

THE INTERNET OF EVERYTHING

New Data,
New Connections,
New Possibilities
for Global
Problem Solving

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The rise of pervasive computing in today's increasingly connected and data-rich world is revolutionizing global problem solving—from the ability to reveal new patterns and relationships that are integral to understanding the root causes of global problems to the use of geographic information systems and remote sensing to provide immediate and increasingly granular feedback about the current state of the problems we are trying to solve.

Case studies on leading networks such as Global Forest Watch and UN Global Pulse demonstrate that big data and pervasive computing technologies are already changing how the world responds to global problems and how Global Solution Networks can harness these tools to improve outcomes.



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“...the proliferation of RFID, satellite imagery, cheap personal video recorders, smartphones and a global grid of wireless sensors is giving rise to a seamless computational network that connects every living being and inanimate object on the planet.”

Idea in Brief

In today’s increasingly connected world, technology not only fosters low-cost connectivity across borders, it provides a much richer pallet of data, tools and techniques to make global solution networks (GSNs) more creative, intelligent and effective than ever before. The rise of ubiquitous computing and connectivity, and an increasingly data-rich world in particular, will revolutionize global problem-solving—from the ability to detect and interpret new patterns and relationships that are integral to understanding the root causes of global problems, to the use of geographic information systems and remote sensing to provide immediate and increasingly granular feedback about the current status of the problems GSNs are trying to solve. Case studies on leading networks such as Global Forest Watch and UN Global Pulse demonstrate that big data and the so-called Internet of Everything are already changing how the world responds to global problems and how GSNs can harness these tools to improve outcomes.

Introduction

In the space of a few decades, the digital revolution has transformed the way we work, the way we connect with friends and family and the way we educate, inform and entertain ourselves. It has upended and reshaped countless industries, from software to financial services and media to pharmaceuticals. And as the Internet’s influence permeates other aspects of society, it is beginning to profoundly transform virtually all institutions, from education, healthcare and science, to the way we produce and consume energy, to the very nature of government and democracy.

As Don Tapscott and I argue in *Macrowikinomics*, the Internet enables new modes of human connectivity and new ways of organizing our knowledge and ingenuity to create change. The growing constellation of complementary devices and information technologies provides an immensely powerful platform for reinventing our institutions, including our institutions for global cooperation and governance.

In the new, networked model of problem solving, technology provides the enabling platform on which diverse participants come together to develop and implement solutions to global problems. Technology not only fosters low-cost connectivity across borders, it provides a rich pallet of data, tools and techniques with which to transform the way we approach global challenges like climate change and water scarcity or assess the impact of rising food and commodity prices on poverty. In fact, the opportunities for new



innovations, new knowledge and new efficiencies will grow as information technologies become both more powerful and more pervasive.

One of the most notable things about the digital technology revolution is not only how much it has transformed the way we work, learn, create and connect, but how fast the underlying and associated technologies have evolved. In just a few short years, the rise of massive online communities like Linux and Wikipedia and social networks like Twitter and Facebook transformed the Internet from a space for publishing information to a global platform for computation and collaboration that unites people and organizations around any conceivable shared interest, goal or pursuit. Today, the proliferation of RFID, satellite imagery, cheap personal video recorders, smartphones and a global grid of wireless sensors is giving rise to a seamless computational network that connects every living being and inanimate object on the planet into an global Internet of Everything. These tools and capabilities continue to develop at breakneck speed, offering a continuously improving toolset for solving complex problems with greater intelligence and ingenuity.

To elaborate and further illustrate the potential for the Internet of Everything to enhance the world's efforts to resolve global challenges, this report focuses on geographic information systems and remote sensing. While by no means a definitive list of ubiquitous computing technologies, these particular technologies have been selected to showcase their current and future impact on global problem solving. The discussion of each trend is supported by case studies of global solution networks and an assessment of the opportunities and challenges associated with using the technology in a global problem-solving context.

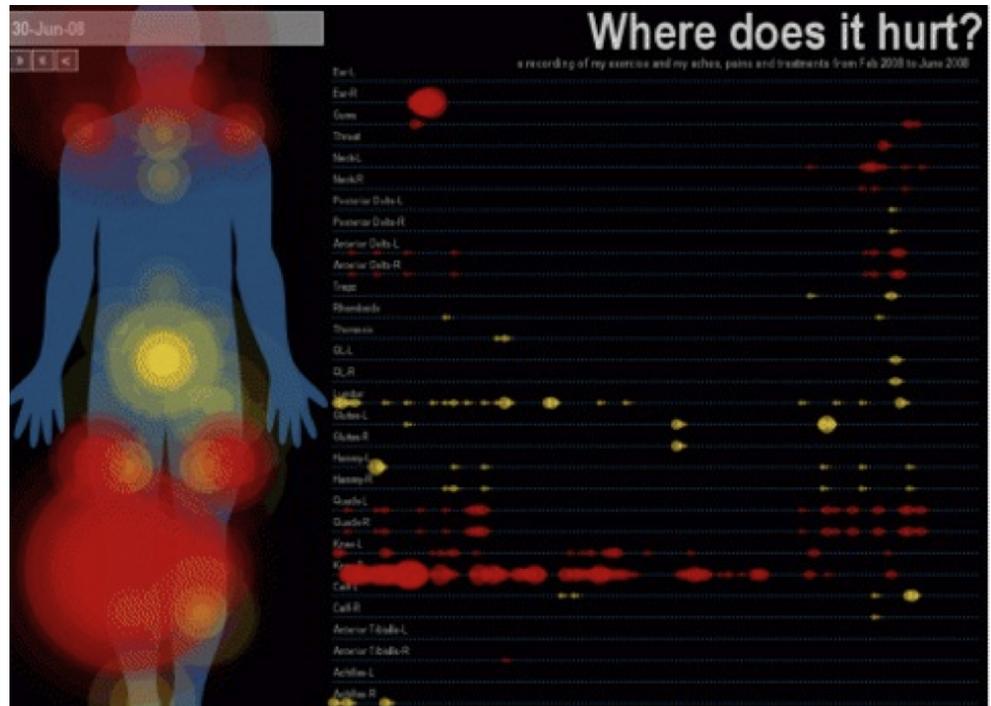
The Internet of Everything and the Rise of a Data-Rich World

Technologists and science fiction writers have long envisioned a world where a seamless global network of Internet-connected sensors could capture every event, action and change on earth. Today, that vision of an Internet of Everything is edging closer and closer to reality. In the past few years, powerful scientific instruments and pervasive computing have powered quantum leaps in the amount of data available to scientists, public policy makers and other stakeholders, raising both new challenges and new opportunities in data-intensive sectors that have had to develop methods, tools and institutions for managing and exploring massive datasets. Of course, the opportunities to extract powerful new insights are also rather tantalizing, and today's big data pioneers are surfacing valuable lessons for researchers and problem solvers focused on global issues ranging from climate change to deforestation to infectious disease prevention.



“*...virtually every animate and inanimate object on Earth will be generating and transmitting data, including our homes, our cars, our natural and man-made environments, and yes, even our bodies.*”

In the data-poor world, the devices scientists used to capture and process data were sparsely distributed and intermittently connected. The result was an incomplete, and often outdated, snapshot of the real world. But distribute billions and perhaps trillions of connected sensors around the planet—just as we are doing today—and virtually every animate and inanimate object on Earth will be generating and transmitting data, including our homes, our cars, our natural and man-made environments, and yes, even our bodies.



