SERIOUS INFECTIOUS DISEASE

Challenges for Security and Defence

Proceedings of the Conference 'Serious Infectious Disease: Challenges for Security and Defence'

Edited by Jennifer Cole

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Serious Infectious Disease
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Proceedings of the Conference 'Serious Infectious Disease: Challenges for Security and Defence', 23 January 2015

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Foreword

Of all the challenges facing the UK today, few are as challenging (or as important) as those affecting national security. Some threats to the UK and its citizens are modern variants of those that the country has faced for many years. Some are entirely new and qualitatively different to anything that has preceded them, while others have yet to be recognised, analysed and understood.

One feature of this large, complex and constantly evolving array of challenges is that few, if any, lend themselves to single-discipline solutions. With this in mind, the Science and Technology Facilities Council (STFC) operates a Defence, Security and Resilience Futures programme. Challenge-led and agnostic with respect to academic discipline, the STFC's aim is to identify and facilitate opportunities to engage relevant capabilities within the UK National Laboratories and university research groups more widely, with some of the highest priority and most demanding challenges in national security.

As part of this programme, the STFC is delighted to fund, and proud to collaborate closely with, the Royal United Services Institute (RUSI) in delivering a series of conferences on topical issues within this domain.

Each meeting is designed to explore the interface between academic research and government policy and operations. The aim is to stimulate debate on how a step change, rather than an incremental one, in the protection of the UK could be achieved. The meetings are strategic in character, with contributions from an atypically broad community drawn from universities, industry, government and its agencies and partners.

The meetings engage with a simple question: what can academic research offer now and in the future, to allow government to further enhance its capabilities in key areas so that it can either do significantly different things, or do what it does now in significantly different and better ways?

The threat, and possibility of new and improved ways to defend ourselves against pandemic disease, is a case in point. While it is not known precisely when or where it first emerged, the novel strain of influenza virus responsible for the 2009 flu pandemic was first identified in Mexico in early April 2009. How long it existed before this is unknown. However, what is now well documented is its rapid spread across the globe. On 25 April 2009 the World Health Organization (WHO) declared its first ever 'public health emergency of international concern' (PHEIC). The same month, the UK Foreign and Commonwealth Office advised against all but essential travel to Mexico and invited citizens already there to 'consider whether they should remain in Mexico at this time'.

The first case in the UK was identified in passengers returning by air from Mexico in April 2009 and the first person-to-person transmission in the UK occurred in May 2009. Retrospective analysis by Sir Liam Donaldson, then chief medical officer for England, and colleagues in the Department of Health and the Health Protection Agency (now Public Health England), attributed 138 deaths in England by November 2009 to the disease, and estimated that 540,000 people had symptomatic flu. WHO reported in May 2010 that 214 countries, overseas territories or communities had reported laboratory-confirmed cases and placed the death toll at 18,036.

This, though chilling, is modest in comparison with other flu pandemics to have occurred in the twentieth century and disease mortality more generally. For example, the Spanish flu outbreak in 1918–19 was responsible for some 50–100 million deaths worldwide, while WHO has estimated that malaria killed more than 630,000 people in 2012 alone. Despite such comparisons, the 2009 flu pandemic is a clear and compelling example of the potential for new diseases, and novel strains of established diseases, to emerge without warning and spread rapidly in an increasingly interconnected world. These fears are reinforced by the outbreak of Ebola in 2014. So great is the threat to the UK that 'animal disease', 'emerging infectious disease' and 'pandemic influenza' all appear explicitly in the UK National Risk Register for Civil Emergencies.

Conflict and post-conflict zones create particular challenges for controlling and containing infectious disease. Damage to hospitals, the degradation of health-care infrastructure and the loss of skilled medical personnel during conflict creates an environment in which infectious disease can emerge and spread rapidly. Meanwhile, failed states and those still struggling to recover from recent conflict are ill-equipped to provide health-care systems that meet the complex needs of their populations. In addition, peacekeeping and stabilisation forces, NGOs and international aid workers can inadvertently bring infectious diseases into communities when they are at their most vulnerable.

In the months preceding this meeting, WHO declared two further PHEICs. The first, in May 2014, was due to the increasing number of polio cases recorded worldwide – particularly in Syria and Somalia, where the disease had previously been eradicated. The second, in August, was in response to the outbreak of Ebola in West Africa, which has since become the largest in history.

In both cases, the geopolitics of the regions have played a key role in the outbreaks. In Syria, polio re-emerged and spread during a conflict that has disrupted the childhood-vaccination programme. The strain responsible originates from Pakistan, where polio remains endemic: Taliban opposition

to vaccination programmes has contributed to this situation. In West Africa, Ebola spread rapidly through communities with little, if any, modern health-care provision and through populations which had a deep mistrust of government agencies following devastating civil wars.

With the wider context for the meeting in mind, this report concentrates specifically on serious infectious disease in conflict and post-conflict zones. It considers three separate but related strands:

1. How does conflict enable disease to emerge and spread in regions lacking sophisticated health-care systems, and how does the resulting humanitarian crisis arising from such events unfold? The re-emergence of polio in Syria; its remaining endemic in Islamist-controlled regions due to anti-vaccination narratives; and Ebola in West Africa, provide vehicles for identifying more general issues and trends

2. Situational awareness is critical. Containing and tackling outbreaks needs more than just additional medical equipment and personnel to be 'parachuted in'. It requires rapid assessment of the situation on the ground, including the condition and capability of local health-care systems, understanding of cultural and behavioural factors and level of trust in the government and other parties. How can these be achieved quickly and effectively?

3. The spread of disease is facilitated by damaged and degraded health-care systems, or in environments in which no effective system existed previously. What technology, including surveillance (for example by crowdsourcing and amalgamation of several different sources), modelling (perhaps in the face of sparse or unreliable data) and laboratory systems (for identifying and characterising infectious agents without laboratory infrastructure often taken for granted) are most critical?

Data (choice, collection, visualisation, analysis and interpretation) is a common thread to all three of these strands, albeit in different ways. While there are undeniably many and complex technical challenges, ethical, legal and other factors will no doubt be important. Many of the factors identified in another conference in this series, particularly 'Data for Security and Resilience', will have obvious resonance.

Thanks must go to the staff at the STFC and RUSI, whose extremely hard work made the event possible. The final word of appreciation and gratitude is reserved for all those who participated so enthusiastically on the day itself, whether as speakers or as delegates.

Anyone wishing to know more about the STFC's Defence, Security and Resilience Futures Programme in general, or these conferences in particular, is invited to contact me at the email address below.

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Introduction

Jennifer Cole

In mid-2014, the World Health Organization (WHO) declared two Public Health Emergencies of International Concern (PHEICs), indicating events that constitute a public-health risk to a number of states and which potentially require a co-ordinated international response:[1] one, in May 2014, because of the increasing number of polio cases recorded worldwide – in particular in Syria and Somalia, where the disease had previously been eradicated – and the second, in August, in response to the outbreak of Ebola in West Africa which went on to become the largest in history. Two simultaneous PHEICs are of particular note as, prior to this, only one had been declared since the introduction of the term in WHO's *International Health Regulations (2005)*,[2] in response to the H1N1 Swine Flu pandemic of 2009–10.

In both instances, the root cause of the emergencies was as much to do with the geopolitics of the regions in which the outbreaks emerged as with the characteristics of the diseases themselves.

In Syria, polio re-emerged and spread during a conflict that disrupted and degraded the country's previously modern health-care system, preventing the administration of the childhood vaccinations that had eradicated it from the country fifteen years before. The strain responsible originated from Pakistan, where polio remains endemic in large part due to Taliban opposition to vaccination programmes.[3]

In West Africa, the current Ebola outbreak began in Guéckédou Prefecture in Guinea in December 2013, and gained a foothold in villages and rural areas of neighbouring Liberia and Sierra Leone, countries still recovering from decades of civil war and whose health-care facilities remain extremely basic. From there, it spread to more urban areas, fuelled by suspicion and mistrust of authority left over from years of conflict, civil war and ongoing government corruption, and from these fragile post-conflict states to other countries such as Nigeria and Senegal. Although these countries' health-care systems were little better equipped to control them – Senegal has less than

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1. World Health Organization (WHO), 'IHR Procedures Concerning Public Health Emergencies of International Concern (PHEIC)', <http://www.who.int/ihr/procedures/pheic/en/>, accessed 18 September 2014. The announcement of a PHEIC triggers the implementation of certain measures by the state experiencing the PHEIC, or by other states to prevent or reduce the international spread of the disease.
2. WHO, *International Health Regulations (2005)*, 2nd ed. (WHO: Geneva, 2008). The International Health Regulations provide a legally binding framework for co-ordinated international surveillance of and response to notable health events.
3. Dara Mohammadi, 'The Final Push for Polio Eradication', *The Lancet* (Vol. 380, No. 9840, 2012), pp. 460–62.

half as many physicians per head of population as Guinea, for example, and spends only $20 more per person on health-care – infection did not spread widely. In the case of Senegal, this was largely due to the quick response of the government and, in particular, the Ministry of Health.[4] Nigeria was praised for its swift efforts to contain the disease after it was brought into the country by Liberian-American national Patrick Sawyer, which included cross-government co-operation, robust contact tracing and increased screening of travellers arriving at the border. This ensured a much smaller outbreak than was seen in other countries.[5]

Polio and Ebola can both be controlled by medical science: polio easily, by vaccination; Ebola with more difficulty, through stringent infection control, good hygiene and bio-containment, and – ultimately – the development of new drugs once there is sufficient financial incentive. However, this is constrained by the fact that neither polio nor Ebola poses a significant threat to the developed West, and the implementation of the above measures depends on an advanced and well-financed health-care infrastructure. The damage these outbreaks have done is due to the lack of availability, in the regions they affected, of the facilities and systems on which modern health-care depends.

