasible, however, to create open 'decision markets' where traders could speculate on the outcomes of particular global policy choices. On the basis of information developed through those markets, rather than simply trust their representatives to negotiate the right outcomes in relatively opaque governance forums, global citizens could pressure governments to support the choices that they believe will most benefit them.

Digital information technology has reshaped our lives, the way we communicate, and our production systems. However, it has not yet fulfilled its promise of peace, justice and human dignity. This is the premise for the final piece, *Finding our shared humanity in the digital age* by Jay Naidoo, Board Member at the Mo Ibrahim Foundation, which focuses on the critical importance

of governance and leadership in Africa. In a world where we see so much progress, why are we still witnessing the repression of citizens, rising inequality and the destruction of natural ecosystems? The model of infinite growth adopted around the world is unsustainable and has generated the greatest inequality. We must rethink technology, not as an end in itself, but as a tool that assists in redefining the economy. For this, we need a revolution of values, where new technology becomes the bedrock for a solidarity economy, and results in the development of new public commons.

The report finishes with a glossary that presents a short introduction to the main technologies mentioned through the text.

ROEY TZEZANA

Roey Tzezana is a futurist and researcher at Blavatnik Interdisciplinary Cyber Research Centre (ICRC), Tel Aviv University. He is also affiliated with the Humanity Centered Robotics Initiative (HCRI) at Brown University, and is a senior scientific advisor for the World Future Society (WFS). The research has been conducted in collaboration with the World Future Society.

1. How will disruptive technologies impact global governance? An expert survey

Roey Tzezana, Researcher at Blavatnik Interdisciplinary Cyber Research Centre (ICRC), Tel Aviv University.

Disruptive technologies can affect societies in unexpected manners. As a first step towards better understanding how technological development may hinder or improve global governance, we conducted a survey with experts around the world. The results shows a high level of optimism. Among eleven disruptive technologies, only two were identified as more likely to have a negative impact: genetic modifications and autonomous robots. On the positive side, clean and abundant energy was seen as the most likely to have a positive effect, followed by big data, digital governance systems, and biometric identification.

Disruptive technologies have a way of impacting the societal order in unexpected manners. Internet-based social media, for example, has already shown its merit in bringing about the Arab Spring on the one hand, and disseminating *fake news* on the other. The immediate impact of disruptive technologies is often unclear – but futures studies methodologies can be utilized to develop scenarios about the way in which future technologies will impact global governance.

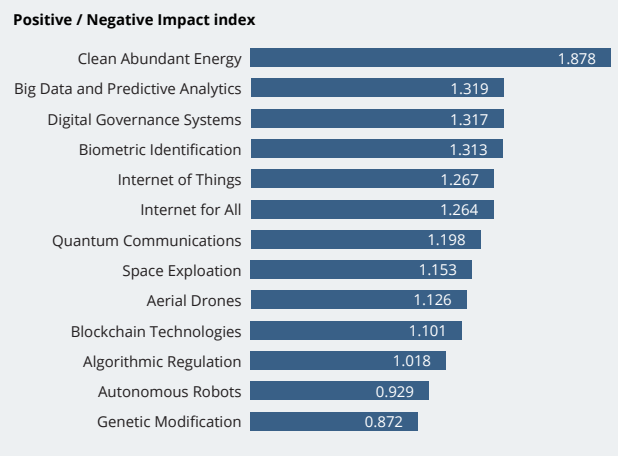
As a first step towards understanding the potential impact of new technologies on global governance, we conducted a survey with futurists in different organizations, including the World Future Society, the Millennium Project, TechCast, Wikistrat and others. We created a preliminary list of disruptive and emerging technologies, presented them with a brief explanation, and asked about their potential to either "improve global governance" or "hinder global governance", with a scale of 1 to 7 (and an "I don't know" option). Participants were also asked to comment on the potential impact of the technology.

Altogether, 285 respondents provided answers to the survey questions: 76% of those hold a graduate degree of some sort, and 49% are American citizens, while the rest come from over fifteen other nations around the world. In total, we collected at least 185 answers for every question, and 80 – 140 detailed comments about the potential uses of each technology.

For each technology, we examined responses as to the potential for improving or hindering global governance, then calculated a Positive/Negative Impact (PNI) index as follows

$$\mathbf{PNI}_{\text{technology}} = \frac{\text{Potential for positive impact}}{\text{Potential for negative impact}}$$

A technology that has a large PNI index is one for which the potential for positive impact outweighs the potential for a negative one. A technology with a low PNI index is one in which there is more potential for a negative impact. This PNI index can help us identify which technologies we should invest in to promote global governance, and which technologies garner more futures thinking and preparation before we make use of them.



The PNI index reflects the overall optimism or pessimism that people feel towards specific technologies. When the PNI index is larger than 1, people are generally optimistic – they think that the technology has greater potential to improve global governance than to hinder it. As such, it is remarkable how optimistic respondents to this survey have been about most technologies.

Biometric identification, aerial drones and algorithmic regulation are often connected to dystopian visions of the future – yet here, experts are generally optimistic about those technologies. Even autonomous robots, which are the stuff of futuristic horror movies, have been recognized as nearly neutral (i.e. their PNI is only just under 1) in the eyes of the experts surveyed.

The precise reason for this optimism is unclear but certainly encouraging. That said, the experts are still cautious about many technologies – sometimes unexpectedly so. "Internet for all", for example, was seen throughout the last two decades as one of the main goals of developed and developing nations. And yet, it receives a PNI index of only 1.264: while the respondents understand its major impact on global governance, they are fearful of its negative uses – as these have been demonstrated lately with the onset of 'fake news' and the rise of a 'winner takes all' phenomenon in the digital world.

In order to better understand the precise arguments for and against the technologies in this report, we conducted a more extensive analysis of the answers provided for the three technologies with the largest PNI index. We also analyzed the two technologies that received a PNI index smaller than 1. These answers can help us understand the hopes, fears, opportunities and risks associated with each technology, while also providing us with expert advice regarding the challenges for making the most out of the technology.

Positive tech #1: clean and abundant energy

With the growing need to move towards an economy less reliant on carbon, new clean forms of energy creation – particularly renewable energy, usually solar- or wind-based – have become a booming market. This, in turn, is expected by many to reduce the reliance of many nations on fossil-based fuels and on centralized power plants, and shift global power relations, particularly in regions that have been heavily reliant on fossil fuels for their development. More generally, some have seen this shift as heralding a new era of energy abundance.

It is remarkable to note how optimistic the experts are about this technology. It has received both the second-largest "positive impact"

Disruptive technologies have a way of impacting the societal order in unexpected manners. The immediate impact of disruptive technologies is often unclear – but futures studies methodologies can be utilized to develop scenarios about the way in which future technologies will impact global governance.

ranking, and the lowest "negative impact" ranking. This may be in part because of the positive description of the technology as "clean" and "abundant".

Participants believed that the main beneficial result of this development would be a betterment of people's lives all over the world. It will lead to a cleaner environment and better health, to better food security due to the capability to utilize energy for growing crops, and to more innovation worldwide – leading to higher productivity. Altogether, these developments should lead to a future of higher prosperity and better subjective well-being (also known as happiness) – and content people tend to fight less. Moreover, abundant energy should reduce the frequency of resource wars, and will shift power away from the select nations that currently control fossil energy sources.

However, this development is not without some risk. The process of moving over to renewable energies will cause a dramatic shift in international power structures, and may lead to much conflict and strife along the way, as nations that base their economies on fossil fuel production suffer greatly. In addition, without the reliance on fossil fuels, some measure of interdependence between nations will be lost, which may make it more difficult to form binding international agreements. Finally, there is currently a move towards global governance agreements regarding climate control, and by 'taking that sword off our neck' we may find that reaching such agreements becomes more difficult.

The experts have expressed some concerns about future developments in this field. They've warned that the new technologies for harvesting energy may fall into the hands of only a select group of nation and that a new "politics of sun" may crop up. They were also worried that governments will turn their attention to other scarce resources, like rare earth metals (which are needed for some renewable energy production systems), or even digital resources like data and AI.

Positive tech #2: big data and predictive analytics

Big data and predictive analytics systems can be used to collect massive amounts of data and determine the likelihood of certain future events (e.g. natural disasters, wars, etc), and thus enable better preparation for them. The capabilities of this technology stand to be amplified by AI-based systems that could directly support decision making.

A technology of this kind could help improve overall efficiency of global agreements by monitoring and tracking food, energy and water usage, and regulating it on a global level. The same would apply

for tracking immigration. The technology would also help nations better prepare for future adverse effects like terrorist attacks, thus limiting damage and preventing escalation of conflicts between nations and non-state actors.

The risks and challenges of using big data and predictive analytics, however, are substantial. Nations will fight over data collection ("data will be the new oil"), and nations with more data and better AI systems will be better positioned to reap the most benefits – while quickly leaving others in the dust. Governments and economic entities could centralize the collection and analysis of regional and global data, and abuse this information to disempower individuals and groups, fermenting anger and dissent.

Finally, an unexpected negative side effect of big data and predictive analytics could be that it will increase the speed of decision making inside nations, while global agreements and decision making will keep evolving at a snails' pace.

While experts see great potential for big data and predictive analytics, they caution us to remember that insights gained from this technology are only as good as the data they rely on. Furthermore, data collection and interpretation could easily be biased to reflect cultural preferences. Therefore, data will need to be collected from many different sources, and interpreted with caution.

Positive tech #3: Digital governance systems

Digital governance systems allow citizens to influence their government or directly participate in decision making through the internet, by taking part in committees, conducting public discussions and voting online.

The experts believe that digital governance systems will increase the public's involvement in the collective global governance systems, by making it easier for people to vote, and making sure there's no fraud in elections and decision making processes. Furthermore, such systems could promote worldwide partnerships at the grassroots level, leading to better acceptance of global governance.

On the other hand, a digital global democracy that is not inclusive could damage global governance. In addition, the experts expressed doubt about the potential of these systems to achieve mass-engagement, as oftentimes the subjects discussed are remote from the daily lives of most people. There is real worry that digital systems for public discourse will be dominated by the most vocal and radical participants, leaving moderate voices unheard. This fear ties closely with the rise of the Internet as a 'fake news' engine, leading to people making unwise decisions under the influence of 'junk information'.

Finally, hacking is a very real issue that will need to be addressed in order to maintain trust in digital governance systems.

Negative tech #1: autonomous robots

Research & development efforts are currently under way to create autonomous robots – robots that can act without human control – to be used in warfare and for keeping order.

While the experts understand that robots could improve monitoring and remote strike capabilities with minimal loss of human life, and thus make it more difficult for conflicts to escalate, there is a concern that they could also normalize war and conflict as a 'lower risk activity'. This could even lead to robots fighting robots, with no humans involved on the battlefield, and result in an AI arms race while reducing trust between nations. This development would obviously be disastrous for global governance.

Some see robots as "fair witnesses" and "fair judges" with no human biases, but others express concern that robots would have the same biases as the humans who programmed them.

As the cost of developing, deploying and operating robots goes down, they will almost certainly be used by non-state actors as tools to wreak havoc and conduct terrorist attacks. Even the most sophisticated robots could still be vulnerable to hacking and potentially be reprogrammed by non-state actors. In the words of one of the experts, *"Autonomous military robots will be a force multiplier for anyone who possesses them – and in ten years, fifteen at the outside, that will mean just about anyone. By reducing human deaths, they will make war more palatable, giving large, technologically sophisticated, and aggressive powers much greater freedom of action against the relatively defenseless."*

Negative tech #2: genetic modification

Genetic modification could allow nations to engineer the next generation according to certain paradigms and perceived needs. Human babies may be engineered, for example, to have enhanced intelligence, or to withstand harsh environments such as those found on high mountains.

The experts are worried that genetic modification will draw a 'new line in the sand' between two kinds of ideologies: those that emphasize human change and adaptation, and those that wish to stay and halt the change. Due to the potential power of genetic engineering in enhancing human intelligence (a power which has not been demonstrated yet), it is conceivable that the next 'arms race' could be focused on this technology. As some countries leap forward ahead of others in this field due to lax ethics and regulations, they will gain greater economic and military power over other, more conservative, nations.

On the other hand, in the far future, genetic engineering could easily be used to increase resistance and immunity to certain diseases, as well as age-related illnesses and potentially even aging itself.

Obviously, the nations that choose to make use of this technology would again receive a great power over other nations that choose not to use genetic engineering – or those that don't even have the choice.

Addendum: blockchain technologies

Blockchain technologies are currently the subject of many discussions, with particular interest in their impact for the future of nations and governance. For this reason, we chose to include the experts' ideas and opinions on this topic. Blockchain technologies enable complete decentralization of data storage and computation, and are the basis for Bitcoin, the first decentralized currency outside any government control. Blockchain technologies could enable the decentralization of monetary systems, dispute resolution (i.e. justice) systems, document storage systems and many other services.