Medical sensors help doctors conduct remote diagnosis.¹

Although our bodies are rarely connected to the Internet today, they will be as sensors embedded in clothing and medical devices enable patients with chronic conditions to report their vitals back to a central database that is monitored remotely by physicians. Our cars aren't sharing their data, but they will be too, including their speed, fuel performance, location and road conditions with an incredibly high degree of accuracy. Eventually, self-driving cars filled with sensors will be able to navigate themselves and help optimize the flow of traffic. In fact, Google's self-driving car prototype has already driven hundreds of thousands of miles in test drives without a single incident.





Google's self-driving car²

And while our physical environment (both natural and man-made) may be sparsely connected now, soon we'll have global insight into air and water quality, vegetation, temperature variations, wind speeds and much, much more, at the click of a button. For example, sensors embedded in farmers' fields will detect moisture and communicate with weather satellites in order to optimize irrigation. Sensors embedded in public works and infrastructure like bridges will give engineers advance warning of potential structural problems.



Sensors in farmers' fields detect moisture and optimize irrigation.³



“...by 2020, the wider adoption of big-data analytics could increase annual US GDP in retailing and manufacturing by up to \$325 billion and save as much as \$285 billion in the cost of health care and government services.”

It's not just that the sensors are getting smaller and faster, as Moore's Law⁴ predicts they will; the absolute number of sensors is exploding as more and more applications emerge. In other words, it's a double exponential in terms of the amount of data being generated. In 2010, former Google CEO, Eric Schmidt, famously noted that the amount of data collected since the dawn of humanity up until 2003 is equivalent to the amount we now produce every two days.⁵

The deluge of data generated by transactions, medical and legal records, videos and social technologies—not to mention the sensors, cameras, bar codes and transmitters embedded in the world around us—has enormous economic potential. Advances in computing and analytics can transform this sea of data into insights into new services, new innovations and new opportunities for significant operational efficiencies. McKinsey estimates that by 2020, the wider adoption of big-data analytics could increase annual US GDP in retailing and manufacturing by up to \$325 billion and save as much as \$285 billion in the cost of health care and government services.⁶

With the right tools and the right training, global solution networks can harness this vast cloud of data to develop more analytical approaches to problem solving. For example, GSNs can use distributed sensor networks, GIS and the data these tools generate to revolutionize our ability to model the world and all of its systems, giving us new insights into social and natural phenomena and the ability to forecast trends like climate change with greater accuracy. At the same time, big data will revolutionize the practice of public policy advocacy and even alter the basic skill set required to participate effectively in global public policy debates. For GSNs, there will be tremendous opportunities to develop new knowledge and inform action with credible data. There will also be deep challenges in coming to grips with the infrastructure and tools required to take advantage of big data. Arguably the most compelling example with which to begin illustrating these opportunities and challenges is the application of planetary monitoring and remote sensing to monitoring and managing the global biosphere and the health of our planet's natural systems.

Remote Sensing and the Future of Planetary Monitoring

In the past, natural resource management came down to the capacity of an authoritative, centralized body in a geographic territory to monitor and control the exploitation of a given resource, whether forests, minerals or fisheries. Today, three forces are opening up the regulation of natural resources to a much broader global audience, making new models of planetary monitoring and natural resource management by global solution networks a genuine possibility.



First and foremost among these forces are the powerful advances in monitoring technologies. When the devices we use to capture and process data are sparsely distributed and intermittently connected, we get an incomplete, and often outdated, snapshot of the real world. But thanks to the advances described above, obtaining granular information about the status of natural systems or even the behaviors of entire populations of people will be cost-effective and increasingly accurate and timely. Satellite imagery, coupled with a plethora of intelligent micro-sensors, allows us to cull staggering quantities of data from our natural and built environments, which in turn empowers policy-makers and practitioners to produce much richer virtual models of real-world systems.⁷ And thanks to tools like Google Earth, much of this information is now freely available on the Internet, which gives considerable ammunition to conservationists and local communities.

Second, there is growing recognition that at least some resource stocks should be considered global public goods, due to the ecological services they provide to the global biosphere. Citizens around the globe have taken an increasing interest in the protection of these public goods, and in doing so they call into question traditional notions of national sovereignty when it comes to planetary stewardship.

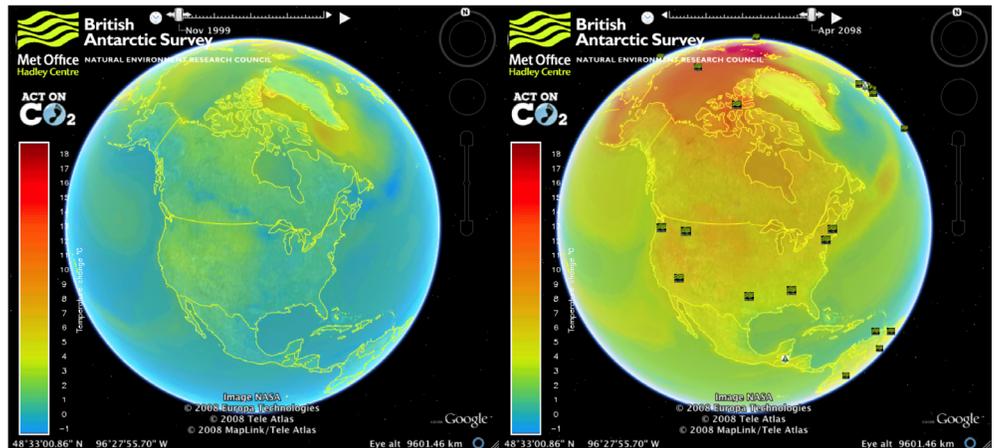
Third, there are well-organized and increasingly agile networks of conservation and environmental groups that reach across national borders and wield considerable influence in key policy debates.

Revolutionizing Climate Science with Remote Sensing

As an example of the first of these trends, consider the work of Greg Asner and Carlos Souza, two scientists at the forefront of environmental science who are hoping to map the locations and rates of deforestation around the world and link the results to climate change. Instead of traversing through vast tracks of jungle in Indonesia or Brazil they have been using a tool available to anyone with a PC and an Internet connection—Google Earth. The scientists are working with Google's team to analyze satellite images that can shed light on the status of the world's forests, without the need for expensive field studies.⁸ In fact, the idea over time is to gather together all of the earth's raw satellite imagery data—petabytes of historical, present and future data—and make it easily available through the Google Earth platform to anyone who cares to make use of it.



“ Within minutes, an interested researcher can see the location and duration of a company’s logging concessions, look up local forestry laws and regulations, and check whether the logging companies have paid their taxes. ”



An example of Google Earth displaying climate data.⁹

The evidence accumulated to date is already helping scientists, governments and conservationists assess the scale of the deforestation problem on a global basis. For example, we now know that emissions from tropical deforestation are comparable to the emissions of all of the European Union, and greater than those of all the cars, trucks, planes, ships and trains on the planet. And thanks to the work of economists such as Nicholas Stern, we also know that protecting the world’s standing forests is one of the most cost-effective ways to cut carbon emissions and mitigate climate change.¹⁰

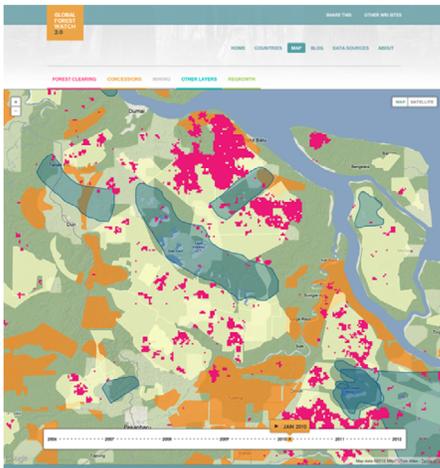
While free tools like Google Earth empower the world’s scientists and policy-makers, they also make information that was once inaccessible and hard to understand available to the broader public. Indeed by displaying this information in bold visual formats, the tools help communicate complex phenomena in a way that most laymen can easily grasp. Whether mapping the world’s oil spills, simulating the effects of sea-level rises, tracking mammals on the verge of extinction or showing national per capita CO₂ emissions, Google Earth, along with the data crunching capabilities of Google’s server farms, provides an ideal platform on which to enhance our understanding of humanity’s impact on the biosphere.