The long life, largely free from infectious disease, enjoyed by citizens of Western societies is an artificial condition created and maintained by constructs of civilisation as unnatural as electricity or tarmac roads. It is also a luxury that costs money which, in turn, requires stable economies. In the UK, *per capita* spending on health-care stood at $3,468 in 2012,[6] in comparison to less than $100 *per capita* spent by many sub-Saharan and central-African countries in the same year. The UK has 2.7 doctors for every 1,000 members of the population; in sub-Saharan and central Africa, the figure is less than 0.5.[7] Sierra Leone, for example, spends just $96 *per capita* on health-care and has 0.02 doctors per 1,000 people and a life-expectancy of just forty-five.[8]

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4. WHO, 'Ebola Situation in Senegal Remains Stable', 12 September 2014, <http://www.who.int/mediacentre/news/ebola/12-september-2014/en/>, accessed 18 September 2014.
5. International SOS, 'Nigeria' <https://www.internationalsos.com/ebola/index.cfm?content_id=418&language_id=ENG>, accessed 22 September 2014.
6. WHO, 'Health Financing: Per Capita Total Expenditure on Health at Average Exchange Rate (US$): 2012', <http://gamapserver.who.int/gho/interactive_charts/health_financing/atlas.html?indicator=i3>, accessed 16 September 2014.
7. WHO, 'Health Workforce: Density of Physicians (Total Number per 1000 Population), Latest Available Year', <http://gamapserver.who.int/gho/interactive_charts/health_workforce/PhysiciansDensity_Total/atlas.html>, accessed 22 September 2009.
8. WHO, 'Health Financing'.

With regard to health-care, you get what you pay for: there is a strong correlation between life expectancy, in particular, and health spending *per capita*; indeed, it is even stronger than that between life expectancy and GDP *per capita*.[9] The average case-fatality rate for Ebola is 50 percent. However, depending on the specific outbreak, this rate can range from 25–90 per cent. Even the most basic health-care – the ability to rehydrate patients who are sweating profusely (with orally administered rehydration salts as well as intravenous drips), to manage blood pressure and treat other infections that strike while the patient's immune system is overworked – improves the chances of survival.[10] All but one of the Westerners who contracted the illness survived once evacuated from Africa to the significantly more advanced facilities of the US and UK. They also had the benefit of greater access to the experimental drug ZMapp,[11] which was fast-tracked through the usual clinical-trialling process. The deliberate satire embedded in the *Onion* article entitled 'Experts: Ebola Vaccine at Least 50 White People Away' worked because the truth hurts.[12] An Ebola vaccine does not exist yet not because it is scientifically impossible to develop one, but because there has been insufficient incentive for pharmaceutical companies to meet the enormous cost of developing treatments for a disease which, so far, has affected only relatively small numbers of people in some of the world's poorest countries. As with AIDS in the late 1980s, that will change if and when large enough numbers of people are affected to ensure a sufficient return on investment. The cost of developing AIDS drugs meant that in the early years, treatment cost $10,000–15,000 per patient.[13] This has since come down to below $300; however, there is no incentive to produce a drug until sufficient numbers of patients are likely to be able to afford the higher price for it. Guinea, Sierra Leone and Liberia all have gross national incomes of less than $500 per person per year, making them unlikely to be able to afford such drugs at their cheapest, let alone in the more expensive, earlier stages. Despite instances of the disease having been recorded in Africa for more than forty years,[14] the drug development that has been undertaken in relation to Ebola

9. OECD, 'Health at a Glance 2011: OECD Indicators', 2011, <http://www.oecd-ilibrary. org/sites/health_glance-2011-en/01/01/index.html?/ns/Chapter&itemId=/content/ chapter/health_glance-2011-4-en>, accessed 18 September 2014.

10. WHO, 'Ebola Virus Disease', Fact Sheet No. 103, updated April 2015, <http://www. who.int/mediacentre/factsheets/fs103/en/>, accessed 22 June 2015.

11. Centers for Disease Control and Prevention, 'Questions and Answers on Experimental Treatments and Vaccines for Ebola', <http://www.cdc.gov/vhf/ebola/outbreaks/ guinea/qa-experimental-treatments.html>, accessed 16 September 2014.

12. *Onion*, 'Experts: Ebola Vaccine at Least 50 White People Away', 30 June 2014, <http://www.theonion.com/articles/experts-ebola-vaccine-at-least-50-white-people- awa,36580/>, accessed 22 September 2014.

13. Avert, 'Antiretroviral Drug Prices', <http://www.avert.org/antiretroviral-drug-prices. htm>, accessed 22 September 2014.

14. Centers for Disease Control and Prevention, 'Outbreaks Chronology: Ebola Hemorrhagic Fever', <http://www.cdc.gov/vhf/ebola/resources/outbreak-table.html>, accessed 18 September 2014.

has been due more to concern in the US that the virus could be used as a biological weapon, under the US government's $50-million Project BioShield initiative.[15] It was not until a significant impact on Western economies was recognised that investment in fighting the disease, generally, grew. As of June 2015, this includes grants of $1.62 billion by the World Bank to support response and recovery efforts mostly in Guinea, Liberia and Sierra Leone.[16] The US has been a signficiant contributor. It has spent $1.4 billion on its response although the funding is allocated differently and incorporates the signficiant logistical costs in deploying resources to the region.[17]

Dangerous Narratives

Health and health-care systems depend on stable governments and economies for their implementation. While mistrust of corrupt governments has been a factor in responses to the Ebola outbreak in West Africa, and particularly in Sierra Leone and Liberia, where early action was most required, elsewhere, it is the instability caused by conflict – rather than mistrust and the lack of effective governance structures in post-conflict situations – that threatens epidemics: for instance, the disruption of the previously stable Syrian society that has led to a re-emergence of polio in the country, prompting the declaration of 2014's PHEIC.

As noted, polio is easily controlled by vaccination. In the 1950s, polio paralysed hundreds of thousands of people – mostly children – worldwide. A total of 57,628 cases were recorded across the US in 1952, the year in which the first effective vaccine was developed, but within five years, this had fallen to 5,300, with the last case recorded in 1979.[18] By the end of the following decade, North America, Australia and much of Europe were free of the disease: by then, polio was a problem confined to the global South, prompting the WHO to adopt in 1988 a resolution to eradicate the virus by 2000. This goal was not achieved, not because of ineffective medical science, but because of human opposition in many countries. In northern Nigeria, notably, imams and local political leaders in three states issued a polio-vaccination boycott in 2003 – based on claims that vaccines had been contaminated in an attempt by the West to kill Muslims and limit population growth – that put efforts to eradicate the disease back a decade.[19] On the

15. White House, 'Project BioShield: Progress in the War on Terror', <http://georgewbush-whitehouse.archives.gov/infocus/bioshield/>, accessed 18 September 2014.

16. World Bank, 'Ebola Response Fact Sheet', 18 May 2015, <http://www.worldbank.org/en/topic/health/brief/world-bank-group-ebola-fact-sheet>, accessed 22 June 2015.

17. World Bank, 'Ebola: The Road to Recovery', event transcript, 17 April 2015, <http://www.worldbank.org/en/news/speech/2015/04/17/transcript-event-ebola-road-to-recovery>, accessed 22 June 2015.

18. History of Vaccines, 'Polio', <http://www.historyofvaccines.org/content/timelines/polio>, accessed 22 September 2014.

19. Ayodele Samuel Jegede, 'What Led to the Nigerian Boycott of the Polio Vaccination Campaign?', *PloS Med* (Vol. 4, No. 3: e73, March 2007).

basis of similar claims of Western attempts at population control, Taliban opposition is also serving to keep polio endemic in Pakistan and Afghanistan; in Pakistan, violence has claimed the lives of more than seventy polio workers in the last four years.[20]

The re-emergence of a previously controlled disease in Syria is a warning of how fragile scientifically controlled health can be. Polio vaccination was made mandatory in Syria in 1964, with the last indigenous case of the disease recorded in 1995. By 2000, more than 80 per cent of the population received vaccination, and by 2011, at the beginning of the Syrian crisis, this was estimated to have reached 95 per cent. At that time, Syria was a medically advanced country: there were 1.5 doctors per 1,000 people, good health-care coverage, near universal vaccination, and sound surveillance and monitoring systems in place. As the crisis unravelled, however, the Syrian health-care system – like so much else in the country – was severely damaged. Standards of surveillance for Acute Flaccid Paralysis (AFP) – the international gold standard for detecting cases of polio[21] – were noted to have fallen in 2011 and by 2012 vaccination coverage was estimated to have dropped to barely 50 per cent of the children eligible for vaccinations that year. This sparked fears that unvaccinated Syrian children were at risk of contracting polio from environmental reservoirs known to be present in nearby Egypt, for example, from which polio can spread through contact with contaminated faeces or through contaminated food. These fears were realised in July 2013 and by the end of January 2014, thirty-six cases had been recorded in Syria,[22] putting seven neighbouring countries at risk. Though the outbreak had been contained by the end of January 2014 through a concerted effort by the WHO and neighbouring countries, the fragility of vaccination-controlled health-care had been highlighted and there are major concerns that polio might emerge once again in the regions currently controlled by Daesh (also known as the Islamic State of Iraq and Syria, ISIS). Similarly, as long as the disease remains endemic in Pakistan, there is also a danger that it could inadvertently be carried, for example, by jihadist fighters to other areas of instability across the globe – an outcome made all the more likely by the fact that less than 4 per cent of people infected with the poliovirus display obvious symptoms.[23]

Elsewhere, the activities of other Islamist groups are having a similar impact on efforts to eradicate polio. In May 2013, cases of the virus were

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20. *BBC News*, 'Four Kidnapped Polio Workers Are Found Dead in Pakistan', 17 February 2015.

21. Polio Global Eradication Initiative, 'Surveillance', <http://www.polioeradication.org/ Dataandmonitoring/Surveillance.aspx>, accessed 22 September 2014.

22. *Ibid.*

23. Centers for Disease Control and Protection, 'Polio Disease In-Short', <http://www.cdc. gov/vaccines/vpd-vac/polio/in-short-both.htm>, accessed 22 September 2014.

recorded in Mogadishu, Somalia, for the first time since 2007, caused by strains imported from northern Nigeria, where Boko Haram murdered nine young women working on polio-vaccination programmes in February 2013. The spread of the disease across Somalia has been helped by Al-Shabaab extremists discouraging parents from vaccinating their children by claiming that the vaccines contain AIDS.

Prevention and Containment in Conflict and Post-Conflict Zones
The conditions that lead to PHEICs need to be approached from directions other than purely medical science. Sometimes the challenges are economic, sometimes they are cultural, often they have security aspects, but none are simple. The more cross-disciplinary the approach, the more likely the solutions are to succeed.