These technologies can help move funds around the world more quickly, speed efforts to share resources across borders, and decrease the power of large corporations. They could, however, prove to be a major force to challenge the control of nations over these services, and even aid the formation and existence of black markets and money laundering schemes, as well as monetary manipulation. While experts were generally enthusiastic about the potential of the technology to provide greater transparency and hinder governments' ability to conduct misdeeds, they also recognized that blockchain technologies could diminish the overall coordination and governance capabilities of traditional governments by pushing the power to the edges of society. As one of the experts wrote: *"Blockchain could be the first step in the death of the nation state and the democratization of power to the community and citizen level."*

LIU CIXIN

Liu Cixin is China's foremost science fiction writer. His most famous work, *The Three Body Problem*, first serialized on the Chinese Internet in 2006, was translated and published in English in November 2014, and won the 2015 Hugo Award for Best Novel. It has been described by some critics as 'the Chinese Star Wars', and a film adaptation is currently in preparation.

2. Imagining the future of global governance

Liu Cixin, science fiction writer, author of *The Three Body Problem*.

Science fiction has been an important vehicle for anticipating technological developments. When imagining the future of global governance in his world-acclaimed best-seller *The Three Body Problem*, what did Liu Cixin, China's most prominent sci-fi writer, take into consideration? With information technology making the world smaller, global cooperation is becoming increasingly important – particularly as the development path of rising nations may conflict with the values of the dominant west. Virtual reality, AI and 3D printing will all play a role in the future of global cooperation, but spatial exploration may be the technology most likely to unify the planet.

Liu Cixin is a Chinese science fiction writer, nine-time winner of the Galaxy Award, China's most prestigious literary science fiction award. His most famous work, *The Three Body Problem*, was first serialized on the Chinese Internet in 2006, then published in 2008. The book was translated and published in English in November 2014, and won the 2015 Hugo Award for Best Novel.

The Three Body Problem has been described by some critics as 'the Chinese Star Wars'. President Obama counts among the enthusiastic readers of the book, whose immense scope, he said, put day-to-day political challenges in perspective[1], and Liu Cixin has been invited by the Chinese government aerospace agency to consult on science missions. A film adaptation of *The Three Body Problem* is currently in preparation, and is expected to be the first major science fiction production coming out of China.

Science fiction has been an important vehicle for anticipating future technological developments, and the UN features prominently in *The Three Body Problem*. On this basis, we invited Liu Cixin to further describe what he envisaged as the future of global governance.

Global Challenges Foundation:
How did you envision global cooperation in the future? What did you need to take into account when you were thinking about describing the UN in the far future?

Liu Cixin:
I think global cooperation is a major future trend. With the development of Internet information technology, the world is increasingly getting smaller. The information network is uniting the world as a single entity. At the same time, mankind is also facing common challenges and opportunities. Environmental issues and the establishment of sustainable economic systems are turning mankind into a community of shared interests. Countries, groups and individuals are increasingly aware that we can only have a bright future if we consider issues from the perspective of all mankind.

The United Nations is an international organization that was established after the Second World War. At that time, its main focus was on international security. However, in the future, the world needs more cooperation in the fields of economic development, technological progress and environmental protection. The United Nations must undertake major reforms in order to adapt to the future international community.

GCF: What do you consider the biggest hurdles facing global cooperation in the coming century?

Liu Cixin:
In the course of global development, different countries will inescapably explore and discover development paths most suitable for themselves.

> Exploring the space frontier may be the ultimate way for mankind to finally address major global challenges.

In this process, differences between civilizations and cultures will be more apparent than before. Inevitably, the development paths of different countries and ethnic groups will be in contradiction and conflict with the values of the West, as well as Western political and economic systems, which are currently dominant. This will become the biggest obstacle to future global cooperation.

GCF: Which technological tools do you consider as potentially helpful for the global community to be able to coordinate action and share goals?

Liu Cixin:
Information and Internet technology is an important technical force to promote global cooperation. Today, the Internet has already made unprecedented exchange of information between different regions of the world smooth and convenient, turning the world into a village in terms of information flows. Existing and upcoming new technologies will accelerate this trend. For example, the growing virtual reality technology will allow face-to-face communication among people at a long distance. The development of artificial intelligence and increasingly sophisticated machine translation technology will enable people from different regions and ethnic groups to overcome the language barrier. The development of 3D printing technology is likely to enable hardware items to be transmitted over the Internet.

In the long run, another technological area that will promote global cooperation is likely to be space technology. Exploring the space frontier may be the ultimate way for mankind to finally address major global challenges. For example, environmental and global warming issues could eventually be resolved by moving high pollution and high emission industries to the space orbit. The current scope of space exploration and development is still limited; this huge market has yet to take off. Once the space market jets off, its scale may be stupendously broader than that of the IT industry, and its impact on human life may be even more profound. However, early investment in space exploration is extremely large; global cooperation is needed to achieve the cause. In the areas of space exploration and development, the future may see unprecedented large-scale global cooperation. If we say that the Internet unites the world, then mankind will discover a common future in space.

JENNIFER DOUDNA

Jennifer A. Doudna is a professor at the University of California, Berkeley, investigator with the Howard Hughes Medical Institute, researcher at the Lawrence Berkeley National Laboratory, and executive director of the Innovative Genomics Institute. She is co-author of *A Crack in Creation: Gene Editing and the Unthinkable Power to Control Evolution.*

SAMUEL STERNBERG

Samuel H. Sternberg will start as assistant professor at Columbia University in 2018. He is co-author of *A Crack in Creation: Gene Editing and the Unthinkable Power to Control Evolution.*

3. Preparing for the global ramifications of gene-editing technology

Jennifer Doudna, Professor, Departments of Chemistry & Molecular and Cell Biology, University of California, Berkeley.
Samuel Sternberg, Assistant Professor, Department of Biochemistry and Molecular Biophysics, Columbia University.

CRISPR technology now places the power to easily rewrite the genetic code of living organisms – including humans – into the hands of scientists worldwide. What type of oversight is required for this technology to deliver on its immense potential to improve the human condition? Scientific, regulatory, and governmental agencies are starting to get involved at the national level, but discussions and guidelines must extend beyond national boundaries, to support transnational policy diffusion and strengthen cooperation on a global scale.

Progress in international collaboration has largely been driven by global catastrophes and new technological developments. Wars, epidemics, and natural disasters reveal a shared vulnerability, while technological innovations, particularly in the fields of healthcare, transportation, and communication, increase our capacity to interact and bring us closer together. Efforts to aggressively pursue those innovations that unlock great areas of human potential must also be balanced, however, by parallel efforts that anticipate their potential disruptive effects on society, particularly when those effects cross national boundaries. This is especially so with a transformative technology that promises to redefine our relationship to the very building blocks of life.

Not long ago, basic research to determine how bacteria fight off viral infection seemed about as likely to impact human health as the sign of one's horoscope. Since then, however, so-called CRISPR systems have transformed biomedical science by enabling researchers to make precise changes to the DNA of virtually any cell or organism. Proof-of-concept experiments in cultured human cells using this transformative gene-editing technology have erased the mutations that cause cystic fibrosis, Duchenne muscular dystrophy, and countless other genetic disorders. Research efforts already underway are applying these methods to develop new therapies that may alleviate or even cure genetic disease and certain cancers.

Yet the diverse applications of CRISPR technology, which go well beyond human therapeutics, are not without far-reaching ethical, legal, and social ramifications. Agricultural companies are harnessing new breeding technologies involving CRISPR to improve traits in plants and animals without the scars of gene splicing, blurring the lines of what is considered a genetically modified organism. In vectors of disease like the common mosquito, CRISPR-based gene drive technology is being developed to spread pathogen resistance into wild populations, an approach that could save thousands of lives but also irreversibly alter the genetics of native ecosystems in unknown ways. Perhaps most profoundly, the union of CRISPR and assisted reproductive technology may allow physicians to correct disease-associated mutations in human embryos such that changes would be inherited by all future generations, an application that has provoked concerns over equal access, a slippery slope towards genetic enhancements, and eugenics abuses.

While scientific research on CRISPR technology continues unabated, it is crucial that we step back to systematically investigate all the pros and cons, and to determine how proper governance can ensure

that the products of research and innovation impact society in a beneficial manner. By placing the power to easily rewrite genetic code into the hands of scientists worldwide, CRISPR offers immense potential to improve the human condition, but only with appropriate oversight.

Scientific, regulatory, and governmental agencies are starting to get involved at the national level. In the United States, for example, the US Department of Agriculture has begun informing some food producers how gene-edited crops will be regulated, and the National Academies of Sciences, Engineering, and Medicine have authored studies on human gene editing and gene drive technology that include comprehensive sets of recommendations for future uses and oversight. Similar analyses and prescriptions are also being published in other countries.

Moving forward, these discussions and guidelines must extend across national boundaries as well, given the global implications of gene editing.

Take gene drive technology, in which CRISPR-modified animals would be released into the wild, with the intent of spreading traits like malaria resistance. By their very nature, these modified organisms would cross national boundaries and territories, complicating questions of governance, such as who should make decisions about field trials, who should be accountable, and how should liability be handled. In the case of malaria-resistant mosquitoes, careful global engagement would be especially important since the field trials would likely take place in those low- and middle-income countries disproportionately affected by the disease, whereas early research would likely occur in high-income countries like the United States and the United Kingdom.

Proactive and assertive global governance is also an imperative in the controversial area of heritable gene editing in humans. Although the potential impacts would be slower to surface than gene drive technology, uncontrolled advances in certain parts of the world could lead to an international genetic arms race or the emergence of regulatory havens and a "race to the bottom." A cautionary tale on the risks of inaction can already be seen with a related assisted reproductive technology known as mitochondrial replacement therapy, which is being developed but is not yet clinically approved in the US. In a recent case, however, a New York physician exported genetically modified embryos to Mexico for implantation, specifically to evade US restrictions. Imagine the type of industry that might result if the intent were not to produce an embryo free of genetic disease, but an embryo with a genetic enhancement enabled by CRISPR.

> By placing the power to easily rewrite genetic code into the hands of scientists worldwide, CRISPR offers immense potential to improve the human condition, but only with appropriate oversight.

Robust international governance could discourage this kind of medical tourism, assure equal protection for the citizens of all nations, set international gene-editing standards for scientists and companies, and help prevent trade disputes with gene-edited foods. The challenge is determining what mechanism of international convergence is actually possible, given the substantial legal differences that are already in place across the globe on issues like GMOs and genetic modification of human embryos.

Formal regulatory harmonization across the many CRISPR applications, such as would be accomplished through international treaty, is unlikely to be feasible. Different countries exhibit unique social, political, and ethical norms that are often mutually incompatible, and the substantial resources required to arrive at legally-binding agreements are often not justified by the outcomes. For example, despite numerous meetings in the early 2000s aimed at a prohibition of human reproductive cloning, the United Nations General Assembly was unsuccessful in reaching a consensus on a binding convention. In the case of the Cartagena Protocol on Biosafety, which ensures the safe handling, transport, and use of genetically modified organisms produced through biotechnology, over 150 countries are member parties but the protocol has not been ratified by major global players including the United States, Canada, and Argentina.

So what should effective global governance of gene-editing technology look like? A critical first step is transnational policy diffusion, in which regulators and governing bodies from different nations maintain frequent and open lines of communication as technologies develop. An excellent precedent was set with the 2015 International Summit on Human Gene Editing in Washington, D.C., in which scientific agencies from the US, UK, and China acted as co-hosts and another dozen countries were represented by invited speakers.

The next step is looking for ways to strengthen international cooperation and coordination, especially through the involvement and broadened oversight offered by other stakeholders such as NGOs, professional scientific societies, and public-private partnerships. For example, the International Standards Coordinating Body was recently established to create standards for cell and gene-based medicine products, and the International Society for Stem Cell Research has published guidelines for experiments involving genetic changes to human embryos. Also crucial is a reliance on public outreach and engagement to facilitate decision making, so that the multinational diversity of opinions on gene editing's societal impact becomes an asset rather than an impediment.

Gene-editing technology offers incredible potential to positively transform our world, but only by persistently confronting and addressing its global ramification can we ensure that the benefits accrue to all. As Louis Pasteur once said, "La science n'a pas de patrie, parce que le savoir est le patrimoine de l'humanité, le flambeau qui éclaire le monde". Science has no homeland, because knowledge is the heritage of humanity, the torch that illuminates the world.

KOK YAM TAN

Kok Yam Tan is Deputy Secretary in charge of the Smart Nation and Digital Government program in the Singapore Prime Minister's Office. Prior to his current post, he served in a number of other Ministries within the Singapore Public Service, including the Ministry of Defence, the Ministry of National Development and the Ministry of Education.

4. Machine learning for better governance

Kok Yam Tan, Deputy Secretary (Smart Nation and Digital Government), Singapore Prime Minister Office.

Artificial intelligence based on machine learning could revolutionize the very core of the governance process. It could overcome the biases and limitations of the human mind, and offer a radically new way to address highly complex problems such as climate change. How can governments and global institutions learn to deploy such capabilities? Cities offer a good testing ground, and Singapore has made some early inroads. However, to harness the full possibility of machine learning, we must invest in the know-how to deal confidently with questions of ethics and risk management.

At the Montreal international airport, near the immigration counter, a sign proudly declares, "the border goes digital". In that context, the message is clear: border controls are being automated and shall be a lesser pain to all who pass. Strip away the airport context, and the statement is deliciously ironic. Modern digital technologies, by their nature, invalidate physical borders, they do not augment them. Their reach and operating span transcend distances and boundaries. In this digitally connected world, what new opportunities and risks come? And how can and should nations and governments now work together?