Protecting the World’s Forests with Global Forest Watch

Documenting sea level rises or the location and rates of deforestation on an interactive mapping platform provides a powerful input into science. But when it comes to actually mobilizing local communities to do something about deforestation, there is perhaps no better example than the Washington DC-based World Resources Institute (WRI). WRI maintains Global Forest Watch (GFW), a global watchdog network that improves transparency and accountability in forest management decisions by increasing the public’s access to information on forestry developments around the world. First launched in 1998, the underlying principle is that increasingly powerful



Global Forest Watch empowers local communities to report and prevent illegal logging operations.¹¹



Global Forest Watch provides near real-time forest monitoring capabilities.¹³

information technologies make transparency one of our most potent mechanisms for strengthening the incentives for responsible industry practices and building the capacity for sustainable forest management. The site provides access to a wealth of information about threats to forests and the entities behind those threats. Within minutes, an interested researcher can see the location and duration of a company's logging concessions, look up local forestry laws and regulations, and check whether the logging companies have paid their taxes. Most information can be easily navigated using a visual map interface that taps into a combination of satellite imagery, national forest data sets and "on-the-ground" reports. More advanced users can download geographical data from WRI's warehouse and manipulate it for their own analyses using third party apps like Google Earth.

According to Crystal Hamilton, the WRI's senior manager for GFW, the technology for forest monitoring has improved dramatically since GFW first launched in 1998. In the past, data on forest cover in countries with advanced regulatory regimes was updated annually, while data for developing nations was updated much less frequently, if at all. Regardless of the source, Hamilton called the data unreliable and noted that assessing the rates of deforestation was extraordinarily difficult and labor intensive. "Someone would need to go through the data to compare past and present satellite imagery," she said. "It required a lot of technical expertise and a lot of time."¹²

Today, GFW taps into NASA's satellite imagery and an advanced analytics platform called FORMA that was developed by computer scientists at the Center for Global Development. The new system analyzes the entire planet every 16 days at a resolution of 250 meters. FORMA's built-in algorithms can automatically detect changes in forest cover, allowing researchers, policy makers, industry and communities to respond to issues immediately. Hamilton calls the new system "exceptionally powerful and a vast improvement in the tools available to communities, policy makers, scientists and companies."¹⁴

For many communities that rely heavily on forest ecosystems, GFW fills a gaping hole in their capacity to move toward sustainable forest management. Take Gabon, a small West African country with an extensive system of lush tropical forest that covers 80% of its territory. During past decades, forest data and maps were guarded from the public—sowing confusion on the ground and creating a significant obstacle to sustainable forest management. Citizens living within Gabon's forests were frequently confronting logging operations that had crossed into their communities or customary lands unannounced, posing a serious threat to their livelihoods. Companies operating in logging concessions faced a similar predicament, unable to secure their concession borders and prevent neighboring companies from poaching trees. In the absence of clearly defined, publicly available logging boundaries, forest communities and companies alike had no platform from which to defend their rights. So in 2006, WRI signed an agreement with the Gabonese Ministry of Forest Economy, Water, Fishing and Aquaculture (MEFEP) to collect data and create interactive tools to support sustainable management.¹⁵ These efforts culminated in the publication of a collection of maps and data sets in May 2009. For



“By fostering a global network of nature watchers, we are extending the Internet’s reach and immediacy beyond the human species.”

*Martin Ceperle
Chief Technology Officer
Project Noah*

the first time, policy-makers, companies and citizens have access to an accurate presentation of activity occurring within Gabon’s forest sector.¹⁶

Gabon is just one example. Since 2001, the WRI has built a network of 75 environmental groups and universities that monitors forest development activities in nine countries, which encompass over 60% of the world’s remaining large tracts of intact forest.¹⁷ The network’s broader footprint includes hundreds of additional forestry groups that rely on its data to mobilize global concern and build local capacity in their countries.

With the relaunch of Global Forest Watch 2.0 in 2014, WRI has added many new powerful features to the platform. For example, communities will be able to engage with the forestry industry directly, as companies sign-on to use GFW to report to the public on their forestry operations. Hamilton suggests that companies criticized by Greenpeace for unsustainable forestry practices will have a credible way to demonstrate that they are logging more sustainably. Civil society watchdogs, meanwhile, will be equipped with powerful tools for monitoring compliance with industry commitments.

Other new features include a utility to allow users to post video clips, pictures and audio testimonies, thus bolstering their ability to participate more directly in monitoring nearby logging activities. GFW has also integrated more advanced map servers and social media technologies into its platform. And third party developers are being encouraged to build new applications on top of the Forest Watch platform, creating the potential for even more powerful and ubiquitous applications in the future.

Project Noah and Eye on Earth: Unleashing Multi-Stakeholder Models of Environmental Regulation and Governance

The cases above illustrate how our ability to monitor the world’s forests and understand the ecological effects of global climate change will improve as a combination of satellite monitoring and remote sensors placed in sensitive natural environments gives us instant access to current indicators and data is fed into real-time modeling programs. The granularity and timeliness of the data will not only help establish greater certainty about cause and effect and current and future impacts, it will help provide a basis for sound policy responses.

Just as important, citizens can now participate directly in environmental governance, which vastly expands the human resource pool available for ecological monitoring. “By fostering a global network of nature watchers, we are extending the Internet’s reach and immediacy beyond the human species,” says Martin Ceperley, the Chief Technology Officer for Project Noah, a watchdog network dedicated to monitoring the state of biodiversity on the planet. “As members grow, I envision



an army of citizen scientists, ready to use their cameras and mobile phones to tackle the latest issues at a moment's notice."¹⁸



Project Noah harnesses citizen science to monitor biodiversity on a global basis.¹⁹

Forest management and climate change are only two of many domains where new technologies have enabled participatory models of governance lead by global solution networks. Biodiversity and water scarcity provide other useful examples of how GSNs can augment local regulations and management systems by pooling the resources of a diverse group of stakeholders and leveraging ever more powerful technologies to scale up their impact. When it comes to biodiversity, for example, Ceperley argues that the speed of participatory monitoring solutions can be critical, as when an aggressive invasive species threatens the natural order of delicate ecosystems. "Thanks to the speed at which citizen scientists can document and share observations, invasive species, and their effects, can now be closely identified, studied and remedied before widespread ecosystem troubles emerge—allowing ample time to enact policies to help mitigate further damage," says Ceperley.²⁰

Water scarcity is another urgent issue where a combination of ubiquitous computing, big data and participatory governance arrangements could make a crucial difference. Currently, the world's lack of fresh water is shaping up to be a catastrophe for humanity. 2.8 billion people (44% of the world's population) live in regions where fresh water resources are under severe stress. This troubling figure is set to rise to 3.9 billion by 2030.²¹ As yet, nobody has determined exactly how the world's long-term need for fresh water will be met. But in the meantime, advanced informatics



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solutions such as remote sensing and geospatial mapping are helping policymakers and affected communities better understand the implications of the current demands being placed on regional water systems.