One approach that could be taken is for affected states and international health organisations (ideally in collaboration) to build up better situational awareness at the beginning of outbreaks, not only in terms of epidemiological surveillance, but also by mapping the cultural, societal, and economic situation and analysing the effect this is likely to have on health-care responses. Barry Hewlett and Richard Amola proposed such an approach in their study of the Ebola outbreak in Uganda in 2001–02,[24] suggesting an equivalent of the military Human Terrain System for the public health sector in an effort to ensure that plans to fight disease are context- and culture-specific, taking into account what is likely to work and the local conditions in which NGOs and international aid teams must work.[25] Such mapping would help to indicate the fragility of health-care systems, how quickly they might collapse (a country with extremely few doctors cannot afford to lose even a small number to Ebola, for instance), and where simply parachuting in additional supplies and personnel – and importing Western approaches – is likely to be an inappropriate or inadequate response. In the case of the Ebola crisis, for example, while the UK and US commitment to contribute military field hospitals and troops to Sierra Leone and Liberia, respectively, bolstered the weak health-care systems in these countries, it did little to address the cultural issues that prevented locals from seeking medical care from the country's established clinics or from the NGOs operating there since before the outbreak began. There may well be short-term benefit, but the long-term strategy for dealing with this and other future outbreaks also needs to be considered. A one-size-fits-all approach will not work in all geopolitical contexts.

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24. Barry S Hewlett and Richard P Amola, 'Cultural Contexts of Ebola in Northern Uganda', *Emerging Infectious Diseases* (Vol. 9, No. 10, 2003), pp. 1242–48.
25. US Army, 'Human Terrain System', <http://humanterrainsystem.army.mil/>, accessed 18 September 2014.

Such methods would also help to identify emerging narratives in public discourse and ensure that negative ones are countered as early as possible. For example, a key factor in the widespread unwillingness among parts of the population to believe official statements regarding the outbreak of Ebola in Sierra Leone can be traced to political tensions between the ruling All People's Congress (APC) party and the main opposition, the Sierra Leone People's Party (SLPP). The latter draws greater support in the region in which the outbreak originated and some among the local population saw Ebola as the APC's latest sinister ruse: by killing those with 'Ebola' symptoms once they present themselves at government-run health clinics, the ruling party could limit the local population numbers ahead of the election. Early engagement by SLPP politicians in support of government and international measures in the Ebola-affected regions may thus have helped to contain the outbreak.

In addition, a better understanding of the mistrust of government and science among parts of the population might have led to an approach based more on encouraging people to quarantine themselves in their homes and villages so that appropriately trained NGO and international health-care workers could treat them *in situ* – thereby mitigating the risk that those infected might inadvertently spread the virus as they travel led to clinics for treatment. Approaches that have focused more on the social and cultural aspects of disease control have experienced success in the past: WHO's Global Polio Eradication Initiative, for example, has worked with the Organization of the Islamic Conference to counter the Islamist narratives by issuing fatwas in support of polio vaccination.[26] Similarly, other followers of Islam make efforts to highlight that the Qur'an does not prohibit vaccination and in fact requires followers to act to protect their fellow man – an excellent example of this being a recent article about Islam and polio in *The Lancet*[27] – while Pakistan has encouraged senior imams to speak out on the topic. This socio-cultural approach should really have been implemented a decade ago however, before the negative narratives gained purchase. A key challenge is to determine how well the counter-narratives will work in future.

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26. Global Islamic Advisory Group, 'Final Communique: First Global Islamic Advisory Group Meeting on Polio Eradication', February 2014, <http://www.polioeradication. org/Portals/0/Document/Resources/Declaration_Resolution/Jeddah_Declaration_ EN.pdf>, accessed 18 September 2014; Global Polio Eradication Initiative, 'Resolution No. 14/31-S&T on Global Cooperation in Polio Eradication Programme Among OIC Member States', thirty-first session of the Islamic Conference on Foreign Ministers (Session of Progress and Global Harmony), Istanbul, June 2004, <http://www. polioeradication.org/content/publications/OIC_resolution_0604.pdf>, accessed 18 September 2014.
27. Fatima Riaz and Yasir Waheed, 'Islam and Polio', *The Lancet Infectious Diseases* (Vol. 14, No. 9, September 2014).

Rather than science, it is cultural understanding – of the type proposed by Hewlett and Amola, more than a decade ago, which maps beliefs, behaviours and likely compliance, as well as recognising and mitigating likely barriers – that will finally defeat polio in these remaining regions, and which will facilitate strong – or even temporarily stronger – health-care systems capable of containing and extirpating the current Ebola outbreak in West Africa. Better cultural understanding will also alert health-care experts to areas where culture, as well as vaccines, viruses and bacteria, may challenge medical science in the future. Without this, the medical technology on which modern health-care depends so strongly is unlikely to win the battle alone.

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Serious Infectious Disease: Challenges for Security and Defence

Alasdair Walker

The stimulus for this paper is the recent public-health emergencies such as Ebola, polio, SARS and HIV. The following are the themes covered:

- Developing situational awareness
    - information and medical intelligence
- Application to military medicine
- Force generation
    - history
    - deployed health
    - specific diseases
    - military degradation
    - local effects.

Developing Situational Awareness

Situational awareness is important. There is a virtuous cycle of information gathering which is assessed for credibility, analysed and put into context.

When examining a region, we look at the situation and gather intelligence such as whether the economies are failing, whether there is a political dictatorship or ruling elite, whether the armed forces are strong and if there is overall public dissatisfaction with the government. Our approach looks at the threat from a military point of view and assesses it. The threat must be based on facts that can be measured.

Once we have that intelligence, we might ask questions such as: Why are they mobilising their field hospitals? Why are blood stocks being preserved from civilian practice? Why are home hospitals being cleared? These are all signals that something might be about to happen.

A country may have a sophisticated health-care service on the surface but one that is only for the political, military and ruling elite. Underpinning that might be a failing state with limited public health and primary care – and consequently public dissatisfaction with a risk of uprising.

It is not enough to just collect and analyse intelligence, it needs to be fed back to the command teams so that they are aware of the situational awareness that has been developed.

Force Generation
With a smaller military, the UK has to focus the numbers of personnel with the emphasis on fitness to deploy. The smaller a military gets, the more important it is that there is no fat to lose.

At any given time, around 5 per cent of UK forces are unfit to deploy for various reasons. A member of the forces may have broken a leg or be recovering from appendicitis – very few of that 5 per cent will have infectious diseases. These numbers may limit a commander's intent to prosecute a mission. But while a commander might consider 20 per cent battle losses as catastrophic, he or she might not look quite as carefully at the 20 per cent losses due to disease non-battle injury.

Take General Slim,[1] who visited units in Burma as malaria was rife because of a failure to take effective precautions. If he found that less than 95 per cent of the unit were not taking the quinacrine hydrochloride at the time, he would sack the commanding officer (CO). He said in his memoirs, 'I only had to sack three before the rest got my meaning.' Similarly, COs in Afghanistan might delay operations if there were a major diarrhoea and vomiting outbreak, because of concern that there were not enough people to actually prosecute the intent.

Historical Military Relevance
Some of the great figures who have assisted in advancing microbiology during the late nineteenth and early twentieth centuries served in the army medical service. Almroth Wright helped to reduce the high instances of typhoid in the military; David Bruce investigated Malta Fever, or brucellosis as it is now known; and there is William Leishman, after whom Leishmaniasis is named.

US Surgeon General William H Steward declared in 1967: 'The war against infectious diseases has been won'. But really, we still have a major problem. As Joshua Lederberg and Robert Shope said in 1992, there are 'new, re-emerging, or drug-resistant infections whose incidence in humans has increased within the past two decades or whose incidence threatens to increase in the near future.'[2]

Challenges for the British Military
The British military brings together people from different geographical locations, genetic backgrounds and vaccination histories. It is also open to colleagues across the Commonwealth, so there is international geographic

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1.   See The National Army Museum, 'William Slim', <http://www.nam.ac.uk/exhibitions/ online-exhibitions/britains-greatest-general/william-slim>, accessed 7 May 2015.
2.   Joshua Lederberg, Robert Shope and Stanley Oaks Jr, *Emerging Infections: Microbial Threats to Health in the United States* (Washington DC: The National Academies Press, 1992).

variation. Gurkhas come over from Nepal, for example, where there is high incidence of tuberculosis; the UK has to screen for this disease before they start. Recent figures show that 8.1 per cent of the British army is from outside the UK.[3]

These people live in close contact with one another with mass catering – it is a milieu for problems. Respiratory diseases have broken out, such as influenza A in barracks in 2009; the Americans frequently have adenovirus and a pneumococcal problem – an atypical pneumonia not seen much in the UK – for which they have been vaccinating people for twenty years. The UK military had respiratory transmission problems including meningococcal disease and has been immunising people against it since 1995.

Intervention
We try to intervene early and vaccinate people from day one, not only to reduce the instance of infectious disease, but also to reduce the loss of training days. It is not always easy – there is a consent issue – but we make sure that is done.

Gastrointestinal (GI) problems are common; with mass catering it is difficult to avoid instances of food poisoning despite training chefs and those going into the food halls to clean their hands. Hand gels and basins are installed at military bases abroad to reduce that incidence. Norovirus and other pathogens causing vomiting and diahorrea can shut down operational capability, particularly on an enclosed space such as a ship. To mitigate this, the military is providing more single accommodation – often with ensuite bathrooms – rather than mass dormitory accommodation. Catering standards are kept as high as possible with contractors required to maintain these. Environmental-health staff monitors standards and advises accordingly.

Deployed Health
When abroad and operating in austere conditions with close living accommodation, with food supplies from various sources, it is important to ensure that these are well looked after. Water and sanitation has also been an essential part of military campaigning. In Camp Bastion in Afghanistan there was a borehole down to natural aquifers and a bottling plant to help get water out to the various units.

There is endemic local disease to address. In Afghanistan, for example, there are GI and respiratory problems, as well as Q fever (a bacterial infection that can be spread to humans from infected animals). When briefing ministers for

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3. Ministry of Defence, 'Statistical Series 2 – Personnel Bulletin 2.01 – Service Personnel', 25 September 2014, <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/357724/tri_service_personnel_bulletin_2_01_2014.pdf#page=21>, accessed 20 March 2015.

when the armed forces were going to help in Sierra Leone, I said the problem was not Ebola. Malaria is a much greater problem because it is endemic and there is resistance to it. And in Iraq, people were trained to watch out for Leishmaniasis.

Problems of Modern Warfare

Military warfare has changed. It is not simply one state against another; there are more coalitions. As a result, communities are not isolated and there is greater integration with other nations. A few years ago in Afghanistan there were troops from countries ranging from Togo to Finland; there is quite a disparity in the disease-population history between these areas and each brings its own disease-history problem. There is also a civilian population being employed, including people such as interpreters and locally employed camp workers; again, it is essential that there are no further problems brought in from those sources.