There are many emerging areas at the intersection of governance and technological development where greater international exchange of knowledge is needed. These include particularly new models of city management powered by sensor networks and big data, as well as new forms of monetary transactions through blockchain technology. There is one area, however, that may revolutionize the very core of the decision making process itself: it is the increasing potential for machine learning to support administration and governance.

Automation by machine learning is quite different from automation by rule-based algorithms. The machine is not controlled by well-defined protocols or parameters; instead, it autonomously develops its own problem-solving rules, in a way that is often opaque to its creators themselves. No human directly established the rules that determined Alphago's decision; it "figured out" what to do from a huge set of game data, and thus it could develop moves and responses that surprised every human player of the game.

With increasing advances in artificial intelligence, there is no doubt that governments must learn to deploy such capabilities to serve their constituents better. For Singapore, a key thrust of our Smart Nation initiative is to develop capabilities in machine learning at the national level. Among other endeavours, we have invested in a significant R&D programme called "AI Singapore". Within the government, we are also beginning to scratch the surface in the use of machine learning on a daily practical basis. Early use cases tend to involve needle-in-a-haystack problems where "judgment" needs to be scaled, because rules are not easy to codify, and there are not enough humans to go around and give human evaluation. One example is the task of picking out anomalous transactions from voluminous sets of data points for audit purposes.

Inevitably, though, governments will come to the point where it becomes technically feasible to use machine learning more broadly, either to replace human judgment (for example, determining who is

at fault in minor traffic accidents) or even to substitute codified rules themselves (for example, determining who requires more insurance coverage). In the long term, harnessing this technology for governance purposes can help us overcome the biases and limitations of the human mind. Our cognitive abilities may not allow us to easily grasp some of the greatest challenges, particularly where it is a complex problem that involves systems of systems, where the direction of causality is not clear, and where – perhaps most confoundingly – we ourselves are part of the system. At the global level, climate change is one such challenge. Machine learning can be the basis for a more effective decision making process yielding significant progress towards sustainability.

However, there is a difficult problem to overcome, because effectiveness of decision making is not the only consideration. Human evaluators, as well as written codes and rules, exist also to explain and communicate decisions to those who are subject to those rules. Society and organizations can scrutinize the decisions, by scrutinizing the rulebook and/or the people who made the decisions. We can debate their validity, and alter them over time.

How is that possible when decisions are made in the black box of a learning machine? How do we maintain, influence and alter such a machine to ensure the validity of its decision making over time with changing needs and societal values? These are in many ways technical questions, but they have societal, policy and organizational implications.

As the field of artificial intelligence advances to be more powerful and pervasive, it becomes increasingly necessary for governments to invest now in the know-how to deal confidently with such questions; the other option would be to do ourselves a disservice by avoiding the technology altogether. Moreover, governments' role does not merely stop at using the technology for itself, but in regulating the broader use of machine learning in banking, healthcare, insurance and other industries. Regulation must be informed by good science; hence the importance of research in AI governance, risk management and safety, particularly to address the challenge of aligning AI with societal values that will change over time. These issues tend not to attract as much commercial interest, because the benefits are diffused and the outcomes are not directly monetizable. But if not addressed, the amazing potential of machine learning may bring about serious threats that we do not fully comprehend.

Early movers in this field – industries and governments – should come together with researchers and

Regulation must be informed by good science: hence the importance of research in AI governance, risk management and safety, particularly to address the challenge of aligning AI with societal values that will change over time. These issues tend not to attract as much commercial interest, because the benefits are diffused and the outcomes are not directly monetizable. But if not addressed, the amazing potential of machine learning may bring about serious threats that we do not fully comprehend.

technicians, and develop common language and frameworks to address the issue of managing learning machines. Such work should be grounded in, and be relevant to, the practical applications of machine learning for now and the near future. For this, cities offer a testing ground for models that, in the longer term, could revolutionize not only local, but national and global governance institutions.

The impact of the rapid advances in digital and smart technologies can be transformational to people and businesses. As Singapore pursues its Smart Nation initiative, it becomes increasingly clear that cities and governments will require deep know-how to deploy, maintain and govern these emerging technologies. This work is too important, and too multi-faceted and complex, for any party to pursue alone. It would be ironic if we do not connect our thinking in this, when the very nature of the technology itself is inter-connectivity. We would be putting new wine in old wineskins. We can still make digital borders, but we will have to cross them to truly advance digitally.

SIIM SIKKUT

Siim Sikkut is the Chief Information Officer of the Republic of Estonia. Prior to this, Sikkut was Digital Advisor to the Prime Minister of Estonia.

5. Digital lessons from e-Estonia and applications to global governance

Siim Sikkut, Government Chief Information Officer, Republic of Estonia.

Over the last 20 years, Estonia transformed into one of the most digital countries in the world. What could our global governance institutions learn from this experience? The three pillars of 'e-Estonia' have been the development of a strong digital identity, interoperability systems, and a decisive embrace of change. These could offer promising pathways for more effective global governance systems.

The government of Estonia has been employing information and communications technology to the best of our ability for more than 20 years to improve the efficiency and effectiveness of our public sector. As a result, we have transformed into one of the most digital countries in the world.

Any interaction between government and residents, be they physical persons or legal entities (companies) can take place fully digitally. In the same vein, the back office of government is almost fully digital – the only exceptions being areas such as foreign correspondence and similar services. The country is sometimes even called e-Estonia, signalling the extent to which digital services and solutions permeate the lives of Estonian citizens, entrepreneurs or public servants. These days, our services are even available beyond our borders through e-Residency: anyone in the world can apply to get an Estonian digital identity and start using the digital services that government and the private sector offer from a distance – one important target group for this being cross-border entrepreneurs.

Most of the know-how in digital transformation accumulated by Estonia may not directly translate into anything useful on the global governance stage since, overall, the focus of global governance is not service delivery. However, some of the core lessons we learned on our digital journey might still have relevance for revamping governance on a global level.

First, one of the pillars of our digital government is a strong digital identity. In our case, it comes in the form of smart chip cards (ID-cards that work similarly to an average bank card, with PINs for security) and the equivalent mobile-ID (usable with any devices via your phone). Regardless of the particular form or token of identity, the idea is simple: there has to be a secure way to access and provide services to users online (in other words: to authenticate). This should be available for everyone to ensure economies-of-scale as well as inclusivity. In Estonia, everyone has to have a digital ID-card in their pocket, for example.

Without strong authentication, there cannot be trust between interacting parties. How do you know the other person or organisation is who they claim to be? Global governance needs the same sort of trust – whether for inter-organisational collaborations or, even more so, for any form of direct democracy. Moreover, digital ID can also ensure trust by enabling digital signing, which is a necessity for any bureaucracy, be it local, national or global.

With digital signatures, red tape and hassle are reduced (no more need to courier and keep paper documents) and any interaction can be handled digitally in its entirety.

Digital signatures have been the most instrumental and useful service we ever started using in Estonia – as they are engrained in almost all other digital services, whether government or private sector run (e.g. banking transactions). With a secure way to digitally sign, and to do so in a legally valid manner, no physical meetings have to take place, and no paper documents are required at all. Think about the efficiencies we could reap on the global level! In Estonia, we roughly estimate that we save at least a work week of unnecessary hassle and time for each working person each year, just by using digital signatures across the whole economy.

Now, digital IDs exist in various countries around the world. But three things are necessary to ensure that they operate effectively: to make them usable across jurisdictions (by ensuring mutual recognition, unifying standards, etc); to make sure that more people have access to them (the World Bank and others have started global initiatives in this regard); and to take them into use for existing global governance mechanisms and networks.

The second pillar of e-Estonia is strong interoperability. All governments fundamentally work in silos. Yet, people want integrated and seamless services, which requires exchange and integration of data from various technical sources and agencies. Similarly, cross-referencing and reusing data can greatly boost the efficiency of the back office – for example, by allowing more powerful analytics. Interoperability is what makes it possible for various agencies, work streams, data sources, information systems, etc, to be integrated and collaborate.

Interoperability comes in many ways and at many levels. For example, standards have to be there for data structures, exchange formats, etc. On a practical level, some integration platforms are necessary. In Estonia, our solution has been called X-Road. It is the data exchange platform that connects our whole government together digitally, and integrates the government with the private sector whenever data exchanges are needed. X-Road is not a vast database or service bus, but rather, a shared or standardized protocol on how to transmit data between endpoints. Effectively, it is a lean layer on top of whatever digital solutions some agency may use. If you integrate once, you become immediately interoperable with anyone else in the network.

Any global governance set-up needs interoperability to effectively function. The more parties are involved, the more interoperability matters. Also, the more we try to use digital tools to help our governance, the more interoperability matters again. For example, the management of pandemics, climate change or nuclear arsenal can be greatly boosted by Internet of Things applications. Yet, how do

Our ultimate learning has been that digital transformation is actually not about tech or digital. The core of it is transformation as such – change. Thus, to be able to benefit from digital tools in global governance, we need to rethink how we do things on the global level and boldly try out new practices or methods that new digital solutions allow for.

we make the myriad of devices, sensors and systems work together? Interoperability. That means standards, that means platforms. Estonian X-Road-type solutions could help us move forward on this.

Our ultimate learning has been that digital transformation is actually not about tech or digital. The core of it is transformation as such – change. Thus, to be able to benefit from digital tools in global governance, we need to rethink how we do things on the global level and boldly try out new practices or methods that new digital solutions allow for.

E-Estonia has reached its current level only through strong leadership that was ready to take risks and change the way we used to do things, e.g. radically simplify services based on data exchange and move them online with digital ID. As technology continues to march ahead, the opportunities for transformation will only grow. If the Estonian experience can be useful for transforming global arrangements or those of another country, the government as well as private sector experts of Estonia are always happy to share.

MARCELLA ATZORI

Marcella Atzori is an academic researcher affiliated to University College London, a leading international expert in blockchain governance and GovTech applications, and Blockchain Expert in the European Commission for industrial applications. As Blockchain Advisor for TrustedChain, the first permissioned blockchain of European Trust Service Providers, she regularly advises governments, institutions, SMEs, academic communities, and other relevant actors, helping them to follow-up closely the development of new decentralized applications, and evaluate challenges and opportunities for citizens, governments and services.

6. Promoting sustainable development at the global level through the blockchain technology

Marcella Atzori, academic researcher, University College London;
Blockchain Expert in the European Commission for industrial applications.

How might we reduce the proportion of international aid money currently lost to corruption or inefficient intermediaries? A recent technological innovation, the blockchain, could offer a solution to this challenge. By design, the blockchain supports transparent and auditable transactions, and provides a way to automate the execution of agreements based on mutual satisfaction. With willingness to embrace this technology, the blockchain could therefore radically transform funding models for international organizations – and herald a new paradigm for global resource transfer.

The cost of funding the United Nations is an ongoing source of debate among the populations of member countries. To make things worse, not all of these funds are deployed for their intended purpose: it has been estimated that up to thirty percent of development aid from UN funds may be currently lost to corruption or inefficient intermediaries[2]. However, a recent technological innovation, the blockchain, could radically transform this situation.

The blockchain technology has recently emerged as a disruptive element. The technology is able to automate the processes of data verification, access and exchange through algorithmic protocols, with reduced reliance on trusted authorities. Blockchain technology was developed in 2008 as the underlying technology of Bitcoin, the first peer-to-peer network for decentralized and cashless payments. Since then, it has proven its worth as a stand-alone computing and organizational paradigm, with numerous and significant benefits for many different sectors – such as public administration, finance and banking, industry, healthcare, and insurance. These benefits generally include: improved data security and integrity; better effectiveness of data management and workflows through automation and disintermediation; reduced need for infrastructures, with substantial savings in time and administrative costs; and new opportunities for sharing data and exchanging value between unknown or untrusted participants.

Importantly, the blockchain enables a new ecology of data governance, which is based on neutrality, tamper-resistance and transparency. This can hardly be overstated. Indeed, thanks to the algorithmic protocols of the blockchain, digital transactions can be automatically executed on a large scale with reduced or no human intervention. Records of such transactions are permanently auditable and resistant to possible accidental errors, corruption or fraud by privileged insiders or third parties.

The blockchain may thereby have a number of particularly interesting applications for international organizations. Any financial services – from the management of UN funds to microfinance projects – could be directly provided to the parties involved through peer-to-peer transactions, or managed in a more transparent and effective fashion, with reduced bureaucratic red tape and counterparty risk.

The blockchain opens a possibility for self-enforcing agreements (or smart contracts), digital escrows, which prevent the release of a payment until all of the terms of an agreement are met, and multi-signatures wallets, which require the consent of multiple parties for

the execution of a payment or the transfer of digitalized assets. These could be successfully deployed to overcome difficulties related to the low recovery rate of micro-credit, or to avoid problems typically associated with corruption, fraud, lack of transparency or moral hazard from participants in the process of international fund transfer – such as local intermediaries whose actions cannot be monitored through the use of traditional financial instruments.

Moral hazard and adverse selection – asymmetrical access to information that benefits one of the parties in a transaction – are common occurrence among institutions and credit groups, especially in developing countries, largely due to the lack of advanced regulation. They represent key reasons why so many development projects have failed in many parts of the world in the last decades, and they must be prevented with great care, particularly when donors with sizable funds are involved.