Part knowledge network and part policy network, a GSN consisting of USAID, the University of Colorado at Boulder, and a network of local communities and Asian research institutes is deploying advanced remote monitoring technologies to help understand and protect the High Asia hydrological system, one of the world's most sensitive and important water resources.²² In fact, about one-third of the world's population depends to some degree on fresh water within the High Asia hydrological system, including the populations of Bhutan, Nepal, China, India, Pakistan, Afghanistan, Kazakhstan, Uzbekistan, Kyrgyzstan and Tajikistan. At present, not enough data exists on river and stream flows and the contribution of seasonal snow and glacier melt to paint an accurate picture of the water resources there. But thanks to a combination of satellite monitoring and remote sensing, researchers and local communities will work together to supply more accurate data on how much water there actually is, and how demand and supply are changing as increased development and climate change place new strains on the region's water resources. The data will enable water management officials to forecast the future availability and vulnerability of water resources in the region and make sound decisions with regard to how to manage resources, assess flood risks and understand variations in seasonal flow.

While the USAID project is directed at water management officials, examples like Global Forest Watch and Project Noah have convinced leading regulatory agencies that a more active role for citizens in regulation can increase the effectiveness and legitimacy of new models of global environmental governance. The European Environmental Agency's (EEA) Eye on Earth portal is a case in point. Until recently, environmental quality data across the EU was only available to policymakers and bureaucrats. Now, thanks to Eye on Earth's interactive mapping platform, citizens can access real-time information about environmental quality (including air and water quality readings) not only in Europe's 27 member countries, but in a growing number of countries outside Europe as well. Users can browse the visual imaging interfaces and drill down for detailed, neighbourhood-level data about ozone levels, nitrogen dioxide, particle matter, and carbon emissions. Citizens can even contribute their own data and observations about the environment around them, including first-hand experiences of climate change or potential explanations for environmental degradation in specific areas.

According to Jacqueline McGlade, the EEA's former executive director, the knowledge and increased openness fostered by initiatives like Eye on Earth create new possibilities for cross-sector dialogues where outcomes and scenarios can be visualized and negotiations over strategy are underpinned with the reference data. “We can now bring complex strands of information together into a single, simple-to-use and easy-to-understand application,” says McGlade.²³ “And, as more people understand what's happening in their area, more will contribute to solving environmental problems.” McGlade calls Eye on Earth “an intelligence service for global problem solvers” and argues that shared knowledge has become a critical pathway for creating



multi-stakeholder networks based on trust. And once armed with data, networks can make more effective, data-driven decisions. “Communities are bound together by a shared understanding of the context in which



Eye on Earth provides real-time access to environmental quality data around the world.²⁵

they are trying to solve problems,” she says. “While the multi-stakeholder process will necessarily embody people who may not always agree, the availability of shared reference data creates the possibility to build trust.”²⁴

Establishing trust and a shared evidence base among diverse stakeholders paves the way for more effective collaboration. And the broader promise of increased stakeholder participation is that more transparent and participatory forms of environmental governance will help deliver concrete social outcomes without imposing disproportionate costs on either industry or taxpayers. Systems of regulation will become more fluid and timely, responding both to the evolving needs of societies and the capacity for improvement in industry. Citizens will be more informed to make smart choices and become more empowered to protect their family, friends and communities from harm.

Of course, there are risks too. Governments could cede control of the policy agenda to unelected interest groups or fail to adequately scrutinize the effectiveness of these alternative regulatory frameworks, leaving them vulnerable to gaming or insufficient enforcement. But the greatest risk is that insufficient innovation in regulatory strategies will undermine the legitimacy and effectiveness of policy and undermine economic performance. Worse, systemic regulatory and market failures (comparable in impact to the financial crisis) could unleash detrimental changes in social, economic and political order that will further erode global stability. Harnessing expertise



and resources from emerging global solution networks will be an essential part of developing effective and forward-looking policy responses.

The Future of Real-Time Reporting: From Human Sensor Networks to Intelligent Infrastructure

If a global biosphere laden with sensors could provide GSNs with real-time information about the health of the planet, could human sensor networks supply governments and global solution networks with real-time insights into the health and wellbeing of their most vulnerable communities? And what about the critical pieces of infrastructure that sustain these populations, like the water and sanitation networks that are essential to preventing disease? Could these inanimate objects be connected to the Internet in a way that would make them amenable to real-time analysis? How much useful data would such sensor networks generate? And what steps would need to be taken to ensure the insights are meaningful to policymakers, service providers and other stakeholders in a position to act on the data?

UN Global Pulse: Pioneering Real-Time Reporting



UN Global Pulse pioneers data-driven models of development.²⁶



Such questions are central to realizing the full potential of the Internet of Everything for global problem solving. The good news is that a collection of data scientists working with the UN Global Pulse team not only thinks that such real-time reporting is a possibility, it is actively building the tools and infrastructure to make such possibilities a reality. If successful, such contributions could allow UN projects and policies to move faster, adapt to changing circumstances and be more effective, helping to lift more communities out of poverty and even save lives. The broader global problem solving community would surely benefit too. The UN Global Pulse team's open source ethic means all of its data, research and tools are freely available for other institutions and networks to use.

Set up in 2009 as an innovation arm in the office of the UN secretary general, the Global Pulse team, headquartered in New York, has spent the past four years pioneering data-driven models of development. While a number of solution networks and non-profits are using Internet technology and open data for humanitarian ends, Global Pulse has set its sights on re-engineering traditional development projects in areas such as transportation, water supplies, health care and food distribution.

One of the key problems with major institutional development efforts today, according to Global Pulse, is that development strategies are often built using unreliable and out-dated data. In fact, hundreds of millions of dollars of development assistance pour into poverty alleviation programs, health interventions, educational initiatives and much else on the basis of evidence provided through statistical surveys. Such surveys provide valuable information. But they have many limitations as well. For example, surveys cannot identify trends in real-time or over a short period of time. Because surveys capture data at a single point in time, it is difficult to measure changes in the population unless two or more surveys are done at different points in time. Such repetition is often expensive and time-consuming, making frequent periodic surveys impractical. The field costs in remote, rural communities, in particular, are significant. And, as a result, surveys measuring the health and wellbeing of isolated populations are typically carried out annually or even less frequently than that.

Annual snapshots are inadequate in a world where the factors that determine health and wellbeing in vulnerable populations are constantly changing and subject to unpredictable external shocks. For example, such episodic reporting is incapable of responding in a timely fashion to the information needs of emergency responders in the aftermath of a natural disaster. Nor can episodic reporting provide early warning of an impending health crisis when the presence of certain risk factors, if measured, could otherwise have alerted health officials to the problem.