Expeditionary forces are often sent out rapidly to places with their own zoonoses (infectious diseases of animals that can be transmitted to humans) and vector-borne diseases. Small groups such as diplomatic staff and civil servants may be attached to other militaries. In every situation, safe water and food supplies could be compromised, personnel could be exposed to arthropod and animal vectors and disease; there is limited access to medical care and they could be in close contact with the local population during times of heightened disease transmission.

Each of these activities involves exposure to a different level of risk to that of a normal civilian holidaymaker or businessperson. This could lead to the term, which my colleague Andy Green has used, of 'the Sentinel Soldier'.[4] In his paper, Green reflects on the possibility of a novel disease appearing for the first time in this group and being brought back to the UK. The military therefore sees itself at the forefront of medical research on the understanding and treatment of infectious disease.

Widest Effects

Infectious diseases affect everybody, including political and military leaders. Their acquisition of infectious disease can skew decision-making and cause all sorts of problems. A politician or leader needs to perform at the highest level; if he or she were to pick up an infectious disease it could have national and even international military and political consequences.

There are effects on emerging military forces – similar to those seen in the UK – but these countries' militaries may be resource-poor with a lack of access

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4. Andy Green, 'The Sentinel Soldier', conference paper presented at Tackling Antimicrobial Resistance: Identifying Future Research Themes, RUSI, London, 6 February 2013.

to drugs and vaccines; vector control may also be inadequate. There is a tendency in some places to encourage risk-taking behaviour. Soldiers, airmen and sailors are often 'rich' compared to the population at large, and can go out and do risky things within the local population. Sexually transmitted diseases such as HIV are not uncommon in these groups.

Foreign militaries may not embrace a force health-protection concept – for example, the Russians had no environmental-health teams in Afghanistan, they lived off the local economy. That, perhaps, led to a lack of infection prevention and control standards in primary and hospital care.

There are many examples, both recent and historical, of disease degradation. Most recently there was meningococcal disease in Afghan forces in Kabul. There have also been instances of sexually acquired infection in Vietnam, chronic problems of HIV and outbreaks of typhus in the French army during Napoleon's Russian campaign, which degraded the army at a critical moment and had a key role in prompting the retreat from Moscow.

Secondary Effects
Infrastructure and support services are required to manage the environmental-health side. There are family effects as well. Who supports the worried and anxious families back home? Who looks after the families of local militaries managing the Ebola crisis? How much is the military degraded if soldiers are worrying about what's happening in their families and not focusing on the job at hand?

The availability of drugs and vaccines is another issue. Whenever there is a problem they tend to be bought up by the rich Western world which can afford it. Other countries are not always able to get the stocks they require when there is only finite availability.

Civilian-Population Effects
The Department of Health's paper, 'UK Influenza Pandemic Preparedness Strategy' talks about planning and business continuity during a pandemic.[5] It looks at how communities work under threat, and the consequential wider effect on national stability due to anxiety.

CIA Global Trends and our own Development, Concepts and Doctrine Centre predict pandemic influenza as a major threat to international security, whether it happen today, tomorrow, next year or in ten years' time. It is considered to be as much a threat as terrorism.

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5. Department of Health, 'UK Influenza Pandemic Preparedness Strategy 2011', Reference 16463, 10 November 2011.

What Does It All Mean?

Military and security forces have historically invested in intelligence to assess security threats. Infectious diseases are common but are often perceived as less important and so the commanders ignore them. This has a knock-on effect on force generation and effectiveness. If a force is degraded it does not achieve its objective. So we spend a lot of time asking commanders to think about it and telling them it is important.

Infectious diseases may have direct effects on the UK and Western security forces in conflict. They may have indirect effects on military security forces and people in humanitarian peacekeeping. They may affect a society as a whole because of the local casualties and refugees that the UK has to address. They may affect other organisations with which the UK has to interact, such as NGOs, national contractors and charities. Infectious diseases may even stop an operation or campaign, as seen in Bagram Airbase which had a major outbreak in 2002.[6]

Infectious diseases on a global scale may lead to political and security instability. This could have consequences for societal change leading to disruption and conflict. They are important.

This paper aims to examine a number of different themes in this area: research; understanding of the spread of disease; the gathering of relevant information and its assessment and analysis; surveillance and intelligent modelling; and cultural and environmental issues. There is also the issue of anti-microbial resistance. While the paper has not examined bio-terrorism, it is important to consider the consequences of secondary poisons from biological agents. I hope that this paper helps readers gain a greater understanding of the major issues.

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6. Khabir Ahmad, 'Norwalk-like Virus Attacks Troops in Afghanistan', *The Lancet* (Vol. 2, No. 3, July 2002), p. 391.

PHEICS: Background and Impacts

I. PHEICs: Pathogen Signatures, Taxonomy and Resilience

Tony Barnett

Infectious diseases are not restricted to the human world. They appear in the animal, plant and microbiological worlds. For humans, infectious diseases are social, cultural and economic phenomena. This means not only that humans live in shared places and spaces and so may infect one other; but also that human actions affect the environments within which pathogenic organisms live. They, in turn, affect not only our environments and how and where we can live,[1] but also our genomes.[2] Humans breed animals, keep them and transmit diseases backwards and forwards.[3] Humans alter environments for disease, and the disease alters ours. An infectious-disease event is part of a dynamic situation, and from the human perspective it is, whether endemic or pandemic, a continuing social, economic and cultural event. It is also a political one, as the public discusses and debates how to deal with the implications and origins of an outbreak. This has been evident in the case of the 2014–15 Ebola outbreak in West Africa, while the politics of HIV/AIDS has certainly altered attitudes, understandings, institutions and resource flows globally. Politics also affects the way that those socio-cultural and institutional extensions of human immune systems – disease surveillance systems – are constructed to fit with particular local political traditions and arrangements.[4]

How Many Pathogens Are There in This World?
This question provides an idea of the scale of the challenges humanity faces. The answer can only be approximate which is an indication of an order of magnitude. The answer depends on taxonomic criteria, continuing evolution and sampling error and confidence intervals. Taxonomy is important and classificatory distinctions will depend in part on how closely pathogen genomes are analysed. Mark Woolhouse and his team from Edinburgh

1. Robin Weiss, 'Lessons from Naked Apes and Their Infections', *Journal of Medical Primatology* (Vol. 36, No. 4–5, August 2007), pp. 172–79; see also Robin Weiss, 'Apes, Lice and Prehistory', *Journal of Biology* (Vol. 8, No. 2, February 2009), p. 20.
2. Muminatou Jallow et al., 'Genome-Wide and Fine-Resolution Association Analysis of Malaria in West Africa', *Nature Genetics* (Vol. 41, No. 6, May 2009), pp.657–65.
3. Marco Liverani et al., 'From Risk Drivers to Risk Management: Understanding and Managing Zoonotic Risk in the New Livestock Industries', *Environmental Health Perspectives* (Vol. 121, No. 8, August 2013), pp. 873–77.
4. Tony Barnett and Corinna Sorenson, 'Infectious Disease Surveillance in the United States and the United Kingdom: From Public Goods to the Challenges of New Technologies', *Journal of Health Politics Policy and Law* (Vol. 36, No. 1, February 2011), pp. 165–85.

attempted an answer to the question a few years ago, estimating that there are about 1,400, of which approximately 815 are zoonotic.[5]

Niche Shifting

Both natural (immunological) and social human responses to infectious-disease pathogens are part of a large-scale evolutionary process within which all life is contained. Simon Levin, in his paradigmatic book *Fragile Dominion,* drew attention to the non-linearity of evolutionary processes, the evolutionary nature of ecosystems at different scales and the way that niches are not unchangeable places occupied by species but are themselves the result of complex evolutionary processes.[6] It is against that background and also the idea of critical transitions that Figure 1 should be considered.[7] The figure is a matrix showing, as columns, the broad categories of pathogen transmission mode and, as rows, the main groups of pathogens. The cells represent very broad niches combining pathogen group and transmission route. This schema is described as a 'complex pathogenic-social space'.

Figure 1: Representation of Complex Pathogenic Social Space.
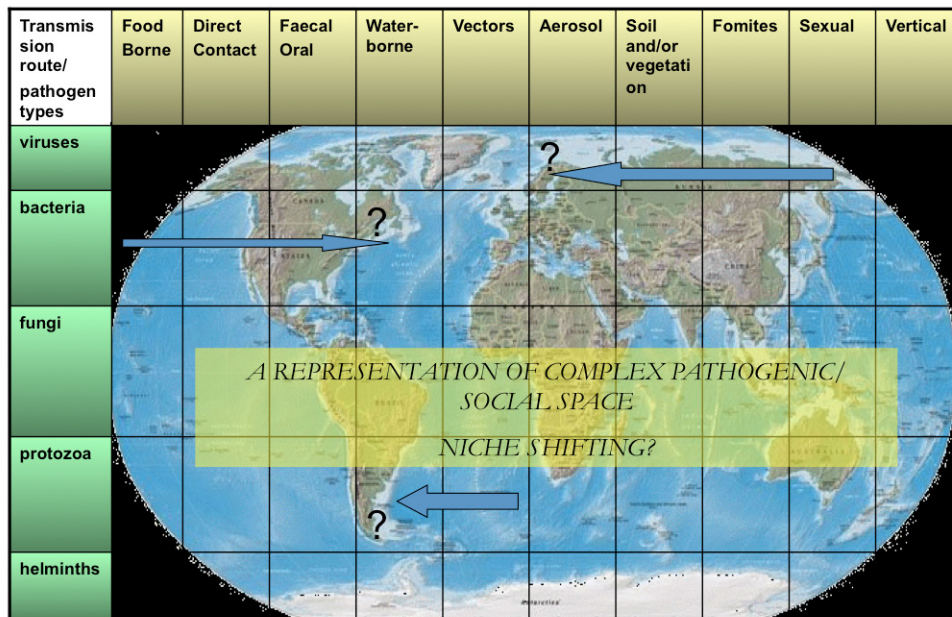
Source: Tony Barnett.

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5. Mark Woolhouse, and Sonya Gowtage-Sequeria, 'Host Range and Emerging and Re-Emerging Pathogens', *Emerging Infectious Diseases* (Vol. 11, No. 12, December 2005), pp. 1842–47.