The blockchain may ensure the effectiveness of projects aimed at the redistribution of wealth and sustainable development, since it provides for the transparency and auditability of transactions *by-design* – namely throughout the engineering process of digital platforms, with a proactive and preventative approach – rather than *by-policy*, i.e. through anti-corruption measures and subsequent verifications of financial operations by the competent authorities, which may turn out to be ineffective. Sheltered from possible opportunistic behaviors, dishonesty or general sluggishness on the part of traditional financial actors and local operators, agreements between parties could be protected and automatically executed through the blockchain, in respect of the original goals and obligations of the subjects involved. International funds could thus be used with less friction and in a more effective way, leapfrogging long value chains and intermediaries, and substantially increasing the creation of social and economic value at local level, for the benefit of the final users. At the same time, the complete traceability and transparency of transactions enabled by the blockchain would also prevent any illicit action or misuse of financial resources. The blockchain could hence be successfully integrated to the policy of the United Nations, NGOs and other global organizations, who have long called for a reliable financial and administrative structure through which to promote specific objectives and monitor their real progress at local level.

It is important to recall, however, that many issues still need to be addressed in the construction of a reliable blockchain-based governance model at the global level. This endeavour requires high levels of coordination and security, and involves great complexity.

From a technical standpoint, the first problem is to establish

The blockchain could be successfully integrated to the policy of the United Nations, NGOs and other global organizations, who have long called for a reliable financial and administrative structure through which to promote specific objectives and monitor their real progress at local level.

well-defined quality standards in the industry. Blockchain networks may present a number of crucial weaknesses, so it is fundamental for global organizations to rely on trustworthy and secure digital backbones that are able to guarantee high performance, legal compliance, and privacy. The underlying systems must also ensure continuity of service and long term preservation of data, from which depend the future execution of smart contracts and the persistence of digitalized assets over time. In this regard, the blockchain networks of Trust Service Providers have recently emerged as infrastructures with the most reliable certified standards at the international level, both in terms of technical and management issues.

Further problems relating to the last section of the value chain must also be addressed before introducing blockchain-based solutions in the management of international funds. The digitization of services generally needs minimal infrastructure – such as stable and high speed connectivity and a sufficient user base – as well as computer literacy, and a sufficient degree of regulation expertise. In many areas of the world where populations are still struggling with subsistence farming, famine and illiteracy, this is still only a long-term prospect.

Since every country or region has its own specific conditions, it is important to assess the potential effectiveness of new technologies case by case, taking into account all the relevant factors at the social and anthropological levels. However, through adequate local innovation policies, together with incubators and small pilot projects run on secure and reliable platforms, the blockchain could be deployed to radically transform the funding models for international organizations– and herald a new paradigm for global resource transfer.

DAVID ORBAN

David Orban is an investor, entrepreneur, author and speaker specializing in disruptive technologies. He has been an early adopter of blockchain technologies and an active Bitcoin investor since 2010. He is advisor & Faculty at Singularity University, a Founder of the Open Government Data working group, and an Advisor to the Institute of Ethics and Emergent Technologies as well as numerous start-ups in Europe and North America. He is the Founder and Managing Partner of Network Society Ventures, a global investment firm for start-ups at the intersection of exponential technologies and decentralized networks.

7. Blockchain technology and decentralized governance

David Orban, Advisor & Faculty, Singularity University;
Founder and Managing Partner, Network Society Research.

In a context of exponential technological development, old centralized models of governance may be outdated. Opportunity may come from a new trend towards decentralization, which allows organizations facing global challenges to trial a range of novel solutions adapted to local contexts. In this perspective, what might be the role of the United Nations? It could operate as a platform, offering a neutral interface to facilitate interactions among a broad range of stakeholders. To bring this vision to life, the best vehicle would be an independent UN Labs that harnesses the potential of blockchain technology to support better global data flows, and catalyze the development of decentralized solutions to global challenges.

Technological change is accelerating, and can be simultaneously observed in a range of uncorrelated industries. Most evident in the information and communication sector, it has created a globally connected world, and exponentially increased the level of uncertainty around the globe. In this context, centralized forecasting by hierarchical organizations has become a blunt and inadaptive tool – but opportunity may arise from an increasing trend towards decentralization.

Blockchain is emerging as one of the key technologies to support decentralized models of organization. Blockchain was invented in 2008, and implemented first in the Bitcoin cryptocurrency. Blockchain based solutions work on a network of computers or smartphones, connected together over the Internet. Its fundamental innovation is that through novel use of cryptography and smart software, the nodes in the network are able to share inalterable data without a central authority. The system works even if the participants never met, or even if they do not trust each other. While the first and still most prevalent application is the storing and transfer of value, underpinning a true digital money native to the Internet, the ambitions and potential applications of blockchain go beyond that field.

The innovation of blockchain enables decentralized organizations to dynamically decide how to allocate resources to achieve their goals. Blockchain systems are based on a shared universal ledger that records data, transactions, and agreements, allowing anybody to verify them without relying on a central authority. This mechanism is already at work in open source software development, where the most popular software libraries are incorporated in a large number of applications. But success now goes beyond reputation, and naturally includes an economic dimension, as most blockchain systems incorporate a tradable cryptographic token whose value reflects the popularity of the project.

Decentralization has two main benefits for organizations facing global challenges. It allows them to more easily implement novel solutions, and to trial variations on the same solution. New approaches can be tried in one part of the network with limited risk and cost, and, if successful, easily circulated, reproduced or adapted across the entire organization. This model directly replicates evolution as it occurs in biological systems, and is crucial for creating resilient systems adapted to their environment.

We can do more than merely recognize the blind forces of evolution in action. Since we can observe and evaluate their implications, orienting them in desirable directions becomes possible. This new interplay promises superior results. In a decentralized structure, a wide variety of solutions

can be implemented and tried out on the basis of a shared global understanding and broad common policy directions. What needs to be done is understood globally; how it is done is understood locally.

Decentralized organizations are naturally non-exclusive, and not necessarily determined by geography: it is possible to belong to a decentralized organization regardless of one's location, and to belong to several of them simultaneously. This is enabled by the real-time global communications networks that have been developed over the past thirty years. Various networks and their members now exist side by side, within shared social and physical locations. This lack of physical separation imposes a much higher degree of tolerance for diversity, and points towards a new kind of coexistence where disagreements cannot be resolved through physical conflict.

In a world driven by decentralization and the emergence of the Network Society, organizations like the United Nations have the opportunity to become a platform – an interface to facilitate interaction and communication which is as neutral as possible, and is not built on the assumption that identical solutions will work in different settings. Importantly, advanced information and communication technologies allow platforms to operate more rapidly and efficiently compared to systems that need to develop ad-hoc interfaces, and to achieve qualitatively superior results. They do this by feeding data into the process, supporting decision making by smartly aggregating opinions, and building consensus in a manner that goes beyond the mere dictatorship of the majority.

One key area where the UN could operate as a platform is by providing access to open, transparent and accountable data flows in a neutral manner, in order to support a range of practical applications addressing global challenges. Such data flows originate from sensor networks, which are becoming ever more universally deployed and connected – forming a decentralized and distributed version of what is often referred to as 'the Internet of Things'. These sensors provide a fundamental reading of objective reality. For example, private and public sources can independently fund numerous air quality monitoring stations deployed across a large metropolitan area. Citizens can make short- and long-term decisions based on the high quality, accessible, aggregated information that they produce. This is already happening in Beijing, and is transforming the conversation around local environmental policies.

Blockchain technology would optimally support the aggregation of those various data flows, because

In a world driven by decentralization and the emergence of the Network Society, organizations like the United Nations have the opportunity to become a platform – an interface to facilitate interaction and communication which is as neutral as possible, and is not built on the assumption that identical solutions will work in different settings.

of its transparent and accountable nature. but implementation must be done in a nimble manner. A potential vehicle could be a new UN Labs, which should be isolated and protected from the larger body of the United Nations. It is naive to believe that a large organization such as the UN can be easily reformed: there is often a protection mechanism, a veritable immune system, that maintains the established practices of hierarchical bureaucracies, and is able to produce honest justifications for killing new initiatives, even if they are wrong.

The mandate of the UN Labs should come directly from the highest functions, ideally from the Secretary General. Its resources could be relatively modest, but it must recruit a combination of highly qualified new staff and self-selecting members from across as many agencies as possible. This will ensure novel technical capacities, while preserving access to and deep understanding of organizational mechanisms.

The objective of the UN Labs would be to develop and rapidly release blockchain based components that can be made available to developers worldwide. Possible applications should not be established by the laboratory itself or larger UN agencies. Because the platform is neutral, and because access to data is open and unfettered, thousands of unexpected, creative and valuable solutions could flourish, developed by other entities: government agencies, NGOs, and private corporations. The measure of success for the UN Labs would be objective: running code, used in thousands of places worldwide, powering applications installed in billions of mobile phones, supporting the design and deployment of tens or hundreds of billions of sensors.

Giving access to blockchain based decentralized data sources and applications will allow a new dynamic balance to emerge. It will yield resilient local solutions to global challenges, and fundamentally increase the adaptability of human societies in the 21st century.

PETER WELLS

Peter Wells is Head of Policy at the Open Data Institute. He works with governments and businesses around the world. Previously, Peter spent over 20 years in the telecommunications industry, worked in a voluntary role to organize an independent review of digital government policy for the UK Labour Party and experimented with creating a collaboratively maintained open address register.

ANNA SCOTT

Anna is Head of Content at the Open Data Institute. She manages its brand and outputs across channels. Anna was previously a journalist at the Guardian, where she wrote and commissioned content on global development, and helped establish the Center for Global Development's Europe office, working on policy outreach across programs.

ALEX LEON

As Junior Consultant at the Open Data Institute, Alex works across a range of international projects, supporting open data initiatives across Europe and Africa with workshop design and facilitation as well as strategic communications advice.

8. Global challenges call for better data infrastructure

Peter Wells, Head of Policy;
Anna Scott, Head of Content;
Alex Leon, Junior Consultant, Open Data Institute.

Today, we can gather and aggregate data more easily than ever before, but how can we best harness the potential of this data to improve the lives of people and address the world's most pressing challenges? Building the right systems will involve strengthening data infrastructure, making more data open, promoting data skills and fostering innovation. In supporting this effort and addressing new challenges around ethics, engagement and equity, global governance institutions will have a crucial role to play.

Since the founding of the United Nations in 1945, the landscape in which global governance institutions operate has changed.

Today, we can gather and aggregate data more easily than at any time in history, whether it be data about people – such as population statistics – or the natural and built environment – such as weather patterns, crop yields and traffic information. This creates huge potential to improve the lives of citizens everywhere, a mandate that has generally been adopted primarily by global governance institutions.

To help solve today's global challenges, however, we need to do more than publish this data. We must build a system that will use it to make more timely and informed decisions. To do this, the global governance community must focus on four key areas: strengthening data infrastructure, making more data open, promoting data skills and fostering innovation.

'Data' has become a widely used word, and its meaning is often unclear. We understand 'data' as any information about people, places and things across the world, existing in digital or other formats.

Data is an emerging infrastructure that all sectors of the economy increasingly rely on. It helps us make more informed, timely decisions as individuals, organizations and societies.

Data should be like roads. Nations invest in roads to make them reliable and available to all. We connect road networks at local, national and global levels. We teach people the skills they need to use roads and take action if they drive badly. We develop a range of organizations to support the operations of road infrastructure, including transport planners, construction companies, driving instructors and traffic police. Data infrastructure is similar: it is not just the data but also the surrounding ecosystem that needs to be built and strengthened.

Data exists on a spectrum, from closed data (held within one organization), to data shared (between individuals or organizations), all the way to open data (available for anyone to access, use and share). The more people use a particular dataset, the more insights are generated from it, and the more impact it has. Therefore, the foundational data that has the potential to solve global challenges must be open.

Open data is already yielding significant benefits in allowing us to map, monitor and respond to extreme events. When hurricanes recently wreaked havoc across the Caribbean, over 2,800 volunteers across the world added buildings to open mapping data on the platform OpenStreetMap. This allowed global aid organizations to conduct rapid damage assessments. Community initiatives are replicating similar projects to address localized issues, such as Dar Ramani Huria, which maps the areas within the

Tanzanian city of Dar es Salaam that are most prone to flooding.

Global initiatives are emerging as awareness of data and its potential grows. The Global Partnership for Sustainable Development Data, for example, focuses on maximizing data's potential to tackle challenges like extreme poverty, climate change and epidemic disease. The International Aid Transparency Initiative and Open Contracting have developed standards for publishing international aid data and procurement data, so that it can better support decision making.

To meet global challenges, institutions must also increase the number of people who can use data across all levels of their organizations. Open data is not a purely technical matter. We need to develop better data literacy for all, data science skills, and experience using data as a tool to solve problems.

After taking its first steps in building data infrastructure, the Tanzanian government worked with the Open Data Institute, the World Bank and the UK government to help build capability both in government and society. The government was then able to harness this initial support to build sustainable data initiatives that could improve the lives of its citizens.

Finally, the capacity to derive benefits from data infrastructure and data literacy depends on a culture of open innovation.