Surveys are also poorly equipped to provide sound evidence of cause and effect. Continuing with the health analogy, the fact that surveys collect data on disease and risk factors at the same time means that researchers cannot easily tell which came first, the risk factor or the disease. Without this temporal association, it is very difficult to prove that the reputed risk factor actually causes the disease. For example, a survey in a refugee



“Data scientists at Global Pulse believe that mining phone records could be particularly useful in poor regions, where there’s often little or no other data-gathering infrastructure.”

population may find high incidence rates of diarrhea, a low prevalence of access to clean water, and a high prevalence of malnutrition. However, a single cross-sectional survey cannot disentangle the relative contributions of each of these factors to the overall situation; in fact, it is likely that malnutrition and limited access to clean water contribute to high diarrhea incidence, while the high diarrhea incidence also contributes to malnutrition.

And finally, surveys are susceptible to measurement errors that limit their accuracy. Such measurement errors can be brought about by respondents’ own behavior (e.g., misreporting true attitudes, failing to pay close attention to a question), interviewer behavior (e.g., misrecording responses, providing cues that lead participants to respond in one way or another), and the questionnaire (e.g., ambiguous or confusing question wording, biased question wording or response options). These factors can be controlled for in a well-designed and well-executed survey, but concerns about data quality in surveys continue to feature prominently in methodological arguments amongst academics.

Harvard School of Public Health: The Rise of Human Sensor Networks

If surveys are flawed, what’s the alternative? The data scientists at UN Global Pulse believe that mining phone records could be particularly useful in poor regions, where there’s often little or no other data-gathering infrastructure. Of the world’s six billion phones, five billion are in developing countries. Many of them are cheap phones that can do little besides make calls and send text messages, but such activity can still be tracked back to cell-phone towers, providing a rough way to trace a person’s movements, and thus the shape of social and economic networks. Throw in the spread of mobile payment technology for simple commerce and you have the raw material for insights into employment trends, poverty, transportation, economic activity and much more. Global Pulse researchers call the resulting networks of data “human sensor networks.”

While human sensor networks enabled by mobile phones and other digital platforms cannot alleviate all of the limitations of conventional reporting, they do offer important advances. A recent report produced for the UN Global Pulse Team cites a number of advantages for global problem solvers.²⁷ First, human sensor networks are ultimately less costly research tools than traditional surveys. Much of the infrastructure for collecting the data (the most costly aspect of field research) is embedded in the personal technologies and tools that individuals are already using, whether mobile phones or communication platforms like Twitter.

Second, with human sensor networks, citizens become largely passive participants in data collection without having to alter their normal routines. Passive research integrates seamlessly into everyday life, such that the data reflects the actual needs and behaviors of communities, rather than





A cell tower in Kericho is the equivalent of epidemiological gold for epidemiologist Caroline Buckee.²⁸

the rationalized needs and behaviors that they express to survey researchers. Even a trip on a bus or simple walk down the street can generate meaningful data.

Research into the spread of malaria conducted at the Harvard School of Public Health is a case in point. Conventional public health strategies for combating malaria rely on sending teams of epidemiologists into the field. But epidemiologist Caroline Buckee spends most of her time examining the anonymized cell phone records of 15 million Kenyans. According to Buckee, just studying one particular cell phone tower near the town of Kericho in Kenya's western highlands represents the equivalent of epidemiological gold.

When she and her colleagues studied the data, she found that people making calls or sending text messages originating at the Kericho cell tower were making 16 times more trips away from the area than the regional average. What's more, they were three times more likely to visit a region northeast of Lake Victoria that records from the health ministry identified as a malaria hot spot. The tower's signal radius thus covered a significant waypoint for transmission of malaria, which can jump from human to human via mosquitoes. Satellite images revealed the likely culprit: a busy tea plantation full of migrant workers, a large proportion of whom were likely infected with malaria.

Buckee's work is now feeding into a new set of predictive models. The models show, for example, that even though malaria cases were seen at the tea plantation, taking steps to control malaria there would have less effect on the disease's spread than concentrating those efforts at the source: Lake Victoria. That region has long been understood as a major center of malaria, but what hasn't been available before is detailed information about the patterns of human travel there: how many people are coming and going, when they're arriving and departing, which specific places they're coming to, and which of those destinations attract the most people traveling on to new places.

The data mining will also help inform the design of new measures that are likely to include cheap, targeted campaigns of text messages—for example, warning visitors entering the Kericho tower's signal zone to use bed netting. And it will help officials choose where to focus mosquito control efforts in the malarial areas.

As with environmental information, the increased granularity and immediacy of the information reported creates the opportunity to yield insights that static and periodic survey cannot replicate. In another example, the UN Global Pulse team found that analyzing Twitter messages can give an early warning of a spike in unemployment, price rises and disease. Such "digital smoke signals of distress" usually come months before official statistics—and in many developing countries today, there are no reliable statistics. Research found, for example, that surges in online mentions of rice prices accurately captured price increases several months before official reports. "If you have information in multiple dimensions, you can begin to understand the dynamics of complex socio-technical systems," says Deborah Estrin, director



“...the exponential adoption of mobile phones in low-income settings—and the new willingness of some carriers to release data—will lead to new technological tools that could change everything.”

Vincent Blondel
University of Louvain

of the Center for Embedded Network Sensing at UCLA. “Through better understanding we can better predict future change.”²⁹

Speeding up the flow of relevant information, in turn, can expedite effective responses. “The minute an observation is made, it is geo-coded, time-stamped, uploaded to a database, put on a chart, as well as a map, with no manual intervention,” Estrin explains. “The data doesn’t sit dormant—the data goes straight from a human making an observation to a proper visualization.”³⁰ Such speed can be vital in saving lives or intervening early enough in a crisis, according to Sharad Sapra, the Ugandan country representative for UNICEF, who suggests that one of the agency’s biggest operational challenges “is to cut down the delay on basic actionable data, especially micro-level, on the ground data.”³¹

Vincent Blondel, a professor of applied mathematics at the University of Louvain in Belgium and a leading researcher on data gleaned from cell phones, is optimistic that Sapra’s challenge can be met. “We are just at the start of using this data for these purposes,” he says, “but the exponential adoption of mobile phones in low-income settings—and the new willingness of some carriers to release data—will lead to new technological tools that could change everything.”³² Of course, there are serious risks and legitimate questions about who owns and controls all of the data the researchers are collecting from telecom companies. Alex Pentland, director of the Human Dynamics Lab at MIT, wonders, for example, what might have happened had a figure like Muammar Qaddafi gained access to this sort of data. To be sure, much work must be done to ensure that a data-driven future does not fatally undermine privacy or make it easier for governments to target dissidents and oppress their peoples.

Smart Santander: Making Infrastructure Intelligent

Human sensor networks give us new insights into the wellbeing and behavior patterns of human communities. But what about monitoring the built environments that they live in, including all of the essential infrastructures that sustain them—from electrical grids to roadways to water and sanitation systems? Until quite recently, the processes for such monitoring have been costly and inefficient. “We’re surrounded by technological assets that are deaf, blind, can’t taste, can’t smell and can’t feel,” says Stan Williams, an HP senior fellow who leads the Information and Quantum Systems Lab (IQSL).³³ But that’s about to change, with sensors that can track the structural integrity of bridges, monitor hospital equipment, sniff out pesticides and pathogens in food, or even ‘recognize’ the person using them and adapt. “We are making sensors that are vastly more sensitive than anything else that [has] ever existed before,” says Williams. And the next challenge will be to make them “absolutely dirt cheap so that we can deploy them in very large numbers.”³⁴





Santander—now one of Europe’s “smartest” cities.³⁷

Motion and vibration detectors are some of the most common among this next generation of sensors. More accurately called accelerometers, they are ever-present in today’s smartphones. The ones you find in an iPhone are sensitive enough to “feel” a heartbeat. But the most exquisitely sensitive accelerometer can detect a 10 femtometer change in position. At less than one-billionth the width of a human hair, it’s exceptionally sensitive.