6. Simon Levin, *Fragile Dominion: Complexity and the Commons* (Cambridge, Mass: Perseus Publishing, 1999).

7. Marten Scheffer, *Critical Transitions in Nature and Society* (Princeton, NJ: Princeton University Press, 2009).

This figure is fundamental to the argument and will be returned to in the final paragraphs of this paper. The figure raises the following practical as well as theoretical question: how does this pathogenic social space resonate with the effects of the diseases on human social, economic and political life, so that society can actually prepare rather than just react? The key idea is 'niche shifting'. Across the top row there are general categories of how diseases are transmitted: direct contact, faecal oral, waterborne, vectors, aerosol, fomites (things that you touch), among others. The key question is: under what pressures (for example environmental/climate change, human trading practices, changes of bird-migration paths) might a pathogen shift its niche, or might a pathogen *vector* shift its niche?[8] This has just occurred with Ebola in West Africa. So the potential for niche shifting is really significant in terms of the dynamism of the environment and any attempts to prepare for pandemic events. Woolhouse, among others, illustrates this point, and the results of this work are sometimes contrary to intuitive assumptions.[9] For example:[10]

> 1) the marked association of emerging or re-emerging fungi with hospitalisation, poor population health, or both; 2) the greater importance of pathogen evolution and contaminated food and water and the lesser importance of international travel and changes in land use and agriculture for bacteria in comparison with viruses; 3) the greater importance of changing land use and agriculture for zoonoses than for non zoonoses.

Another section elaborates further:[11]

> Although some drivers are numerically more important than others, the overall impression is that pathogens are exploiting almost any change in human ecology that provides new opportunities for transmission, either between humans or to humans from a nonhuman source.

What is a PHEIC?
A public health emergency of international concern (PHEIC) is defined in the International Health Regulations as: 'An extraordinary event that is determined as provided in the regulations to constitute a health risk

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8. Kurt Reed et al., 'Birds, Migration and Emerging Zoonoses: West Nile Virus, Lyme Disease, Influenza A and Enteropathogens', *Clinical Medicine and Research* (Vol. 1, No. 1, January 2003), pp. 5–12.
9. Mark Woolhouse, 'Epidemiology: Emerging Diseases Go Global', *Nature* (Vol. 451, No. 7181, February 2008), pp. 898–99; see also Woolhouse and Gowtage-Sequeria, 'Host Range and Emerging and Re-Emerging Pathogens', pp. 1842–47.
10. *Ibid.,* p. 1845.
11. *Ibid.,* pp. 1845–46.

to other states through international spread of disease and require a co-ordinated international response.'[12]

Thus, a PHEIC is unusual, carries implications for public health across national boundaries, and may require an international response.

Within those regulations and definitions there are terms such as 'risk', 'serious', 'unusual', 'unexpected', 'implications', 'public health', 'international actions' – and each of those requires close attention. The question is: how can these be examined in a way that is helpful to early warning, response and resilience? One possible way into the puzzle is via the idea of a 'pathogen signature'.

Two examples illustrate this point. The first is the social and economic effects of HIV/AIDS. The second is the very different social and economic effects of Ebola. In each case the analysis begins from characteristics of the pathogen, its life cycle and its natural history. The underlying theory of this paper is that characteristics of the pathogen and its life cycle within its host(s) resonate at a social and economic level. So there is a micro/macro resonance, and that is the basis for trying to understand and prepare for different kinds of outbreaks and public-health events. The idea of 'signature' is used because the underlying characteristics of the pathogen may inscribe themselves in possibly limited and classifiable ways upon human societies.

It is worth noting some major principles. First, all societies, economies and cultures are changing and dynamic. Second, humans tend to live their lives in an illusion of an 'eternal present', described as 'the end of history illusion'.[13] Third, the ideas of 'stability' are at best merely relative to something, some place or some other time. Fourth, 'stability' is a political term. Fifth, all societies and economies experience events which change them over the shorter or longer term. There is a resonating relationship between these 'events' and the surface of observable economic, social and cultural structures – this is what the historian Fernand Braudel described as 'the structures of everyday life'.[14] These 'structures', experienced in the lives of individuals and groups, are here described as the 'signature' of an event.

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12. World Health Organization, IHR Procedures Concerning Public Health Emergencies of International Concern (PHEIC), <http://www.who.int/ihr/procedures/pheic/en/>, accessed 7 May 2015.
13. Jordi Quoidbach, Daniel Gilbert and Timothy Wilson, 'The End of History Illusion', *Science* (Vol. 339, No. 6115, January 2013), pp. 96–98.
14. Fernand Braudel, *Civilization and Capitalism: 15th–18th Century*, tr. Siân Reynolds (London: Phoenix Press, 2002).

Many 'natural' and other events may have 'signatures'. The idea of a signature is that the event inscribes itself onto society and the economy via a series of processes of resonance. Among the simplest of these resonances is the effect of demography. This is a resonance to social, economic and cultural life that is fairly familiar. It is spectacularly expressed in relation to the demography of an ageing population in, for example, Japan where allegedly sales of incontinence pads greatly exceed sales of children's nappies.[15]

HIV Characteristics
HIV is best thought of as a 'cloud' of ribonucleic acid (RNA) viruses with a high rate of mutation. The process of reproduction leaves plenty of room for viral mutation in quite short periods. HIV has a long latency period, so it can be spread by people who are relatively active (including sexually) for a long period of their illness. It has a high reproductive number (R_0) – it has between two and five secondary cases for each primary case. And all of those characteristics feed through in a very specific way: to demography; the labour force; age-specific mortality; and political structures. In South Africa, high levels of prevalence did not destroy the military – which was a concern at one stage – or kill all the senior politicians. However, the results of one study suggest that HIV had, and continues to have, significant effects on local government councillors who are becoming younger and less experienced as the older generation has fallen prey to AIDS.[16] This is a significant impact and could have implications for political order and developments in that country. This is an example of resonance between the life history and the natural history of the pathogen and very specific social and economic impacts.

Another illustration of this resonance between virus, demography and society is a study using Ugandan census data from the early 1990s.[17] A very detailed age-gender pyramid constructed from those data shows AIDS-related distortions in the pyramid consequent upon premature mortality in the 14–16 year age cohorts (Figure 2).

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15. Faith Aquino, 'Sales of Adult Diapers in Japan Surpass Those for Babies', *Japan Daily Press*, 11 July 2013.
16. Kondwani Chirambo and Justin Steyn (eds), *Aids and Local Government in South Africa: Examining the Impact of an Epidemic on Ward Councillors* (Johannesburg: The Institute for Democracy in South Africa, 2009).
17. Daniel Low-Beer, Rand Stoneburner and Andrew Mukulu, 'Empirical Evidence for the Severe but Localized Impact of AIDS on Population Structure', *Nature Medicine* (Vol. 3, No. 5, May 1997), pp. 553–57.

Figure 2: Uganadan Census Data – National, District and Parish Levels.
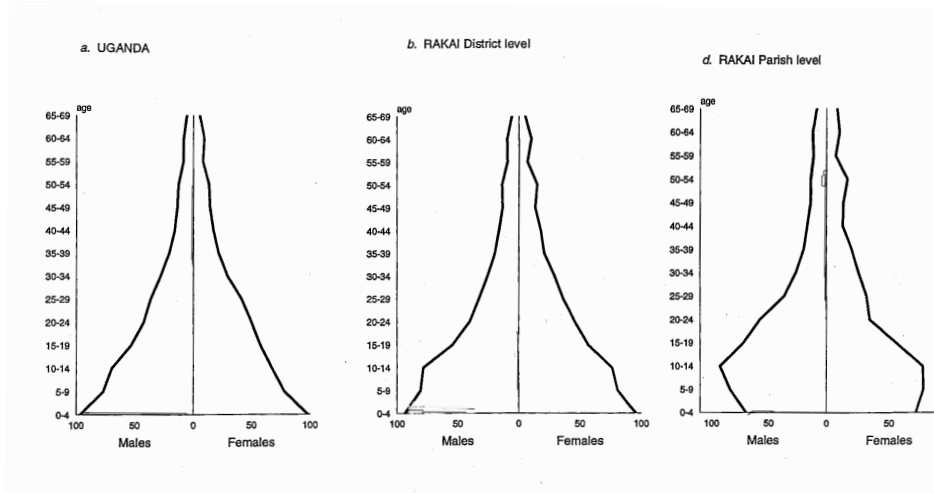
Source: Daniel Low-Beer, Rand Stoneburner and Andrew Mukulu, 'Empirical Evidence for the Severe but Localized Impact of AIDS on Population Structure', Nature Medicine *(Vol. 3, No. 5, May 1997), pp. 553–57.*

Figure 3 provides a hypothesis concerning possible large-scale social effects of HIV on societies where high prevalence levels have existed over decades in the absence of anti-retroviral response. Viral latency and high rates of mutation, characteristic of the pathogen, have serious effects. In particular, they result in high levels of orphaning. These orphans are exposed to early HIV infection as they grow to puberty. With poor socialisation and exposure to early sexual debut, this pattern repeats over three generations, where the generation time is rapid because of premature mortality.

Figure 3: Sundering the Bonds of Human Society.
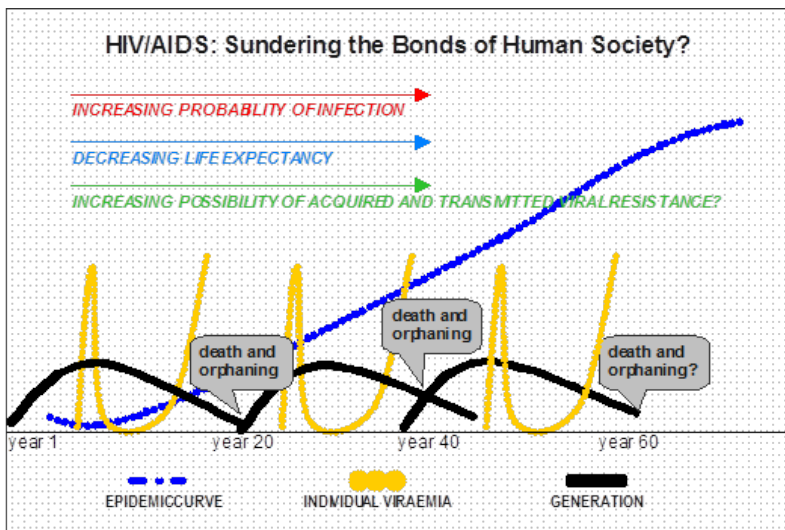
Source: Tony Barnett.