In 2015, the UK Department of Environment, Food & Rural Affairs (Defra) engaged external experts to show their public servants how opening data could enhance their current and future work. Roundtables were held with private sector and civil society stakeholders to find areas where they could collaborate. Through this open approach to innovation, Defra improved flood risk management and farming, saved money for researchers and campaigners, and strengthened relationships. In Mexico, the government worked with civic organizations and start ups, through an incubation program called Labora, to open data that could help them solve problems and create social and economic impact.

While recognizing the potential of data, we must also identify challenges in how data can and is being used. Many governments and businesses sell or hoard data that should be either openly available or kept closed and private. This has led to a trust deficit between individuals and the organizations that handle data, and limits its effective use. It risks people and society withdrawing permission for data to be collected or used.

We face significant gaps in three areas that need to be addressed in order to build the necessary trust. First, we must ensure that data is collected, used and shared in an ethical way, considering potential unintended consequences from

Global institutions must recognize the opportunity to develop a robust data infrastructure, and the associated challenges of ethics, equity and engagement.

program design to delivery. Second, those holding data should support equitable access to and use of it. Finally, we must engage and empower citizens to have a say in how data is or isn't used.

Over the next few years, there will be a growing need for existing, or new, global governance institutions to tackle these challenges.

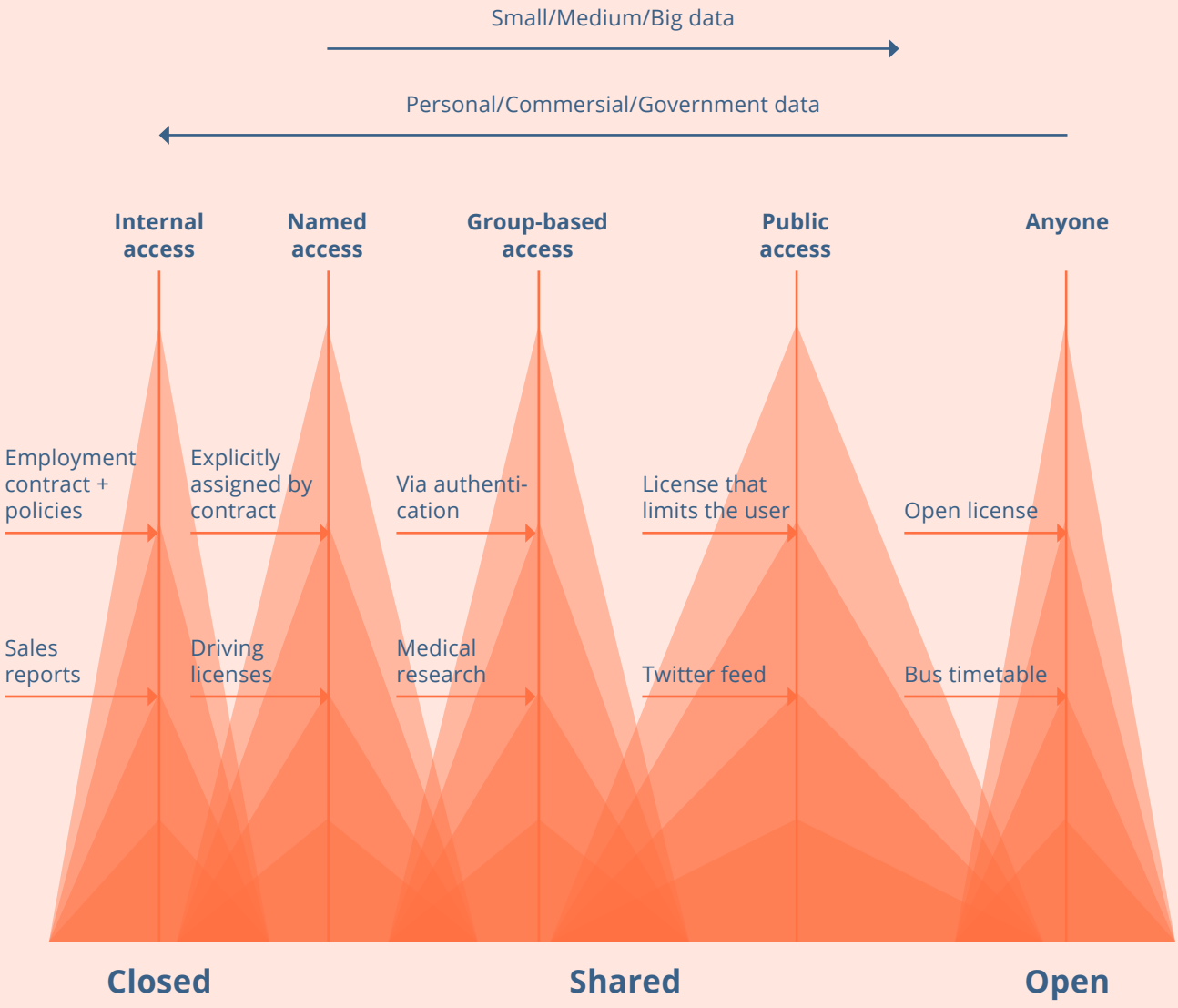
International standards for data protection and open data evolved from the Universal Declaration of Human Rights, principles like those developed by the OECD in 1980, and through pressure from international movements such as the Open Government Partnership.

Reimagining what data access and protection rights are needed in the 21st century, fostering the necessary global agreements, and creating change through data infrastructure, skills and open innovation will take time, but it will be necessary for data to reach its full potential. Global institutions must recognize the opportunity to develop a robust data infrastructure, and the associated challenges of ethics, equity and engagement.

For this, they need to start with targeted aspects of global problems, and work with other global institutions, governments, businesses and civil society, to tackle them using data. Learning lessons, before scaling, is the best way to help everyone learn how to use data better.

Each day, data plays a vital role in helping individuals, businesses and governments make decisions. Now, global institutions must lead systemic change to solve global challenges through the possibilities it offers.

THE DATA SPECTRUM[3]



CHACKO THOMAS

Chacko Thomas is an experienced consultant and researcher in the field of energy systems and climate change regulation and policy. He is an Electrical Engineer, with a Masters in Energy Studies and Environmental Law. Chacko's doctoral research lies at the intersection of 'complexity science' and environmental regulation. In the emerging reality of the Internet of Things, Chacko seeks to understand how environmental policy and regulation adapt to meet the needs and challenges of a rapidly evolving technological landscape.

9. The Internet of Things – coordinating data for better environmental management and reporting

Chacko Thomas, Researcher, Climate and Environmental Governance Network (CEGNET), Australian National University.

The Internet of Things is an emerging network where integrated sensors, communicating through the Internet, generate diverse, granular and real-time data. This technology could revolutionize the way that we monitor the economy and our environment, and respond to risks and challenges. What steps do we need to take so that the Internet of Things can effectively support evidence-based and data-driven decision making to benefit humanity? Four areas require particular attention. We must build understanding of this new paradigm, including its limitations; we must shift our discourse from 'Big' to 'Smart' data; we must embrace open data; and we must unify data standards around the world.

As we stand at the cusp of an environmental data revolution, harmonising data governance requirements is vital to ensure that evidence-based and data-driven decision making can benefit humanity. The Internet of Things (IoT) is the name given to an emerging integrated technological network, where digital and sensor technologies embedded in vehicles, buildings and other physical devices can communicate with each other using the Internet. Consequently, the IoT promises the potential to create an electronic skin to monitor our environment, driven by scalability and virtually endless connections. Present day examples include Smart homes (e.g. NEST and Amazon echo), Wearables (e.g. Fitbit), Smart Cities, as well as autonomous and connected vehicles, while planetary scale visions include IBM's Smarter Planet and HP's Central Nervous Systems for the Earth (CeNSE).

Today, relatively inexpensive IoT devices are being deployed on a large scale, generating diverse, granular and real-time data. By accessing this rich data, the IoT makes otherwise labour-intensive processes simpler, more efficient and cost-effective. In this emerging reality, the IoT offers the possibility for new forms of compliance monitoring and evidence-based regulation, and could revolutionise the way we monitor the economy and our environment. For example automated and connected vehicles have the potential to make cities greener by reducing congestion, and improve safety and road conditions through preventative and targeted maintenance. Real-time and remote monitoring of lifestyle practices could reduce healthcare costs, while improving overall health and well-being. Therefore, as the IoT becomes more ubiquitous, it will increasingly be viewed as a means of achieving the Sustainable Development Goals (SDGs). Furthermore, coupled with open government, data and technologies, it has the potential to improve the transparency of the decision making process.

Contemporary applications of the IoT in the environmental monitoring field include natural disaster warning systems, flood management, smart agriculture and air quality monitoring. Given that the applications are diverse and vary across time and scale, the IoT provides us with analytical tools to understand local, regional and global environmental changes in near real-time. By accessing data from these systems and applications, decision and support systems for early detection and responses can be built to better influence and direct preparation efforts and emergency response, thereby minimising loss of life and property. Thus, the IoT could not only become a tool for understanding complexity, but also a means of responding swiftly.

It is worth noting that there are many stakeholders and actors in the environmental field, who use different vocabularies and technologies – and this raises a challenge. Traditionally, there has been little interaction across environmental domains, resulting in data silos. In contrast, the IoT vision hinges on device connectivity and unencumbered data flow, within organisations and sectors, and across sectoral domains. For this imminent future to become a reality, we need to bridge the incongruity between digital opportunities and traditional governance. Consequently, four areas require particular attention.

First, we need to build greater understanding of this new technological paradigm among leading actors – particularly regarding its limitations. Until recently, monitoring the environment had a specific purpose (such as air or water monitoring, to measure pollution levels), it relied on specialised equipment and trained personnel, and generally followed international or national standards. Such monitoring processes yielded limited data, but decision makers could have clear appreciation for its quality, reliability and consistency. Presently, the same is not true for data collected through IoT devices. Given the relatively cheap costs of sensors, mass deployment by different agencies or organisations for the same application is a possibility. For example, air quality monitoring sensors could be deployed on city buildings, lighting poles, and on vehicles. However, since devices may vary in quality, be used by people with different training and skillsets, and the data generated may or may not be quality controlled, we cannot place the same trust in these devices as we do with traditional monitoring equipment. Therefore a range of frameworks and clear guidelines must be developed to increase data reliability and trust.

Secondly, as environmental IoT devices become more ubiquitous, we need to shift the dominant discourse and practices from 'Big' to 'Smart' data – i.e. towards devices and data that are fit for purpose in relation to their application. In particular, data for policy and/or compliance monitoring needs to be of higher quality than data used for general awareness raising. Alas, currently, we do not distinguish between device and/or data quality. Given the imminent deployment of billions of sensors, this problem is exacerbated all the more. Additionally, we presently don't know how sensors will deteriorate over time in the real world, and what impact this may have on the data generated.

Thirdly, while governments have embraced open data, certain companies are increasingly closing up their datasets or making them available for a fee or via license.

Given that data is regarded as the oil of the 21st Century, the IoT can act as a catalyst to achieve the SDGs and accelerate the rate of global development. However, to do so, the flow of development data – environmental, economic and social – has to be unencumbered to prevent a new digital divide from occurring.

Given that data is regarded as the oil of the 21st Century, the IoT can act as a catalyst to achieve the SDGs and accelerate the rate of global development. However, to do so, the flow of development data – environmental, economic and social – has to be unencumbered to prevent a new digital divide from occurring. If private stakeholders increasingly close their datasets, it will result in what one may call 'the tragedy of commodification', resulting in a situation akin to "water, water everywhere, nor any drop to drink". This, unfortunately, seems to be the current trend with environmental data. Certain companies while providing users' control of who sees their data may not allow users to delete, update and amend machine, production or administrative data. Furthermore, they treat the large amounts of data generated by their devices as a private resource to be harnessed for profit. Consequently, without discoverability, availability, accessibility and (re)usability of data, the next generation of innovations in environmental regulation will remain inconsistent, and in some way abstract.

Finally, unifying standards is of crucial importance. Environmental data is produced by many stakeholders, including government departments and agencies, private companies, community groups, NGOs, citizens, etc. Hence, while standards help to consolidate technology, networks and data requirements, and assist with interoperability within a given sector or environmental domain, they fall short in cross-sectoral coordination. By overcoming the siloed nature of environmental regulatory practice, we must develop adaptive policy to inform stakeholders on the ever-changing natural environment. This new form of policy needs to be informed by a 'connected collective intelligence', resulting from the synergistic interaction between humans and the multitude of 'things.'

TASHA MCCAULEY

Tasha McCauley is a technology entrepreneur living in Los Angeles. Her current work with GeoSim Systems centers around a new technology that produces high-resolution, fully interactive virtual models of cities. Prior to her work with GeoSim, she co-founded Fellow Robots, a robotics company based in Silicon Valley. She co-directs Ten to the Ninth Plus Foundation, an organization focused on empowering exponential technological change worldwide.

10. Making big data intuitive – the challenge of representation

Tasha McCauley, Board Member, GeoSim Systems.

New technologies allow us to gather more data than ever before. However, what use is all this data if decision makers cannot access its meaning? The information revolution is not just about aggregating more information, but also creating better ways of visualizing it. Recent advances make it possible to create virtual models of entire cities and run accurate simulations of future scenarios, giving experts and non-experts a visceral experience of potential catastrophes such as major floods. This could create a powerful drive towards action and support better decision making on the most pressing global challenges – as long as institutional practice embraces the possibilities offered by these new modes of data visualization.