Accelerometers are merely the tip of the iceberg, though. There are sensors for light, temperature, barometric pressure, airflow and humidity. And around the corner are sensors that can “taste and smell.” Researchers in universities and corporate labs are using nanomaterials to boost a standard chemical and biological detection technology (Raman spectroscopy) to 100 million times its usual sensitivity rates. As sensitivity rises, sensor size can shrink. That could lead to detectors small enough to clip onto a mobile telephone. With a wave over produce, the sensor might warn consumers of salmonella on spinach leaves or pesticides present in “organic” produce.

This plethora of new sensing capabilities will unleash countless new monitoring and real-time reporting opportunities. Indeed, the potential to make dumb infrastructure intelligent has companies like Cisco, HP, IBM and Microsoft hastily developing intelligent infrastructures to measure everything from water and natural gas flows to urban infrastructure, transportation networks and agricultural supply chains. Sensors and RFID tags attached to foodstuffs, for example, can track meat or other agricultural products from the producer all the way to the supermarket shelf.³⁵ Armed with this data, retailers can ensure the quality of supply while customers can make smarter purchasing decisions. Meanwhile, IBM’s headquarters in France is laden with sensors that regulate lighting and the indoor temperature in accordance with external conditions. Additional sensors curtail water flow as individual areas of the building approach pre-determined limits.

Urban planners think that equipping entire cities with such capabilities could have a massive impact on utility usage, as well as a wide range of other benefits. As a test of this proposition, the coastal city of Santander in Spain recently won a multi-million dollar grant from the European Commission to become one of Europe’s “smartest” cities. The city has deployed more than 10,000 sensors to monitor everything from garbage collection to crime to air quality.³⁶ Some of these sensors conserve energy by optimizing street lighting, dimming the lights when there is no one on the street, and emitting less light during a full moon than on a rainy night. Sensors in parking spaces direct drivers to available spaces and enable a time-based metering system that matches prices to demand. City buses transmit their position, mileage and speed, as well as data from the ambient environment, such as ozone or nitric oxide pollution levels. Taxis and police cars do the same. Back at the University of Cantabria, which houses the data and the city’s central dashboard, researchers and city officials can observe where the traffic jams are and where the air is bad. Citizens can access all of the same data on their smartphones with a few clicks on the Santander’s “Pulse of the City” app.

The drive to make all things “smarter” by connecting inanimate objects to the Internet will, within a few years, result in a flood of new data that can



“Development dollars continue to be pumped into new ‘things,’ rather than maintaining what we already have. Things get built, work for a year, then break and never get repaired because there is no communications platform to alert the proper authorities.”

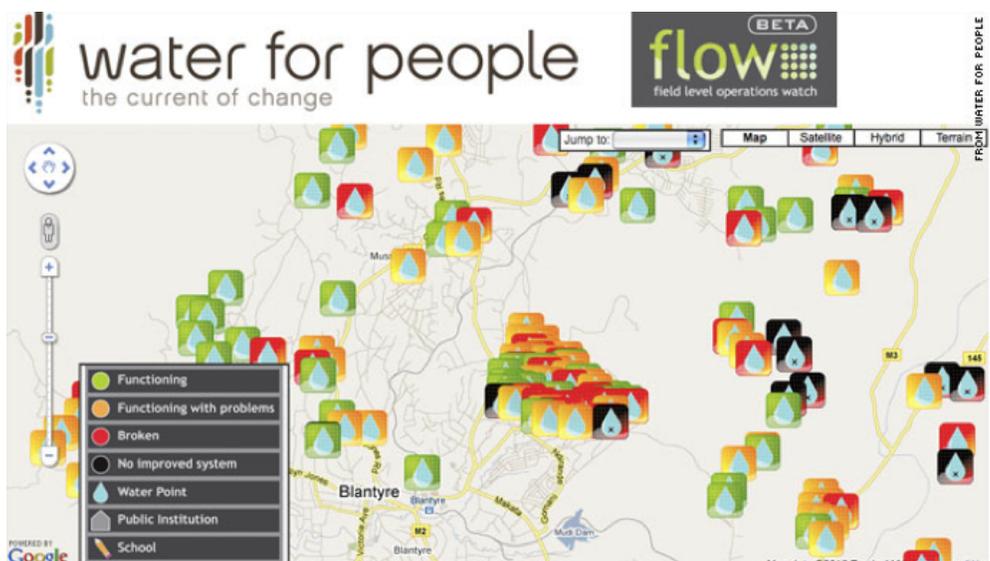
Andrew Hoppin,
Chief Information Officer
New York State Senate

be aggregated and analyzed, providing a powerful engine for infrastructure management dashboards that provide a real-time view of how assets across the system are faring. Reaching that kind of scale, however, will take some work. Williams figures that it would take a million or so sensors for a big business application, such as cargo shipping, and at least a trillion sensors to “informat” the entire Earth. At that rate, sensor nodes must cost next to nothing, yet measure everything.

Even then, the data processing and storage issues still present major challenges. “How do you capture and use all that data?” asks Williams. At a typical data rate, one million sensors running 24 hours a day would require 50 hard disks running in parallel to capture the 20 petabytes of data created in just six months. Imagine the data flowing from one trillion sensors. “The amount of data we’re talking about here is ferocious,” says Williams.³⁸

Akvo FLOW: Bringing Intelligent Infrastructure to Developing Countries

The intelligent infrastructure plans of global tech giants aside, is it reasonable to propose that such advanced technologies could be readily applied in low-income countries where underdeveloped infrastructure and embryonic monitoring capabilities might suggest other priorities? The prospect is not as distant as one might assume. In fact, solutions enabled by the Internet of Everything could help governments and global solution networks address the very challenges low-income countries face in monitoring their infrastructure assets effectively. “Development dollars continue to be pumped into new ‘things,’ rather than maintaining what we already have,” says Andrew Hoppin,



Akvo FLOW, an open source sensor network, connects wells and pumps across Africa to create real-time reporting systems.⁴¹



the Chief Information Officer for the New York State Senate. “Things get built, work for a year, then break and never get repaired because there is no communications platform to alert the proper authorities.” When it comes to critical infrastructure—like infrastructure for water and sanitation—such lapses in information and management capacity can turn deadly.