In this situation, high levels of orphaning might be thought of as akin to chopping up strands of DNA because they actually cut one of the key processes of inter-generational coding in human society. HIV is an extraordinarily 'cunning' virus because the effects of its illness are premature death, inadequate socialisation of orphans, early entry into sexual relations in a high-prevalence society and more orphans.[18]

Ebola Characteristics
Ebola is markedly a different kind of virus, another kind of retrovirus. It has a very immediate impact. It has a very high case-fatality rate, reportedly around 75 per cent. However, it is much higher in some groups, notably pregnant women where it evidently reaches 90 per cent. R_0 is reported to be in the range 1.2–2.5 but with a possible rapid drop to one over the course of an outbreak because of the high and early case-fatality rate.[19]

Ebola is extremely socially disruptive in the very short term and has a markedly different kind of resonance between the pathogen and society as compared with that of HIV/AIDS. In contrast to HIV/AIDS, the response to Ebola has focused on isolation and quarantine. This has led to immediate disruption and a loss of economic output – although a recent World Bank report implies it is rather less than was initially assumed.[20] Yet the short wavelength of the disease, resulting from its life history and natural history, exposes societies to rapid shocks where, in what are sometimes described as 'failing' or 'weak' states, it makes governments vulnerable to crises of legitimacy and whole populations to the power of rumour. Helen Epstein describes these processes as she observed them in Liberia during the latter months of 2014.[21] In sum, there is a different kind of resonance with Ebola as compared with the much longer wavelength of effect and response associated with HIV/AIDS.

Some Enquiries
Could the resonance between the pathogen, understood along very specific dimensions such as those outlined here, and the kinds of effects it has on the labour force, demography and even political legitimacy be described? What would happen if you could describe that as a signature that the pathogen inscribes on a whole society? And what if the rather more difficult areas to explore – such as the effects of rumour, which is part of the social nature of an infectious-disease event – are taken into account? What would happen if, in

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18. Tony Barnett, 'The Long Wave of HIV/AIDS: A Special Case of Pathogen-Host-Environment Interactions', in Paul Volberding et al. (eds), *Global HIV/AIDS Medicine* (Amsterdam: Saunders Elsevier, 2008), pp. 779–86.
19. Christian Althaus, 'Estimating the Reproduction Number of Ebola Virus (EBOV) During the 2014 Outbreak in West Africa', *PLOS Currents Outbreaks*, 2 September 2014.
20. World Bank, 'The Economic Impact of the 2014 Ebola Epidemic: Short and Medium Term Estimates for West Africa', Report no. 91219, 2014.
21. Helen Epstein, 'Ebola in Liberia: An Epidemic of Rumors', *New York Review*, 18 December 2014.

this exploration, pathogens could be classified into a limited number of social pathogenic classes which shared common, predictable signature effects on societies? And what if you could say that there were particular classes of pathogens that could be identified, in terms of their R_0 and latency period, their mutability and a range of other things, that had rather typical kinds of predictable signatures that they would write on societies? The next question, of course, would be 'what kinds of societies?'

Some Caveats
There are some important caveats which play an essential role in understanding the interactions between infectious diseases and politics and society:

The Perils of the Zeitgeist
If these processes were examined rigorously, using combinations of quantitative, qualitative and quasi-quantitative methods, it might be possible to develop a framework for pandemic/epidemic preparedness in relation to potential social, economic and cultural effects, thus contributing to improved resilience. There are, of course, many hazards on the path of doing that kind of research, because it is highly political and it is highly exposed; it is susceptible to being taken in particular directions. It would be necessary to avoid political or other knee-jerk framings of the particular *zeitgeist,* an example being the premature securitisation of a pathogen and its effects which has been characteristic of the response to HIV/AIDS.[22] The general lesson is to beware of framing the problem of the effects of, and resilience to, infectious disease in ways which have not been exposed to critical examination.[23]

Behaviour Change is Not Straightforward
And here, perhaps, is the more significant observation and caveat: be careful of the word 'behaviour'. Avoid simple-minded perspectives on behaviour change as a response: 'wash your hands', 'stop smoking', 'do not have sex without a condom'. These are undoubtedly great and important messages. These changes are also very difficult for people to do for complex social and

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22. Tony Barnett and Gwyn Prins, 'HIV/AIDS and Security: Fact, Fiction and Evidence— Report to UNAIDS', *International Affairs* (Vol. 82, No. 1, March 2006), pp. 1–19.

23. Adam Kamradt-Scott and Colin McInnes, 'The Securitisation of Pandemic Influenza: Framing, Security and Public Policy', *Global Public Health* (Vol. 7, Supplement 2, October 2012), S95–110; see also Colin McInnes et al., 'Framing Global Health: The Governance Challenge', *Global Public Health* (Vol. 7, Supplement 2, October 2012), S83–94; Colin McInnes and Kelley Lee, 'Framing and Global Health Governance: Key Findings', *Global Public Health* (Vol. 7, Supplement 2, October 2012), S191–98; Anthony Simpson and Virginia Bond, 'Narratives of Nationhood and HIV/AIDS: Reflections on Multidisciplinary Research on the HIV/AIDS Epidemic in Zambia Over the Last 30 Years', *Journal of Southern African Studies* (Vol. 40, No. 5, August 2014) pp. 1065–89.

economic reasons. Behaviour change is a very complex process which is tempting to simplify into purely rational processes when 'rational' may be very specific to a time, place and socio-cultural position. Some commercial advertisers have a better understanding of the problem than many specialists in behaviour change related to health. They also have bigger budgets, addictive substances and lifestyle memes on their side.

Adopting innovative approaches to behaviour change which take account of the relationship between the individual and the structures within which they live their lives should be considered. 'Culture', of course, is very important, but it needs to be defined clearly: not 'these people do weird things'. There are other ways of looking at the problem, ways which take into account the relationship between human motivations, the evolution of emotions and the problem of behaviour change.[24]

The Seductive Power of Epidemiological Modelling
Large data, affordable and very fast computing, and tremendous progress in mathematical modelling, mean that the uses and potential of modelling are extraordinary. 'Intelligent modelling' is also adding to these advances. It is hard for those outside of the modelling community to really understand what these powerful and useful models do. Their outputs show ranges of possibilities at a time when politicians, the media, the general public and individuals simply want certainty. But that is not what models actually do; their value is in providing impressive graphic visualisations that may show various scenarios for the spread of a pathogen, like pandemic influenza, across a society in days and weeks.

However, rumours are part of the epidemic/pandemic process and infectious diseases are social events. Models and their outputs become part of the pandemic process. Politicians and ordinary people hear about these things and they think, talk and reflect, and the model outputs become part of the epidemic, particularly when there is an event like pandemic influenza. It has a longer wavelength, a very high potential impact and is very high on the UK's National Risk Register.[25] So it is quite important to think about the resonance between a disease, a pathogen and society. It is also important to reflect on the 'social life of models' as

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24. Tony Barnett et al., 'Some Considerations Concerning the Challenge of Incorporating Social Variables into Epidemiological Models of Infectious Disease Transmission', *Global Public Health* (Vol. 10, No. 4, February 2015), pp. 438–48; see also Tony Barnett et al., 'Hope: A New Approach to Understanding Structural Factors in HIV Acquisition' (Vol. 10, No. 4, February 2015), pp. 417–37.
25. Cabinet Office, 'National Risk Register of Civil Emergencies', <https://www.gov.uk/government/publications/national-risk-register-for-civil-emergencies-2015-edition>, accessed 14 May 2015.

part of a pandemic event. Models have social lives and specialists lose control of them.[26]

Conclusion

We could be better prepared to understand the complex pathogenic social space which inhabits us and within which we conduct our lives. The first step in scientific understanding – taxonomy – is the first stage in understanding this problem. It is a complex and challenging task, but it is worth doing because it could set us in a position to have a set of categories – a set of potential signatures – which would generate a better knowledge of the likely impacts. This might help society to become better prepared and more resilient.

This is a transcription of a talk by Tony Barnett, Professor in the Social Sciences of Infectious Diseases, London School of Hygiene and Tropical Medicine. He is co-investigator on a study of the relationship between poultry markets, poultry farming and the emergence of avian influenza in Bangladesh. He has recently co-authored the following two papers, both in the journal Global Public Health*: Tony Barnett, J Seeley, J Levin, and J Katongole, 'Hope: A New Approach to Understanding Structural Factors in HIV Acquisition',* Global Public Health *(Vol. 10 , No. 4, 2015); Tony Barnett, Guillaume Fournié, Sunetra Gupta and Janet Seeley, 'Some Considerations Concerning the Challenge of Incorporating Social Variables into Epidemiological Models of Infectious Disease Transmission',* Global Public Health (Vol. 10, No. 4, 2015)*.*

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26. Erika Mansnerus, 'Questions to Artificial Nature: A Philosophical Study of Interdisciplinary Models and their Functions in Scientific Practice' (Ph.D. thesis, Helsinki, 2006); see also Erika Mansnerus, 'Using Models to Keep Us Healthy: Productive Journeys of Facts Across Public Health Research Networks', in Mary Morgan and Peter Howlett (eds), *How Well Do 'Facts' Travel?* (Cambridge: Cambridge University Press, 2011).

II. Public Health Emergencies of International Concern

Brian Jones

My role in Sierra Leone, since April 2013, was leading the UK government-funded security-sector reform programme, known as the International Security Advisory Team. I led a team of ten UK military, police and civilian mentors engaged in supporting the development of the Sierra Leone Police (SLP) and Republic of Sierra Leone Armed Forces (RSLAF).

When the Ebola outbreak began to take hold in May 2014, my team's role advising the Sierra Leone security sector intensified. Managed initially as a health crisis, it was clear that local mechanisms were becoming overwhelmed as early as June/July 2014.

This paper will cover some of the underlying vulnerabilities in Sierra Leone; the role of the security sector in the Ebola response; and the lessons learned for future public health emergencies of international concern (PHEICs) elsewhere, and for future crises in Sierra Leone.

Underlying Vulnerabilities

On a macro scale, Sierra Leone was still recovering from the civil war twelve years earlier. The war not only destroyed physical infrastructure, it damaged the social contract between state and people, and a twelve-year UN peacekeeping mission skewed Sierra Leone's relationship with the international community to one with elements of dependence rather than partnership. These factors reduced Sierra Leone's capacity to cope with the Ebola outbreak.

The following issues in particular frustrated attempts to isolate the virus.

Communications

Sierra Leone did not have a central emergency telephone number for the police, fire or medical assistance. There was no landline infrastructure and mobile telephony was patchy. Operators were divided on a geographical basis with no one provider claiming full, nationwide coverage and there were significant gaps in service availability, particularly in the border regions. Securing a licence to use geostationary satellite frequencies was also a complex, bureaucratic procedure which led many response agencies to use portable satellite voice and data 'B-GAN' systems instead. This almost overloaded the system at one point of the response. There was no formal government communications system, either physically or in a co-ordinated

policy sense. The Ministry of Information and Communications was not resourced to fulfil this function during the outbreak.