In the movie Amadeus, the composer Salieri reads Mozart's music off the page and, without hearing a single note played aloud, exclaims "It is miraculous!" Salieri is an expert: he can hear the music in his head with near-perfect fidelity. In many disciplines, as in music, only experts can experience the meaning of symbols directly. The vast majority of us can only have direct experience when our senses are engaged – when the orchestra plays.

Despite the fact that 90% of the global datasphere was created in the last two years[4], its meaning will remain largely invisible to us until we can set it against backdrops we understand. The term "information revolution" is often used to describe the exponential advancement of technologies that generate, transmit, and store information, but the real revolution will be one of context.

When we think about how to protect civilization from physical catastrophe, it is clear that intuitive representation of data about the physical world allows for better decision making. We need to display data gathered from the world around us in a way that helps us assess and plan for global risks, and better forecast their local impact. This applies both to decision makers and to the public. If governance is to become more inclusive, information must become more egalitarian. Better presenting it is part of this effort.

New technological developments promise a golden age of data visualization. The idea that we can get real-time information about objects in our physical environment is already pervasive. The Internet of Things increasingly monitors the physical world with embedded sensor technology, providing us with information about everything from smart grids and smart homes to biochips and heart monitor implants. But as we use sensors to record information about the objects that surround us, we are creating an absolute flood of data. We must represent that data in a way that is natural for humans to understand – a way that better couples the information to the human nervous system. This will be increasingly important as we analyze data on larger scales.

Cities are an important focal point when considering approaches to mitigating catastrophic risk. Google and Apple have both done exemplary jobs of capturing and modeling cities at great scale from the air, but not with the street-level accuracy and geometric detail that enables the kind of intuitive data representation we're talking about.

Very recent advances in technology have made it possible to build virtual models of entire cities with centimetric precision, and these models can generate accurate visualizations of real city-related data. The combination of ultra-high

spatial precision and visual resolution gives rise to functionalities that were not possible before. Objects in a virtual city model of this kind – windows, fire hydrants, parking meters, power transformers, vehicles – can have discrete identities and be part of a searchable database. Data from IoT sensors in the real, physical city can now be linked directly to the corresponding objects in the 3D city model. The data can then be visualized in real time, not on a 2D dashboard with numerical and graphical displays, but in the virtual copy of the physical location where the information is actually being generated in the city.

Here's why this is so powerful for catastrophic risk mitigation: not only can we use high-fidelity models to track and visualize all kinds of human activity, but we can run highly accurate simulations of future scenarios in order to quantify the effects, and visualize them. Using these simulations, experts, non-expert city officials, and city residents alike can get a visceral understanding of what would happen in the case of, say, a major flood caused by rising sea levels.

Anyone who has seen a standard 2D flood zone map knows that they're far from emotionally riveting. They have legends, symbols, and shadings that require interpretation. And they are static. Unlike real water, nothing moves. This is a tool with which city officials plan for floods, but when we look at one of these, our nervous systems are barely engaged. We're not driven to act.

But if we immerse ourselves – either with a laptop or in full VR – in a precise 3D model of a city, and run a dynamic simulation of the same flood zone data, our nervous systems kick into gear. As we manually change the water level, we see the water lapping at the doors of individual office buildings and coffee shops in neighborhoods we know. We can observe, at the spatial precision of a few centimeters, whether a bridge will be inaccessible, or whether an unprotected power substation will be submerged. We can see where the best escape routes would be and where we'd need to dispatch first responders and emergency personnel. The technology removes the task of interpretation and replaces it with what comes naturally to human beings: immersion and interaction.

From there, we can imagine a world where all of that information isn't just shared within a city, but also between and among cities: an expanding global network of virtual cities that exchange information in order to educate, optimize, heal and self-construct, sharing the best practices discovered by each in order to raise the effectiveness of every city as they plan for the future.

However, institutional practice is still decoupled from the capabilities of technology. We know that good visualization works. But we're still

Institutional practice is still decoupled from the capabilities of technology. We know that good visualization works. But we're still expecting people – and particularly decision makers – to understand data by reading it off of a page.

expecting people – and particularly decision makers – to understand data by reading it off of a page. Both the public and representatives of the public need tools that enable them to model and visualize risks in a way that compels them to act.

We're leaving behind a time when only Salieri-like experts could read the code, and entering a new era in which the visualization of complex data will become a living performance, contoured for our human senses. This will enable all of us to experience meaning more naturally, and inspire us to take actions that will preserve the places – and principles – we value most.

WILLIAM HAMILTON

Before dropping out to become an entrepreneur, William was a researcher in clinical psychology at Stockholm University. In 2014 he founded Mimerse with the mission of spreading evidence based psychological treatments through immersive technology. He also co-founded Vobling, a leading VR/AR-agency with offices in Stockholm, Manila and Lagos servicing world leading brands, corporations and institutions.

11. Governance in the age of Virtual Reality – from data to experience

William Hamilton, Founder, Mimerse.

Virtual reality is an immersive technology that produces the illusion of real presence in a virtual environment – allowing its users to receive a mediated experience rather than be presented with information. What should decision makers know about an innovation that, with large investments from major industry players, will become commonplace in the coming decades? The technology is about to radically change the way we conduct meetings and conceive of interpersonal relationships. Soon, fully virtual summits will be commonplace, and the perspectives gained from immersive VR experiences could be harnessed to make decision making processes at major governance events more conscientious and collaborative.

VR is on the far end of a mixed reality (MR) continuum that ranges from augmenting part of the real world with virtual objects to fully immersive systems. Consumer interest and adoption of MR has accelerated recently with apps like Pokémon Go going viral and most big hardware companies releasing VR headsets and platforms. Mixed reality technologies will soon become commonplace, and are widely seen as the future of computing. In a recent keynote at Oculus, a division of Facebook specialising in the development of VR technology, Mark Zuckerberg set the goal of getting 1 billion people inside VR – the technology today only has around 10 million users. Microsoft has extended their Windows platform to fully support immersive and spatial computing with Windows Mixed Reality, and Magic Leap, a secretive company that hasn't unveiled a product yet but is promising a revolutionary mixed reality display technology, is raising money at a 6bn USD valuation.

These and other massive investments by leading technology companies are quickly expanding the market, applications and capabilities of VR, making possible things that, so far, have only been seen in science fiction. In the coming decades, VR and its related technologies will develop from novel to truly disruptive and commonplace. Paying attention to the possibilities opened by the technology is therefore increasingly critical for decision makers and leaders.

VR technology is commonly referred to as an "empathy machine" due to the effect it can have on users. Instead of being presented with information, the user receives a mediated experience. VR makes it possible to step into a first person perspective and feel what it is like to be in a warzone or a flooded area. There is a common saying that leaders are too far removed from the people: VR has an obvious role to play in that area, as it can bring powerful decision makers in closer connection with the people affected by their decisions.

Some early instances of development show great promise. The UN co-produced a documentary on the Syrian Refugee crisis from the perspective of a young girl. It premiered at the World Economic Forum in Davos and allowed leaders and potential donors to feel the plight of refugees with a level of empathy that had never been possible before. This VR experience was later used in a fundraising event in Kuwait in March 2015 that raised 3.8bn USD.

VR not only carries the possibility of making stories and experiences immediately felt at a distance, but it can make the world itself feel smaller than ever before. In the 1960s, Steward Brand successfully campaigned for NASA to release a photo of the entire planet seen from

space. Brand thought that this image would be a powerful uniting symbol for humanity. With Google Earth VR, you can now access a similar image of the whole planet, spin the globe, pick a location, and zoom all the way to the ground level, until you find yourself standing on the street.

In a future where self-driving cars, wearables and drones, all equipped with cameras, become commonplace, companies like Google will be able to aggregate information from these devices to create and maintain a perpetually updated, high resolution 3D model of the entire earth. Imagine if the people involved in each negotiation with consequences for a certain border, village or landmass could actually visit that place in real time through VR? They would be able to directly empathize and hold a less abstract perspective on the issue at hand. Today, in international forums, VR is still an accessory to the main event, but this may be about to change. It should become an obligatory part of the process to take a virtual survey of the regions involved before sitting down for a discussion. This would lead to more conscientious, rational and collaborative discussions and decisions.

With Google Earth VR, it is already possible to adjust the time of day and see the world under different lights. Imagine running more advanced simulations that allow negotiators to actually experience the simulated impact and outcomes of their decisions, with areas of application ranging from infrastructure development to climate change and wars. A UK Startup, Improbable, is building an engine for such complete simulations and recently raised a $500M series B round. Receiving such an experience of the likely long-term impacts of policy could profoundly change global governance.

VR is also about to change meetings and interpersonal relationships. Microsoft R&D has already demonstrated a feasible concept for full telepresence through human holograms. Real time 3D scans will make it possible to interact at a distance with a much higher quality of human contact than what is possible through video conferencing today. Participants will be able to hold and sustain eye contact, communicate through body language, and experience mutual closeness.

Communicating this way opens up a plethora of possibilities, particularly when combined with other technological developments. Imagine being able to customize your own avatar to any appearance, while ensuring that your facial and bodily movements are perfectly mapped in real time to this virtual avatar, directly conveying emotion. Imagine being able to integrate real time translation to a distance interaction, removing the need for translators. This prospect could make the huge

Today, in international forums, VR is still an accessory to the main event, but this may be about to change. It should become an obligatory part of the process to take a virtual survey of the regions involved before sitting down for a discussion. This would lead to more conscientious, rational and collaborative discussions and decisions.

machine of the UN translation system obsolete in the coming decades. Taking it even one step further, imagine being able to remap emotions and body language, so that personal communication styles are better matched, and greater intuitive alignment becomes possible.

In the area of global governance, fully evolved mixed reality will bring revolutionary change. Soon enough, fully virtual summits will be commonplace, and decision making processes will hopefully become more constructive, thanks to the gained perspectives that come with the power to go anywhere and experience anything. Thanks to the exponential development of its enabling technologies, VR, MR and AR will create a new era not only in human computer interaction, but in human to human interaction – and radically shift our perspective on ourselves, our globe, and the fabric of reality itself.

PABLO SUAREZ

Pablo Suarez is associate director for research and innovation at the Red Cross Red Crescent Climate Centre, and a scholar at Boston University and University College London. He has consulted for the UN Development Programme, the World Food Programme, the World Bank, Oxfam, and twenty other humanitarian and development organizations, working in more than sixty countries. His current work ranges from financial instruments to machine learning to collaboration with artists to inspire thinking and action.

12. Rethinking the future of governance through games

Pablo Suarez, Associate Director for Research and Innovation, Red Cross Red Crescent Climate Centre.

At major governance events, the present modes of interaction are far from optimal: as long as sequences of unidirectional statements followed by insufficient Q&A continue to prevail, can we expect any genuine change? Serious gameplay, uniquely conducive to systems thinking, could provide a precious alternative. Games have been harnessed in a range of development projects, and resulted in major breakthroughs. Games could reveal systemic shortcomings in current frameworks, they could deepen the role of citizens in day-to-day governance mechanisms, and even improve the workings of major UN bodies. They could trigger new ways of approaching unfamiliar problems, and harness the power of creative thinking to develop new solutions for the world's greatest challenges.

Changes in governance happen at the speed of trust. Regrettably, our current ways of approaching governance change seem rather slow to engender trust. This is particularly true in the realm of climate risks: threats are rising faster than our collective ability to understand and address causes and consequences.

Part of the problem is the way we choose to interact during governance events. A large proportion of the interaction time is dominated by traditional meeting formats, such as the dreadful sequence of presentations followed by insufficient Q&A. Unidirectional statements dominate, establishing an atmosphere of 'more of the same', and rarely leading to genuine transformation in ideas and positions. To help participants meaningfully rethink the future and their role in it, a different approach is needed.

Games[5] offer a promising option. They present playable system dynamic models that can help people and organizations inhabit the complexity of future risks. As digital technology spread to the mainstream in the last decades, video games have emerged as an increasingly popular cultural phenomenon. In turn, this has led to broad interest in game mechanics as a way to approach strategic challenges in a range of sectors, whether on digital platforms or face to face. Well-designed games, like well-designed governance systems, involve decisions with consequences: a set of simple rules engenders emergent complexity. Participants can explore new ways to address threats and opportunities, while bonding and building trust in ways that are both serious and fun.

Games are uniquely conducive to systems thinking. They compress space and time, and offer an embodied experience of the tensions that dominate governance challenges –"now versus later", "certainly versus probably", "me versus us versus them". Importantly, through gameplay, people combine the concentration of analytical rigor with the intuitive freedom of imaginative, artistic acts. As a result, game-enabled processes that capture the essence of real-world systems allow for safe and rich explorations of how those systems could be changed. In the words of SimCity creator Will Wright: "Games amplify our imagination, like cars amplify our legs, or houses amplify our skins."

In a range of projects that engaged the Red Cross Red Crescent Climate Centre, the World Bank, Oxfam, the UN World Food Programme, NASA and many other partners, breakthroughs in humanitarian and development work have emerged through gameplay.