Around the world, 783 million people lack access to safe drinking water and 2.5 billion are without adequate sanitation facilities. Every day, nearly 6,000 people die from water-related illnesses, and the vast majority of these are children.³⁹ Improving water and sanitation is essential to improving the lives of those living in poverty. In fact, basic infrastructure improvements that address water and sanitation problems have a measurable payoff, according to the World Health Organization. In a cost-benefit analysis, the WHO found that “water and sanitation improvements are cost-beneficial in all developing world sub-regions.” The analysis suggested that, “The return on a US \$1 investment was in the range of US \$5 to US \$46, depending on the intervention.”⁴⁰

Some of the most beneficial improvements are those that enable authorities to assess and maintain existing water infrastructure before problems cause deleterious health effects. Consider Akvo FLOW, whose open source sensor network connects wells and pumps across Africa to create a real-time reporting system that is revolutionizing the way authorities manage water quality and water supply issues. Founded in 2010 through a partnership between an NGO called Water For People and an open source software development group called Akvo, Akvo FLOW was initially established to enable aid networks to monitor and evaluate initiatives in the world’s poorest and most remote places, using location-aware mobile phone surveys. The group quickly determined that water and sanitation issues provided an effective test of their technology. As of August 2013, Akvo FLOW water monitoring networks are being used by 69 organizations⁴² in 28 countries.⁴³

Prior to the availability of Akvo FLOW, the majority of governments doing fieldwork to assess water and sanitation infrastructure would compile data manually, through paper-based surveys. Data collection was slow and the tabulations rife with errors. Once the data was collected, it often took too long to reach the appropriate audiences. Akvo FLOW solves this problem by deploying sensor networks and mobile software to more efficiently collect, analyze and report monitoring data, enabling fieldworkers to track the status of sanitation and water projects more effectively.⁴⁴

Even where connectivity is limited, FLOW’s infrastructure is still useful. Data can be collected offline for weeks, and when the phone is in a location with connectivity, the data is uploaded to central databases. At a project based in Sierra Leone, data for about 30,000 water points was collected completely offline, with the enumerators delivering the phones to field managers every two weeks, and the field managers downloading the data from the phones to their laptops and uploading it later.

Often, when projects begin, most governments are struggling with limited or inaccurate information and need to improve (and in some cases, rebuild)



“Our tools provide a way for governments to get data and have a fact-based discussion. While they still may debate about policy, there should be no disagreements about facts.”

*Dr. Mark Tiele
Westra
Akvo FLOW*

infrastructure. For example, after the lengthy and devastating civil war in Liberia (a conflict that lasted over four years and killed as many as 300,000 people),⁴⁵ the government needed to understand its water situation. After a nation-wide mapping exercise of 10,000 water points using Akvo FLOW, the government produced a water atlas and a comprehensive plan to improve water provision. According to Dr. Mark Tiele Westra, a manager with Akvo FLOW, the team is working on new functionality that will enable Liberia to monitor its water infrastructure on a real-time basis. “For this whole process, the flow of information enabled by the FLOW software is crucial,” he says.⁴⁶

Akvo FLOW could also be used to help settle disputes over shared water resources in regions such as the Zambezi river basin, an area inhabited by residents of Angola, Namibia, Botswana, Zimbabwe, Zambia, Tanzania, Malawi, the Democratic Republic of the Congo and Mozambique. As an NGO, Akvo cannot institute binding rules for allocating water rights, but it can work with governments to provide valuable and reliable data. According to Dr. Westra, “Our tools provide a way for governments to get data and have a fact-based discussion. While they still may debate about policy, there should be no disagreements about facts.”⁴⁷ And, while Akvo FLOW is mainly used to manage wells and pumps in developing countries, it could be used to monitor a variety of local infrastructure, suggesting that the promise of real-time infrastructure monitoring in developing countries is just getting started.⁴⁸

Making Real-Time Reporting a Reality

The promise of big data and ubiquitous computing in the domain of global problem solving boils down to the capability to obtain a more granular, encompassing and immediate view of the problems GSNs are trying to solve. Whether monitoring nature or people or built environments, accurate information at the right time can lead to better decision making and inform timely action. Martin Ceperley of Project Noah sums up the value of human sensor networks, intelligent infrastructure and real-time reporting as follows: “Metcalf’s Law says that the value of a network is proportional to the square of the number of connected nodes. As new nodes are added to our networks, both mechanical sensors and human observers, we are slowly building a data network that has the capability to reflect the ever-changing tides of life on earth. In one sense it has become a 911 service for the planet, in that cries for help that previously went unnoticed, can now be heard.”⁴⁹

How can GSNs help bring this reality closer to fruition? The UN Global Pulse team has pinpointed a few essential requirements for global solution networks. GSNs will need access to a wide variety of data points that collectively provide an encompassing picture of the welfare of individuals, communities and the planet. They will need technologies to collect, filter and analyze information to know when human populations or natural systems may be in the early stages of suffering from an external shock, like an emerging health crisis for example. And they need to nurture the capacity to use real-time data to inform both short-term operational priorities and long-



term policy objectives. In the next section, we explore these requirements in greater detail.

Implications for Network Leaders

A data rich world will generate many new opportunities, but there will be some difficult adjustments and issues such as privacy, intellectual property and national security to confront along the way. “We’re going from a data poor to a data rich world,” says Larry Smarr, a pioneering data scientist at the California Institute of Technology. “And there’s a lag whenever an exponential change like this transforms the impossible into the routine.”⁵⁰ People aren’t necessarily good at thinking about exponential changes, he argues, and as a result, it seems that people in the business of solving global problems are vastly under-investing in the skills and tools required to take advantage of the “big data” revolution. The following are some observations on the challenges and opportunities that global solution networks and those who lead them will encounter.

Prepare for exponential change. More powerful instruments and sensor networks have led to exponential increases in the amount of data available to everyone, including scientists, governments, companies, NGOs and interested citizens. This is not only true of data-intensive disciplines like biomedicine and astrophysics but also other fields like oceanography where sensor networks are providing researchers with an astonishing wealth of undersea data once accessible only through costly marine expeditions. At the same time, open government initiatives around the world are liberating the mountains of public data that lay dormant inside government agencies, a strategy that has proven in numerous cases to increase transparency and stoke public service innovation when third parties develop their own services using the data. Things are bound to get much more interesting when open government innovators start to harvest new data from the real world, as scientists are doing today. And case studies such as Global Forest Watch, Project Noah and UN Global Pulse show how this explosion of data will drive incredible improvements in our ability to solve global problems.

Time compression will lead to the need for accelerated decision making. As information is collected more frequently, the more significant events will be reported and recognized in real-time. Businesses, for example, will be forced by competitive pressures to speed up their operations as the flow of information through the firm (orders, customer feedback, money, materials, people, etc.) increases by orders of magnitude. And while the acceleration of economic activity may be the most acute example of time compression, evidence of time compression will be found in almost all aspects of life as more immediate and frequent reporting of events causes the public to expect speedier responses to emerging issues. For global



solution networks, time compression will increase the social and economic uncertainties brought on by the speed of change. Accelerated decision-making could be challenging, particularly for networks that feel the pressure to ensure that appropriate deliberation takes place on major issues.

GSN leaders will need to implement more effective decision-support systems (e.g., intelligent agents and simulation software) and processes for probing, monitoring, and assessing information about the rapidly changing environment. A robust predictive capacity would enable GSNs to begin formulating responses before trends and patterns emerge as full-blown issues that demand a hasty response. More comprehensive data from the users of health care interventions and services, for example, could provide public health officials with richer feedback on how to improve or target services or programs, well before costly health epidemics emerge.

Remote sensing could unleash new social controversies and undermine privacy. Human sensor networks and smart cities like Santander show the potential of data-driven decision-making. The ability to obtain granular digital information about people, populations or physical objects and places, however, will not come without risks that these technologies will be used by certain parties to violate privacy, commit crimes or even exercise forms of excessive social control. Indeed, the recent revelations of NSA spying are already causing concern. Increased data granularity will heighten these concerns and stir up new controversies as societies wrestle with the social implications of a world with pervasive connectivity, where every minute movement or trivial utterance could be detected and recorded for subsequent analysis.