Health-Care Structures and Institutions
Sierra Leone's health-care system was fragmented, drugs-procurement systems were frustrated by corruption and the rural facilities were poor. The few formal hospitals operated independently of district health structures, which themselves operated with a high level of devolution from the central ministry of health. The population's health metrics reflected this, with Sierra Leone scoring one of the lowest global numbers of doctors per thousand population (0.02 doctors per 1,000 population in 2010).[1] International donors broadly focused on HIV, polio and malaria, with few taking a holistic, system-wide approach. Endemic cases of Lassa fever and other haemorrhagic fevers, particularly in the border region with Guinea, and poor diagnostic capacity, further frustrated the initial response to the outbreak.

Logistics
Freetown seaport was configured to manage bulk cargoes of iron ore and minerals by barge and limited container traffic. The port was broadly inefficient, insecure and open to corrupt practices. The airport received less cargo, had unsophisticated cargo-handling, security measures and limited secure storage. Neither facility was capable of dealing with the influx of supplies required to manage the PHEIC. Government logistics functioned slowly often with inefficient bureaucratic systems open to patronage and corruption. These included systems to pay salaries to government employees, including in the health sector. Salary payments were unreliable and open to corruption.

Public Trust in the State
There was a high reliance on 'word of mouth' and oral tradition, including conspiracy theories in formal and informal (social media) journalism. Government announcements, certainly from central level, were not regarded as reliable information and were often woven into elaborate conspiracy stories. An element of this distrust stemmed from the civil war and fractured state structures. Many stories formed around the Ebola outbreak, blaming it on black magic, Western governments' testing of bio-warfare agents, a Western attempt to overthrow Africa and divine intervention. Such stories distracted the public from the real risk-reduction messages, delayed practical acceptance of the virus spread and therefore measures to contain it. It was as late as October 2014 before measures undertaken began to use local trusted influencers and groups to spread messages, which showed some success.

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1.   Central Intelligence Agency, *The World Factbook* 2013–14, <https://www.cia.gov/library/publications/the-world-factbook/fields/2226.html>, accessed 10 March 2015.

Strength of Traditional Beliefs
Traditional beliefs, particularly around treatment of the dead, remain strong in Sierra Leone. These traditions require that the deceased be bathed by family members before burial. The more senior or influential the deceased, the wider the group is who must bathe the remains. Cremation is forbidden in local custom. As the Ebola virus is very strong in the recently deceased, this cultural practice was responsible for around 70 per cent of infections, often with whole family groups, communities or religious groups becoming infected by one individual. Addressing or changing these practices proved difficult, even in relatively cosmopolitan urban areas of the capital.

Land Rights and Law Enforcement
This is a perennial problem in post-conflict countries. But it matters in a PHEIC because land is required urgently for treatment facilities, burial grounds, co-ordination centres and vehicle depots. Without clear land rights or means of procurement, securing land at short notice becomes expensive, risky and often occurs in compromised locations. Securing new burial ground proved particularly challenging.

Poverty
This is an obvious, but important point. The outbreak was of secondary importance to many of the population who lived in poverty. In reality, this translated into individuals taking advantage of situations for personal financial gain rather than what might be seen as 'civic duty' in another context. There, of course, were many examples of selfless, charitable individuals who put their lives on the line for their country and people – but hunger and economic opportunity were the drivers for the majority's involvement in the response either as burial assistants, educators, hygienists, quarantine monitors or ambulance drivers. This obviously skewed any attempt to incentivise certain behaviour, because the focus was on how to obtain the incentive rather than deliver what the incentive was designed to promote, as is the case in many development scenarios.

The Role of the Security Sector
There were good reasons for early involvement of Sierra Leone's security sector in delivering the response. There were also reasons why early involvement was not broadly supported. Much of this related to perceptions of the sector more than the practicalities of the situation.

Jackson and Albrecht, among others, discuss the long-standing UK role in building the capacity of the RSLAF since the end of the civil war in 2002.[2] By 2013, the RSLAF was judged by the UK military, US and multilateral observers

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2. Paul Jackson and Peter Albrecht, *Reconstructing Security After Conflict: Security Sector Reform in Sierra Leone* (Basingstoke: Palgrave Macmillan, 2011).

to be a 'better than average small African army'. It had just sent an infantry battalion of peacekeepers to Somalia as part of the African Union Mission to Somalia (AMISOM). They were performing well – taking the fight to Al-Shabaab and building strong relationships with local communities. In local-perception surveys, the RSLAF was the most trusted government body, above the SLP and other institutions. The SLP had not benefited from a concerted support effort since the war, but, at the basic level, maintained a reasonable level of order and community policing in Sierra Leone.

The issues described above show how the Ebola virus outbreak exposed Sierra Leone's vulnerabilities in crisis co-ordination, logistics, rapid-deployment or medical facilities, mass communication and public engagement. Responsibility for delivering these tasks was spread across numerous government ministries with patchy internal and cross-departmental co-ordination. Yet one sector, the security sector, had the capacity to deliver most of these tasks, to a lesser or greater extent, and was well co-ordinated between national agencies and across Sierra Leone's districts and provinces.

The Ebola outbreak in Sierra Leone could not be categorised wholly as a health emergency (the objective was not to cure the sick as the virus would prove fatal to most of those contracting it and the health system was incapable of the required scale and pace of co-ordination), a development challenge (it was a crisis and had to be managed in that mind-set, rather than employing accepted development principles of consultation, capacity-building and partnership – although they were good if achievable) or humanitarian emergency (the principles of isolation to cut transmission prioritised rapid achievement of safe burial and isolation above management of wider suffering and consequences). At first, it was not a national-security issue; but it became one later.

The only Sierra Leonean mechanism that could have stood a chance of controlling the outbreak, if deployed much earlier, was the security sector. My evidence for this assertion is that the reduction of the replication rate of the virus (R_0 value) from 1.8 in August 2014 to 1.0 in January 2015 was not the result of a vaccine (there was none) or mass-treatment facilities opening (these only trickled online in December and January) but was the result of enhanced 'command, control and co-ordination' of the response efforts at the national and district level – almost entirely achieved with military personnel and principles; rapid management of alerts; co-ordination of response; and recording of the data and decisions.

Lessons Identified for Future PHEICs and Sierra Leone
There are lessons for future PHEICS highlighted by the Sierra Leonean case:

- Reconsider how we as health, governance and security professionals, approach PHEICs and infection control. In the UK and US, the military

and police should play an immediate supporting role with strong central co-ordination and technical health leads. We should not be afraid of empowering that solution elsewhere, and building response systems to integrate, manage and co-ordinate support from the security sector. The relevance of its skills and capabilities cannot be ignored in this context

- Post-conflict reconstruction missions should support the capacity of disaster-management institutions to deal with the scale and pace of the most complex threat – for Sierra Leone it is Ebola, for others it will be another infectious disease or seismic threat. Donors focus on stabilising the military and rebels in the immediate aftermath of the conflict – which is necessary. But medium- and long-term support must be more broad-based and holistic

- Act locally. Precious time was lost in the response because responders treated the relationship between the Sierra Leonean state and its people as a normal, trusting one. In addition to the central-government messaging, trusted local voices must be employed early to relay information into the heart of communities – this stands the best chance of achieving behavioural change necessary to combat the outbreak.

- Sierra Leone was a permissive security environment to conduct the response – in our international planning we should consider delivering such assistance in a less permissive security context, for example in the Sahel, Pakistan–Afghanistan border regions, Yemen or Libya. Such cases would pose significantly higher risks and challenges to an international assistance effort

- Other authors have recorded this, but it is worth noting in this context – the UK's investment in the RSLAF was significant over twelve years. It achieved a generational change and delivered a capable military force. Investment in the police, the medical system or the disaster-management institutions of Sierra Leone must begin with such a commitment – it will not achieve meaningful, lasting results unless it is long term (in this case, fifteen years).

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III. PHEICS: Actions and Research Requirements

Obinna Michael Azuikpe

The year 2014 in West Africa and indeed the world will be remembered not for progress made in combating infectious diseases but as the year the Ebola virus crippled three countries in the African continent and inflicted economic damage to many others. What started as an environmental-based crisis descended into a global security, economic and humanitarian nightmare. Similarly, the re-emergence of poliomyelitis in Syria re-emphasised the devastating effects that conflict can have on a country's health-care system.

Though both outbreaks prompted an international response, it is generally perceived that more lives could had been saved from a much quicker response. Therefore, the need for greater alertness and a quicker reaction to the recurrence of such diseases in the future is vital. This calls for greater action from the international community to ensure that the health-care systems in fragile or weak states (especially those in conflict or recovering from conflict) become the primary focus for nation-building and reconstruction. This was reflected in the comments made by World Bank President Jim Kim, who stated that the lack of progress for many fragile states 'should be a wake-up call to the global community not to dismiss these countries as lost causes', and that 'timely and critical support is needed to improve the lives of people living in these fragile countries.'[1]

From his comments, it is pertinent to deduce that if the global community has been sleeping on the job of supporting fragile and post-conflict societies, then the current Ebola outbreak, which has gripped virtually every continent of the world, is certainly something to jostle policy-makers back to their responsibilities.

The presentation from which this paper is written intended to stimulate further discussion on a complex set of issues associated with global infectious diseases. The paper will highlight the challenges of conflict on health-care systems and aims to enhance future humanitarian responses to infectious diseases, and the potential for a military-related response to future public-health emergencies.

The Challenges of Conflict on Health-Care Systems
During periods of conflict, a variety of factors adversely affect medical care and public-health services. Doctors, nurses and health staff are often targeted

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1. World Bank, 'Twenty Fragile States Make Progress on Millennium Development Goals', press release, 1 May 2013, <http://www.worldbank.org/en/news/press-release/2013/05/01/twenty-fragile-states-make-progress-on-millennium-development-goals>, accessed 12 March 2015.

and displaced. Hospitals and health centres are often destroyed leading to the dearth of health-care services within the affected society. All these result in an increased spread of infectious diseases.

Between 1989 and 2004, an unrelenting armed conflict raged in West Africa, moving across borders from Liberia to Sierra Leone, Guinea and Côte d'Ivoire. Violence, looting, and pillaging became an economic opportunity for the impoverished people, and a large mercenary force developed within the region. Mass refugee movements and resettlement camps created a large group of displaced and vulnerable people with the associated environmental impacts that persist today. The mass movement of refugees and subsequent emergence of re-settlement camps further exposed the victims of such conflict to infectious diseases and other vulnerabilities.[2] Such conflicts also had an impact on infrastructure, governance, social cohesion, and the mental and physical health as well as the livelihood of the region's people. These effects have also severely undermined societal resilience as well as public -health infrastructure and service delivery within the region.