Illiterate Ethiopian farmers who don't have a word for 'insurance' in their local language took part in a game with dice and beans designed

to help them learn about parametric insurance bundled with credit. They tried to resolve obstacles by 'hacking' the system. In doing so, they proposed key innovations, such as paying premiums through labor, and measures to combine individual protection with resilience-building mechanisms at the community level. These evolved into the "R4 Rural Resilience" initiative[6] currently providing microinsurance services to over 200,000 farmers in five developing countries.

A game called "Paying for Predictions" brought together Red Cross volunteers with donors and hydro-meteorological experts in Africa, Asia and the Americas. It revealed that funding for disaster management materializes after a disaster, but that no mechanism was in place for shifting money to areas where science indicates unusual likelihood of an extreme event before a disaster strikes. Rapid funding triggered by early warnings could enable early action, drastically reducing the impact of extreme events. Thus "Forecast-based Financing"[7] was born, and is currently being implemented in Bangladesh, Peru, Togo, Uganda and numerous other countries, where science and finance work in alliance to act faster, averting disaster.

There are currently no governance mechanisms regulating the research and potential deployment of 'geoengineering' – the technically feasible option to deliberately manipulate the global climate by spreading sulfur in the stratosphere in order to obstruct sunlight and reverse the effect of global warming. At a 2017 conference in Berlin, a game session explored potential governance mechanisms for geoengineering. Changing regional climates were embodied through foam dice, where 1 marked a drought and 6 a flood. The shape of the dice became more irregular over time, making extreme events more likely. After a few rounds, teams had the option to hack the climate. The geoengineering technology was represented by an electric knife that could chop off pieces of foam – hopefully bringing regional climates to more 'normal' behavior in the short-term, but with unclear implications for other regions. When one participant actually tried to alter the climate, a remarkable range of reactions emerged from other individuals and teams – from silent endorsement to self-sacrifice and even threat of nuclear war. The discussion that ensued had a level of emotional intensity that brought visceral realism to the intellectual examination of potential governance frameworks to prevent predatory geoengineering[8].

Games supporting the development of better governance mechanisms have been played from fishing villages in Fiji to IPCC[9] working groups of Nobel-prize winning

> Games are uniquely conducive to systems thinking. They compress space and time, and offer an embodied experience of the tensions that dominate governance challenges.

scientists, and from the Ugandan Parliament to the White House[10]. Platforms ranged from amphitheaters with 2500 participants to immersive solo experiences in virtual reality[11]. The principles, methods and practices of serious gameplay could be further harnessed to develop global governance opportunities in three main areas.

First, playable explorations of system dynamics can accelerate learning and dialogue about complex issues, improving stakeholder participation, revealing systemic shortcomings and prompting reflection on systemic improvement. Second, engagement games[12] can be integrated to day-to-day governance mechanisms and deepen the role of citizens in global-to-local institutions, involving people in data collection and analysis, policy development or decentralized decision making. Third, well-designed games could improve the workings of UN bodies – including the security council – by enabling a more genuine, informal, out-of-the-box dialogue built on shared rules in pursuit of creative thinking and trust building. Games create a safe space that encourages players to switch roles, and experience the consequences of their decisions from numerous perspectives. They trigger new ways of imagining an issue, and new ways of addressing it.

Of course, games are no panacea: like all forms of designed interaction, things can go wrong. But a growing body of evidence and experience suggests that games can help nurture learning and dialogue processes, so that they become more anticipatory, more inclusive, and more imbued with trust. Notably, fun is functional to governance explorations. Games offer familiar structures designed to allow us to play with the unfamiliar, enabling us to reimagine the space of possibility latent in our shared futures.

ROBIN HANSON

Robin Hanson is an Associate Professor of Economics at George Mason University, and Research Associate at the Future of Humanity Institute, Oxford University. He has long studied prediction markets, developing the commonly used market scoring rule, and was a principle architect of the first corporate markets at Xanadu in 1990, DARPA's Policy Analysis Market in 2003, and IARPA's DAGGRE in 2011. Oxford University Press published his book *The Age of Em: Work, Love and Life When Robots Rule the Earth* in 2016, and will publish *The Elephant in the Brain: Hidden Motive in Everyday Life in 2018*.

13. Decision markets for global governance

Robin Hanson, Associate Professor, Department of Economics, George Mason University;
Research Associate, Future of Humanity Institute, Oxford University.

At present, it is hard for ordinary world citizens to judge the quality of global governance choices. It would be feasible, however, to create open "decision markets" where traders could speculate on the outcomes of particular global policy choices. On the basis of information developed through those markets, rather than simply trust their representatives to negotiate the right outcomes in relatively opaque governance forums, global citizens could pressure governments to support the choices that they believe will most benefit them.

Nations today jealously guard their autonomy. As a result, institutions of global governance tend to rely less on clear rules enforced by authorities with formal power, and more on opaque information sharing that influences private negotiations and perceived norms and agendas. Outsiders can find it hard to judge the concrete policy implications of global governance choices, or even what choices have been made.

And this can make it hard for ordinary world citizens to judge the quality of global governance choices. Citizens must trust their governments to have negotiated in their interest, and to have done so effectively. Which can be a lot to ask. Can we do better?

An alternative exists that could allow better global governance, by helping global citizens to more directly judge the quality of global choices. This alternative is simple and low-tech, and nations need not give up any more of their autonomy. This alternative, however, does have two requirements.

First, it applies only to cases where global governance can allow for clear, discrete choices. For example, a particular treaty might or might not be signed. Or a particular governance body might rule one way or another. While such clear discrete choices may not be the usual case, they do happen often enough to be worth improving.

Second, this alternative requires us to choose and support a few focal after-the-fact global outcome metrics relevant to each set of clear discrete choices. For example, world product in the years after a trade treaty, or war deaths in the years after a peace treaty.

Given such clear discrete policy choices and related outcome metrics, we could create "decision markets", wherein traders can speculate on these focal outcomes, given particular policy choices. If trading in these markets were sufficiently subsidized, either via subsidized market makers or via market estimates influencing contentious policies, then the policy estimates produced by these markets should be as accurate as any competing source of information.

For example, imagine that a particular global-warming treaty is under active consideration. It might or might not be signed by a particular plurality of nations. And it has the stated purpose of influencing outcomes such as global sea levels, storm damage, and crop yields, over the coming decades. For concreteness, let us focus on a particular measure of average global sea levels in thirty years.

In this specific example, we would create two speculative markets, each of which gives one conditional estimate. One estimate would be of that particular sea level metric conditional on the treaty being signed. The other estimate would be

A large empirical literature consistently shows that open speculative markets are among our best institutions for aggregating information into robust estimates available to all. Decision market estimates would thus offer global citizens a clear visible consensus on the effects of discrete global governance choices.

of sea level conditional on the treaty not being signed. The difference between these estimates corresponds to the best estimate of market speculators regarding the effect of this global warming treaty on this sea level measure.

To pay off these bets, and thus to reward speculators for making accurate estimates, we don't need to know the actual causal connection between this treaty and sea levels. We just need to know what sea levels finally were, and if the treaty was signed.

As another example, imagine that a new treaty might be signed to create stronger intellectual property protection, in order to better promote technological innovation. Here we might create markets that estimate world product in twenty years, conditional on this treaty being signed, or not being signed. The difference between these two estimates would say how much speculators expect stronger intellectual property to promote growth worldwide.

A large empirical literature consistently shows that open speculative markets such as these are among our best institutions for aggregating information into robust estimates available to all. Such markets have done well at estimating weather, sales, elections, project completion dates, and more. They are especially resistant to manipulation and able to identify and correct for their own biases. Decision market estimates would thus offer global citizens a clear visible consensus on the effects of discrete global governance choices.

Global citizens could then pressure governments to support the choices that they expect will benefit them. Such citizens would have less need to trust their governments to negotiate opaque global governance outcomes in their interest. Even as nations retain all of their existing autonomy. Which could be a big win for effective global governance.

It is possible, of course, to imagine lots of potential problems with this proposal, including noise, sabotage, media distortions, unequal participation, and selection biases. But most of these problems are more imagined than real. And as these markets can be quite cheap, if they fail for some reason, such as insufficient traders or citizen interest, we would have only lost a small financial investment. So, what are we waiting for?

JAY NAIDOO

Jay Naidoo was the founding General Secretary of the Congress of South African Trade Unions (COSATU) and served as a Minister in Nelson Mandela's Cabinet. He is currently a trustee for Earthrise Trust, looking at new models of rural development and livelihoods. He sits on the board of the Mo Ibrahim Foundation that aims to support leadership and governance in Africa, and remains committed to social justice.

14. Finding our shared humanity in the digital age

Jay Naidoo, board member, Mo Ibrahim Foundation.

Digital information technology has reshaped our lives, the way we communicate, and our production systems. However, it has not yet fulfilled its promise of peace, justice and human dignity. In a world where we see so much progress, why are we still witnessing the repression of citizens, rising inequality and the destruction of natural ecosystems? The model of infinite growth adopted around the world is unsustainable and has generated the greatest inequality. We must rethink technology, not as an end in itself, but as a tool that assists in redefining the economy. For this, we need a revolution of values, where new technology becomes the bedrock for a solidarity economy, and results in the development of new public commons.

We live in the digital age. Information technology has reshaped our lives, the way we communicate, and our production systems. Now robotics, nanotechnology and artificial intelligence may allow us to leapfrog old infrastructure and technological choices, and fulfil the promise made by digital technology at the start of the millennium: a promise to future generations that they could live in a world based on peace, justice and human dignity.

But are we making the right choices? Our world faces an ecological emergency. We currently use the resources of 1.5 planets every year, but if we all had to live like Americans, we would need 4 planets. We cannot continue the growth paradigm that just measures GDP and ignores the value of billions of people who live sustainably in communities around the world.

Infinite growth is an unsustainable model that runs contrary to the natural cycles of Nature. This growth paradigm holds the greatest risk for humanity. Already, 80% of forests have been eradicated, a third of our arable land is poisoned with chemicals used in industrial agriculture, and much of the large coral reefs have been destroyed by pollution. This growth ideology has also generated the greatest inequality, with 1% of the global population owning more wealth than the remaining 99% – and the richest 62 individuals owning more than the bottom 50%.

What should we do? In the mid-Nineties, sub-Saharan Africa had fewer phones than the city of New York. Working together, African Ministers developed a policy framework that gave investors certainty and predictability, and harmonised the use of the radio spectrum. This led Africa to become one of the fastest growing telecommunication markets in the world.

Today, millions of previously unbanked people, especially in East Africa, have access to mobile banking. Just like in telecommunications, the continent leapfrogged directly from analogue to digital technology. With political will, we can do the same in every sector. On a continent with an average of 300 days of sunlight per year, harnessing solar energy means potential for millions of jobs and many successful entrepreneurial ventures. Renewables could empower communities to develop new assets from which they could gain revenue – at a lower cost than the old technologies.

A crucial part of this transformation will be to empower citizens through better access to information. Using exam and school location data, the NGO Twaweza has developed an application, ‘Find My School’, that the citizens of Kenya can use to check the relative performance of primary schools in the country. As

a result, education quality, teacher performance and accountability are visibly transformed in the interests of the students and the country. A similar model allows Ethiopian coffee farmers to improve their bargaining power through the Ethiopian Coffee Exchange, an initiative set up by the Ethiopian Government.

There are many examples of youth activism on the right to good governance and democracy and against abuse of power and dictatorships. In North Africa, particularly in Tunisia and Egypt, youth connected with social media took to the streets to show their power. Digital technology not only helped them to connect locally but, in a world where nation state boundaries are in many ways arbitrary, the world connected to their struggle, and acted in solidarity.

The 2016 Ibrahim Index of African Governance, the most comprehensive open data index in Africa, measures the public goods that our Governments have an obligation to deliver to their citizens. The index measures a hundred indicators, ranging from health to education, and from economic opportunities to the rule of law.

However, data from the Index reveals that over the past 10 years, overall governance improvement in Africa has been held back by a widespread deterioration in Safety and in the Rule of Law – affecting almost two-thirds of African citizens. In a world where big money and vested interests have captured governments and political parties, and where international conglomerates control more wealth than the nations' citizens, we are exposed to abuse of power and the plundering of natural and mineral resources. In order to bring forward a genuine change, tools must be accessible to everyone – through proper design, appropriate costing, and education. When information transparency is standard, and when digital literacy is widespread, citizens are in a position to hold those in power accountable, whether in government, business, civil society or multi-lateral systems.

Where do we go from here? In a world where we see so much progress in technology, why are we still witnessing the repression of citizens, rising inequality and the destruction of the natural ecosystems that bring us life in the first place? Could it be that ownership and control of technology, as well as access to it, still sits with political and economic elites? When 1 GB of data costs as much as 75% of the monthly poverty line income in many African countries, it is clear that an elite is controlling the digital revolution and that, yet again, many are being left behind. There is still a huge digital deficit in who has access to platforms. Internet penetration in Africa today is only 31%, as opposed

Technology must not drive the economy, but assist in redefining it.

to 53% in the rest of the world, and only 9% are using social media, limiting the capacity for coordinated collective action.