We already live in a world where we all leave behind an ever-growing trail of digital breadcrumbs as a growing proportion of our daily lives plays out online—from the books, music and stocks we buy online, to our groceries scanned at the supermarket, to the card reader at the parking lot and prescription drugs we buy at the pharmacy. Now, the increasing number and growing accessibility of connected mobile devices capable of recording and transmitting information will drive quantum leaps in information available about everyone and everything. We are quickly moving into an era in which access to even the most powerful surveillance technologies—including high-resolution satellite imagery—will extend from a handful of government agencies to a much broader audience. Such tools can as easily be applied to humanitarian uses such as tracking the flows of refugees to decide where emergency services are needed as they can to support uses such as illegal espionage. Without safeguards, a world of ubiquitous data and radical transparency could pose even graver risks to our privacy, our identity, our safety and even our sense of personal autonomy.

Harnessing the Big Data Revolution

With these observations in mind, how can GSNs build or acquire the skills and tools required to take advantage of the Internet of Everything and



the associated “big data” revolution? The research and case examples suggest a number of priorities, including the need to invest in data literacy, launch crowdsourcing initiatives to engage the public, develop public interest applications and infrastructure through partnerships with leading technology communities and companies, and build data sharing alliances among GSNs operating in data intensive fields.

Big Data will require new models of data science and make us more dependent on artificial intelligence and on global solution networks.

The term “Big Data” was coined for a good reason: today’s datasets are getting so large and complex that conventional tools for collecting, storing, analyzing and visualizing them have been rendered insufficient. Indeed, the real challenge for scientists and others engaged in global public policy issues is not just collecting the relevant data, but analyzing and making sense of it. And not just each individual data stream in isolation, but the larger emergent patterns arising out of the cacophony of information we are constantly assembling. Big data is already driving the need for advanced artificial intelligence that can detect patterns that the human mind cannot. But perhaps one of the more intriguing results of the big data revolution is that the research and public policy community increasingly recognizes that no one scientist, team or organization has the scale to create and curate the deluge of data on its own. In other words, big data is driving the need for global solution networks. In fact, global knowledge networks and research organizations have little choice but to pool the financial and human resources necessary to undertake these large-scale projects. One of the first priorities for GSNs should therefore be to build data sharing and capacity building alliances among networks that are operating in data intensive fields.

With data sharing alliances in place, GSNs can use social media to break down institutional barriers and develop effective networks for leveraging big data. Recent technology-enabled collaborations that have emerged to accelerate progress in oceanography provide a stunning example of this. Take Neptune, the world’s first regional-scale cabled observatory network, which is located off the west coast of Vancouver Island, British Columbia. The network, which extends across the Juan de Fuca plate, gathers live data from a rich constellation of instruments deployed in a broad spectrum of undersea environments. Data is transmitted via high-speed fiber optic communications from the seafloor to an innovative data archival system at the University of Victoria.

This system provides free Internet access to an immense wealth of data, both live and archived throughout the life of the planned 25-year project. Researchers using Neptune’s Oceans 2.0 platform also have access to a rich suite of social media tools and can tag everything from images to data feeds to video streams from undersea cameras, identifying sightings of little-known organisms or examples of rare phenomena. Wikis provide a shared space for group learning, discussion and collaboration, while a Facebook-like social networking application helps connect researchers working on similar problems around the globe. Adopting similar tools and methods will help network leaders acquire the skills and expertise required to take on data-intensive projects.



GSNs will need to tap into skilled communities to build public interest applications for pervasive computing platforms. Fortunately, a growing number of capable networks have emerged to help facilitate the application of advanced skills to global problems. Random Hacks of Kindness (RHoK), for example, is an operational and delivery network that builds practical open technology to make the world a better place. Now a thriving independent global community of 5,500 innovators in 30 countries, RHoK was formed by Microsoft, Google, Yahoo, NASA's Open Government Team and the World Bank to identify problems where software solutions can help resolve the challenges humanity faces. In 2011, RHoK's volunteer coders created CHASM, a visualization tool for complex landslide risk models that emergency responders in Malaysia, Indonesia and Hong Kong have used to estimate the effects of severe storm events on slope stability. Today, anyone with the necessary skill set is welcome to join RHoK and help create solutions through a regular series of "hackathons," "app competitions" and other community-driven events. Solutions developed by the RHoK community continue to be used by organizations such as the World Bank, governments, emergency responders and citizens.

GSNs can combine satellite monitoring and remote sensing with local crowdsourcing efforts to engage the public. In fact, the combination of these methods provides a powerful way to capture local irregularities and issues that are impossible to detect remotely. GFW has recognized, for example, that while visual maps and computer algorithms can help detect deforestation patterns, there is no substitute for local knowledge and on-site intelligence when it comes to identifying the source of deforestation. The same is true in other domains, including biodiversity and water. Project Noah's detailed maps displaying biodiversity around the planet wouldn't be possible without the on-the-ground photos and reports contributed by its global network of nature watchers. And as Sara Boettiger noted in her report on Global Solution Networks and New Tools for Tackling Poverty, GSNs are working all over the world to address water quality and water supply issues, and crowdsourcing features prominently in the toolkit of effective approaches. In addition to the Akvo FLOW case featured earlier, IBM worked with the government of South Africa in 2013 to create a crowdsourcing platform that allows users to report problems with water pipes and leaks, and generally comment on the delivery of water.⁵¹ In Berlin, WaterWatcher is another a simple, cheap test of water quality that interfaces with your mobile phone.⁵²

GSNS will need data scientists and must invest in data literacy training. Basic data literacy is assumed amongst scientists, but the general population has nowhere near the level of data literacy that will be required in most professions in the near future. And the same can be said of the vast majority of organizations that participate in global solution networks, with the UN Global Pulse team representing a rare exception. Even in science, recent developments have upped the ante. To do path-breaking science, scientists need to be fluent in large-scale data analytics or partner with someone who is. Similarly, skills in managing, presenting and extracting insight from data will be increasingly valuable in the business of solving the world's problems. Indeed, it will be increasingly difficult to convince anyone—citizens,



governments or corporations—of the need to change behavior in the absence of convincing data. Accordingly, GSNs will need to foster data literacy within their memberships through workshops and training sessions and should also work with organizations such as Global Pulse to cultivate an interest in global problem solving among the broader community of data scientists.

GSNs will need to harness cloud computing and parallel programming. As already noted, the emergence of crowd sourcing and citizen science, along with widely dispersed sensors, will produce vast amounts of new data, from low cost unstructured sources. The implication is that implementing these distributed monitoring and data collection strategies will only be viable if sufficient infrastructure is developed in parallel. For example, massive volumes of data might be collected in real time and would need to be uploaded, synthesized and analyzed in relatively short order. Even with numerous real-time sensors, measurements would not be collected at all places at all times, so analytical techniques would be required to discern temporal or spatial patterns from the raw data. Global solution networks will need to enhance their computational and analytical infrastructure, or alternatively, could partner with companies already utilizing similar technologies. Similarly, global problem solvers will need to increase resources devoted to statistical analysis, including Bayesian techniques and other strategies to optimally combine model outputs and monitoring data. In short, the time has come for the global problem solving community to get serious about its need to take advantage of advanced computing services, including new approaches such as parallel programming and cloud computing.



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About Global Solution Networks

Global Solution Networks is a landmark study of the potential of global web-based and mobile networks for cooperation, problem solving and governance. This research project is a deliverable of the GSN program, offered through the Martin Prosperity Institute at the Rotman School of Management, University of Toronto.

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Ten Types of Global Solution Networks