Maybe the real challenge of the digital revolution is to recalibrate the software in order to bring back the human values of service, compassion and solidarity, and to restore the balance between Mother Earth and ourselves. We must not look at technology as the answer, but rather as a tool. It must help us to bring about the collapse of human greed, not embody it. Technology must not drive the economy, but assist in redefining it. We must take the idea of the commons to the digital revolution. We must ensure new technologies are open source, and that they offer a space for all to participate, without centralised control.

For this, we need a revolution of values, no matter what tools are being used. We need the technological revolution to drive a solidarity economy, based on the principles of sharing, peer learning and open source, an approach that will result in the development of new public commons. Technology is the birth-right of every human being. We cannot allow it to be appropriated in order to satisfy our generation's selfishness and sense of grandeur. The premise for any future pursuit of justice is that global institutions play an active role in lifting the veil of secrecy, and that the new shape of global governance be built on open data platform.

Glossary

This glossary attempts to clarify some of the key terms used in this report, including new forms of hardware and software, their applications, and general underlying principles. This is, however, no more than a first rudimentary entry point: the list is by no means exhaustive, and some of the terms below cover entire academic disciplines. To better grasp the complexity behind each of these words, we strongly encourage interested readers to seek more detailed accounts than could possibly fit in the short space of a glossary.

Aerial drones
An aerial drone, also described as unmanned aerial vehicle (UAV), is a flying object without a human pilot aboard. Aerial drones are increasingly sophisticated and becoming capable of autonomous action, as well as increasingly small. Drone networks are planned to become commonplace in both urban and rural environments, supporting a range of surveillance systems, as well as new forms of military and police intervention.

Algorithm
An algorithm is a process or set of rules to be followed in calculations or other problem-solving operations, especially by a computer.

Algorithmic regulation
Algorithmic regulation is a governance system in which data is collected from citizens' devices or through a range of sensors and cameras in urban areas. This data is then used for efficiently organizing the citizens' lives. Algorithmic regulation could be used, for example, to automatically ticket speeding motorists, or – as in China today – to automatically collect photos of people who cross the street under a red light, and display these on digital boards to shame the perpetrators.

Artificial intelligence
Artificial intelligence (AI) refers to technology that enables machines to accomplish complex goals – or forms of intelligence that are non-biological. We typically distinguish between weak or narrow AI, designed and trained for a particular task such as spam filters, self-driving cars or Facebook's newsfeed, and general AI or Artificial General Intelligence (AGI), which is able to find a solution when presented with an unfamiliar task, with human-level ability or beyond.

Augmented reality
Augmented reality is a view of a real-world environment whose elements are "augmented" by sensory input such as sound, video, graphics, or other. These inputs are typically generated by computers, and accessed through devices such as phones, tablets, or Google Glasses. Augmentation typically occurs in real time and in relation to environmental elements – for instance, by overlaying supplemental information like scores over the video feed of a sporting event. The most notable uses of augmented reality would be the popular smartphone game Pokémon GO, car manufacturer Volvo's experiment with augmented reality aided production lines, and ThyssenKrupp's overview for lift maintenance.

Autonomous robots
Autonomous robots are machines that can act without human control, through integrated computer systems. Factory robots, with a degree of autonomy, were already developed in the 1930s (with the first patent granted in 1961) and robots have been used as vacuum cleaners (Roomba), pets (AIBO the robot dog), and as chauffeurs (driverless cars). Autonomous robots are already used in warfare, where their autonomy is restricted by a human giving the final command to attack. Law enforcement is a potential growing area of use for autonomous robots – for instance, the Dubai Police force is now using modified Reem robots.

Big data
Big data technologies are computer systems that collect and aggregate massive amounts of data gathered through a combination of sensors and Internet data sources. This data is used to determine a certain situation (e.g. environmental conditions), or predict the likelihood of a future event (e.g. natural events, wars, etc). The capabilities of this technology will be amplified by AI-based systems that can directly support decision making by analyzing big data in relation to different goals.

Biometric identification
Biometric identification technologies can verify the identity of human beings by examining distinct biological features. They include face recognition, fingerprints recognition, iris recognition, voice recognition and many others. Biometric identification could provide a highly efficient way to identify every person – sometimes from considerable distances (as in the case of people being filmed by aerial drones) – and could be used for airport security, building access, and car access through voice recognition.

Blockchain
Blockchain is a technology that enables complete decentralization of data storage and computation, through a network of computers or smartphones connected over the Internet. Using smart software and cryptography, the nodes in the network can share inalterable data, without any central authority, and the system works even if participants do not trust each other. Blockchain already serves as the basis for Bitcoin, the first decentralized currency outside any government control, and should enable decentralization of monetary systems, dispute resolution systems, document storage systems and many other services – challenging the control of nations over these services.

Clean and abundant energy
Recent technological developments, particularly in the field of renewable electricity sources (solar- or wind-based) or – in a more uncertain future – nuclear fusion, hint at the possibility of clean and abundant energy creation. As these technologies become more prevalent, many expect that they will reduce the reliance of many nations on fossil-based fuels and on centralized power plants, while opening the prospect of economic abundance.

CRISPR
CRISPR is a gene editing technology that allows to precisely target and permanently modify certain sections of DNA in living organisms. The technology relies on a naturally occurring genome editing system in bacteria. Unlike other gene editing technologies, CRISPR uses the cell's own DNA repair mechanisms to add or subtract pieces of genetic information or to replace an existing segment with a tailor-made DNA sequence. CRISPRs do not need to be paired with separate cleaving enzymes as other tools do. It can also be used to target multiple genes simultaneously.

CRISPR is currently applied in biomedical research, crop and livestock breeding, in the research to engineer new antimicrobial drugs and to control disease-carrying insects with gene drives. CRISPR could be applied to humans in the foreseeable future, where it could serve to reverse genetic mutations responsible for a range of illnesses dependent on single genes, such as cystic fibrosis, hemophilia, and sickle cell disease or transform DNA to genetically enhance individuals. The first procedure where an adult received cells edited by CRISPR took place in 2016 in China.

Data
The word data is omnipresent in discourses about new information technologies. Data can be loosely defined as information about people, places, and environmental elements, gathered from a range of sources – from dispersed sensors to texts – that exists in digital and other forms. Information technology allows a range of sources to be converted into formats that allow for their joint processing and computation, whether for the sake of monitoring, prediction, or other purposes.

Digital governance
Digital governance technologies are systems that allow citizens to take direct part in and influence their government's decision making through the internet, for instance, by taking part in committees, conducting public discussions or voting online.

Genetic modification
Genetic modification refers to the transformation of the genome of a living organism. This is typically done through a process called 'gene editing', a type of genetic engineering where DNA is inserted, deleted or replaced in the genome of a living organism. The main technologies to do this are ZFN, TALEN, and CRISPR/Cas9. Genetic modification is already applied to bacteria, plants and

animals, and technology currently exists that can be applied to humans. Genetic modification could allow nations to engineer the next generation according to certain paradigms and perceived needs. Babies may be engineered, for example, to have enhanced intelligence, or to withstand harsh environments.

Internet for all
Internet for all refers to the potential provision of Internet services to everyone (possibly without the consent of the state), through technologies like Google's router-balloons, Facebook's mega-drones, satellites or device-to-device communication.

Internet of Things
The Internet of things (IoT) is an emerging integrated technological network, where digital and sensor technologies embedded in physical devices, vehicles, buildings and other items can collect data from their environment and communicate with each other using the Internet – or this information can be used in human-machine communication. The analyst firm Gartner estimates that by 2020 there will be over 26 billion connected devices in the world. Sensors can detect changes in state – for instance, temperature – and trigger changes of behavior on this basis, operating like a thermostat, but in a connected way.

Machine learning
Machine learning is a field of computer science that gives computers the ability to learn without being explicitly programmed. Various technological models underpin machine learning, but the most common at present is neural networks, which are loosely modeled on the human brain's layers of densely interconnected simple processing nodes. Unlike machines that operate on the basis of algorithms developed by human programmers, machine learning results in computing systems developing models of operation that are opaque to their developers. Machine learning is also an evolving process, whereby machines are capable to improving their own competence and reformat themselves independently of human input.

Mass surveillance
Mass surveillance is the intricate surveillance of an entire or a substantial fraction of a population in order to monitor that group of citizens. Mass surveillance is exerted through the combination of a range of technologies – typically dispersed sensors, aerial drones and biometric identification.

Open Data
Open data refers to one of the underlying principles of the Internet, whereby data should be made available to as broad a range of individuals and organizations as possible, with the minimal level of limitations attached. The principles of open data apply at two levels: that data should be made available at no cost, and that it should be formatted in a way that makes it maximally transferable. The underlying logic of open data is that it will allow and incentivize individuals, governments, NGOs and corporations to produce useful innovations making use of this data in order to address local and global challenges in unexpected ways.

Predictive analytics
Predictive analytics refers to a variety of statistical techniques that analyze large amounts of data to make predictions about future or otherwise unknown events, in order to guide better decision making, by humans or machines.

Quantum communication
Quantum communication is a field of applied quantum physics. Closely related to quantum information processing and quantum teleportation, it works by transferring a quantum state from one place to another. Quantum states code quantum information, or qubits, through single photons. Those photons are randomly polarized to states representing ones and zeroes, and serve to transmit a series of random number sequences used as keys in cryptographic communication. Its most interesting application is in protecting information channels against eavesdropping by means of quantum cryptography, making it practically unhackable by foreign powers.

Sensors
Sensors are electronic components or devices whose purpose is to detect events or changes in the environment, then send the information to other electronic components, typically computer processors, typically communicating through radio waves or wifi. Sensor networks disseminated through cities and the environment underpin the structure of the Internet of things and many big data projects.

Space exploration
Space exploration refers to the development of manned and unmanned craft that can travel in space. Space technology already supports the network of satellites that make GPS and many communication systems possible. Further space exploration opens the possibility of colonising other planets, manufacturing in microgravity – enabling entirely new materials which could not be developed with Earth's gravity – the construction of widespread solar farms in microgravity, or mining resources present in space, such as precious metals present on asteroids.

Virtual reality
Virtual reality (VR) is a technologically-mediated illusion, whereby the human brain falsely infers real presence in a virtual environment. This illusion can be achieved through a head mounted display system that renders a virtual environment in alignment with each eye's perspective, and changes the image projected in relation to the movement of the head. VR technology has been used in areas like aviation training and clinical psychology since the 1960s, and more recently for gaming and entertainment.

Endnotes

1. Nytimes.com. (2017). Transcript: President Obama on What Books Mean to Him. [online] Available at: https://www.nytimes.com/2017/01/16/books/transcript-president-obama-on-what-books-mean-to-him.html
2. Un.org. (2012). Secretary-General's closing remarks at High-Level Panel on Accountability, Transparency and Sustainable Development | United Nations Secretary-General. [online] Available at: https://www.un.org/sg/en/content/sg/statement/2012-07-09/secretary-generals-closing-remarks-high-level-panel-accountability
3. Www.theodi.org/data-spectrum
4. Www-01.ibm.com. (2017). 10 Key Marketing Trends for 2017. [online] Available at: https://www-01.ibm.com/common/ssi/cgi-bin/ssialias?htmlfid=WRL12345USEN
5. Games for a new climate. (2012). Boston, MA: Boston University, the Frederick S. Pardee Center for the Study of the Longer-Range Future.
6. Www1.wfp.org. (2017). The R4 Rural Resilience Initiative | World Food Programme. [online] Available at: http://www1.wfp.org/r4-rural-resilience-initiative.
7. Climatecentre.org. (2017). Forecast based financing - Red Cross Red Crescent Climate Centre. [online] Available at: http://www.climatecentre.org/programmes-engagement/forecast-based-financing.
8. Suarez, P. and van Aalst, M. K. (2017), Geoengineering: A humanitarian concern. Earth's Future, 5: 183–195.
9. Climatecentre.org. (2017). Making better use of scientific information - IPCC authors play 'Decisions for the decade' - Red Cross Red Crescent Climate Centre. [online] Available at: http://www.climatecentre.org/news/503/making-better-use-of-scientific-information-ipcc-authors-play-decisions-for-the-decade
10. Bu.edu. (2017). Pardee Research Fellow Conducts Gaming Session at the White House | The Frederick S. Pardee Center for the Study of the Longer-Range Future. [online] Available at: http://www.bu.edu/pardee/2012/09/19/white-house-pardee-gaming/.
11. Suarez, P. (2017), Red Cross Innovations in Risk Management. Australian Journal of Emergency Management, volume 2, p.11-14. Available at: https://ajem.infoservices.com.au/items/AJEM-32-02-05
12. Gordon, E., Walter, S. and Suarez, P. (2016) Engagement Games, a case for designing games to facilitate real-world action. [ebook] Available at: http://elabhome.blob.core.windows.net/resources/engagement-game-guidebook.pdf

Continuing the conversation

We hope the conversation will continue. You can help us by simply sharing this report with a friend or colleague.

We're looking for partners around the world to join future publications, organise events, workshops and talks, or more generally support our engagement effort.

For more information, visit our website:
www.globalchallenges.org

ADDITIONAL CONTACT INFO

The Global Challenges Foundation:
Norrsken House – Postbox 14
Birger Jarlsgatan 57C
113 56 Stockholm
Sweden

info@globalchallenges.org
+46 (0) 709 98 97 97