Bausch and Schwarz highlighted that Ebola, rather than mysteriously appearing at random, previously appeared in regions with compromised local economies and weak public-health systems, such as northern Uganda, the Democratic Republic of the Congo and South Sudan.[3] In these regions – often devastated by conflict – they noted: 'Poverty drives people to expand their range of activities to stay alive, plunging deeper into the forest to expand the geographic as well as species range of hunted game and to find wood to make charcoal and deeper into mines to extract minerals, enhancing their risk of exposure to Ebola virus and other zoonotic pathogens in these remote corners.'

The fact remains that post-conflict Sierra Leone – which has so far recorded the highest number of deaths in the current Ebola virus disease (EVD) outbreak – is still reeling from the effects of war. The eleven-year conflict that ended in 2002 crumbled the health sector and fuelled social conflict and distrust of government, resulting in its citizens patronising traditional healers rather than health facilities. Even before the war, the Sierra Leonean health-care system was under-performing, with high levels of out-of-pocket spending. Coupled with the lack of efficient service delivery, this shifted health-seeking behaviour towards traditional healers and drug peddlers. The plethora of humanitarian agencies in the country has, however, helped in mitigating the decay of the health-care system.

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2.   A M Mannion, 'The Environmental Impact of War & Terrorism', Geographical Paper No. 169, 2003, pp. 10–11.
3.   Daniel Bausch and Lara Schwarz, 'Outbreak of Ebola Virus Disease in Guinea: Where Ecology Meets Economy', *PLoS Neglected Tropical Diseases* (Vol. 8, No. 7, July 2014).

Nonetheless, in addition to reforming the Sierra Leonean health system, there is the need to identify and address the issues underlying the historically fragile health-care delivery in the country. This should guide the way forward as the current evidence-based health-systems research lacks national ownership. This needs to change in order to ensure sustainability through rebuilding and strengthening the health sector. It is obvious that lessons were not learned from the 2012 cholera outbreak when more than 300 people lost their lives, revealing a degree of complacency in addressing the issues that facilitate a rapid health response to a disease outbreak.[4] In the midst of the current tragedy, Ebola provides an opportunity to take stock of what needs to change in the health system in Sierra Leone.

The current EVD epidemic has also prompted discussions on the brain-drain effect resulting from medical professionals who migrate from Africa to the West in search of greener pastures. According to data from online health-workplace policy journal, *Human Resources for Health*, one in five African-born physicians and one tenth of African-born nurses work overseas.[5] Reasons often adduced for relocating range from seeking better remuneration to the desire to raise their families in more stable environments. Thus, while African doctors make advancements in medical research elsewhere, their native countries' health-care systems suffer. Liberia is no exception. The need to explicitly identify the effect of the brain-drain phenomenon on the fragility of health-care systems in unstable environments therefore becomes important in order to enable effective planning and response to future public-health emergencies.

Enhancing Future Humanitarian Response
There is a broad acknowledgement of the measured response to the Ebola outbreak by the international community. The World Health Organization (WHO) and its surveillance systems have been the main target of criticism in terms of the slow international response. The first case of EVD in West Africa was traced to Guinea in December 2013 when a two-year-old boy fell ill with a mysterious ailment.[6] It was however not until 21 March 2014 that WHO was officially notified that the rapidly evolving outbreak was caused by EVD

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4. World Health Organization (WHO), 'Cholera in Sierra Leone: The Case Study of an Outbreak', September 2012, <http://www.who.int/features/2012/cholera_sierra_leone/en/>, accessed 12 March 2015.
5. Michael Clemens and Gunilla Pettersson, 'New Data on African Health Professionals Abroad', *Human Resources for Health* (Vol. 6, No. 1, January 2008).
6. WHO, 'Ground Zero in Guinea: The Outbreak Smoulders – Undetected – for More Than 3 Months', <http://www.who.int/csr/disease/ebola/ebola-6-months/guinea/en/>, accessed 12 March 2015.

in the forested areas of south-eastern Guinea.[7] WHO finally declared the EVD outbreak as a public health emergency of international concern (PHEIC) on August 2014.[8] Though the health systems of these Ebola-affected countries can be reformed, lessons are required to enhance future humanitarian responses as well as guide the process of revitalising the post-Ebola health system.

To prevent the spread of disease to vulnerable populations, reports of priority diseases should trigger immediate action by personnel with the training, equipment and resources required to investigate and contain outbreaks. Managing cases and preventing the further spread of disease may require extensive co-ordination — not only among clinical and public-health personnel, but with partners in animal health, environmental health and public safety. Many countries face serious challenges in co-ordinating this multisectoral response to public-health events. The absence of policies, lack of information exchange between human and veterinary public-health officials and illegal animal transportation across borders have been mentioned as some of the existing gaps in infectious-disease containment. Consequently, developing a system for cross-border epidemic warnings; having common criteria for ensuring cross-border alerts, risk-assessment procedures and concerted response; and supporting regular meetings between local disease-control officers posted at borders, may further enhance the response time to the outbreak of any infectious disease in the future.

Further to this is the issue of stigma or the contagion effect that surrounds persons or communities that have been affected by such deadly diseases. It is believed that the stigmatisation of persons infected by the virus further led to the escalation of the EVD outbreak in Liberia and Sierra Leone. It is estimated that over 30,000 children across Liberia, Sierra Leone and Guinea may have been orphaned following the outbreak of EVD.[9] The degree of stigma attached to the disease would create a major challenge in resettling such orphaned children. This eventually acts as a barrier to health-care access, thereby preventing early detection and treatment and furthering the spread of the disease. Stigma enhances social marginalisation that often leads to poverty and neglect. This increases the susceptibility of the population to the entry, and the amplification of, infectious diseases. Furthermore, a

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7.   WHO, 'Situation Report 1: Ebola Virus Disease, Guinea, 28 March 2014', <http://www.afro.who.int/en/clusters-a-programmes/dpc/epidemic-a-pandemic-alert-and-response/sitreps/4070-sitrep-1-ebola-guinea-28-march-2014.html>, accessed 12 March 2015.
8.   WHO, 'Statement on the 1st Meeting of the IHR Emergency Committee on the 2014 Ebola Outbreak in West Africa', WHO statement, <http://www.who.int/mediacentre/news/statements/2014/ebola-20140808/en/>, accessed 12 March 2015.
9.   WHO, 'Factors That Contributed to Undetected Spread of the Ebola Virus and Impeded Rapid Containment: One Year into the Ebola Epidemic', January 2015, <http://www.who.int/csr/disease/ebola/one-year-report/factors/en/#>, accessed 12 March 2015.

potentially stigmatised community may distrust health officials and resist co-operation during a public-health emergency. It is therefore essential that research and best practices on this subject inform clinical and prevention planning, implementation and monitoring – which are indeed necessary for the improvement of treatment and prevention outcomes.

The importance of local capacity and the role of local organisations in emergency response is another point of note for future responses. Successive studies and evaluations have found that local capacities can make a critical difference to humanitarian responses. Partnerships among international humanitarian actors (donors, the UN and aid agencies) and the government as well as local and national organisations of affected countries are emerging as a key approach in co-ordinated responses. The Nigerian government was able to swiftly tackle the Ebola outbreak within its own borders through the co-ordinated response of its local health institutions and the entire community as well as through the leadership displayed by all tiers of governance. Some of these health institutions had the local capacity to effectively manage cases of infectious outbreaks. The involvement of NGOs as well as civil society was also instrumental to the rapid response observed in Nigeria. This approach involved everyone: from military officials to religious leaders who continually enlightened the populace on characteristics of the virus. These, as well as the assistance of international donors and agencies, were instrumental to the complete eradication of the virus three months after the first case was identified and reported.

The Potential for a Military-Supported Response
The military serves a unique role in its ability to support international partners with the tools to detect and respond to the earliest evidence of a potential public-health threat or an emerging infectious-disease epidemic. The potential of a military response to public-health emergencies seeks to build and enhance the capability of partner nations for detection, early warning, disease surveillance, outbreak response, clinical and epidemiologic outbreak-response training and clinical research capacity to strengthen the global public-health network.

Through its overseas infectious-disease research laboratories, located in more than twenty countries for more than ten years, the US has been a primary participant in the pursuit of a military-related response to infectious diseases. The Department of Defense Global Emerging Infectious Disease Surveillance and Response System (DoD-GEIS) mobile laboratories were set up for the purpose of responding to outbreaks of epidemic, endemic and emergent diseases. Their location in the Department of Defense as opposed to the US Agency for International Development or the Centers for Disease Control and Prevention, emphasises how seriously the country views the

response to infectious diseases as a vital part of its national security and defence strategy.[10]

The US military and the British armed forces have so far played a pivotal role in delivering the necessary support needed in tackling the Ebola scourge in Liberia and Sierra Leone respectively. This has also galvanised other states including China, the Netherlands and Ireland to contribute members of their armed forces in the fight against the epidemic. Going forward, it is envisaged that the military will continue to play a very vital role, not only in disaster zones, but in areas plagued by epidemics and health emergencies of international concern.

Summary

The EVD clearly poses a threat to the security and stability of countries still struggling to deal with the consequences of prolonged civil wars (Liberia and Sierra Leone) and chronic political instability (Guinea). Indeed, the current epidemic is likely to have a significant effect not only on these countries' economies but also on their public order, peace and social cohesion. The need to develop the health-care capacity of fragile nations remains a major factor to contain PHEICs wherever they emerge. It is therefore important that this gathering come up with practical and workable solutions that will stand the test of time for the benefit of humanity.

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10. Sara Davis, 'Securitizing Infectious Disease', *International Affairs* (Vol. 84, No. 2, March 2008) pp. 295–313.

Situational Awareness

IV. Developing Situational Awareness

Nigel Lightfoot

The Ebola problem, which, at the time of the RUSI/STFC conference, was in recovery phase, has shown that better preparation is needed in future. The next threat is likely to arise in Africa, Southeast Asia or South Asia. Situational awareness is important for better preparation. Solutions that might work in the UK are unlikely to work in places like Africa and Southeast Asia because there is so much building and rebuilding to be done.

Connecting Organizations for Regional Disease Surveillance (CORDS) helps to connect countries so they can work better together with problems like Ebola. It works with twenty-eight countries in six networks around the world, and has worked with some of them for ten years. Its vision is to be able to detect the next pandemic earlier every time.

Within these networks, countries communicate across borders on a daily basis. This can be difficult because it needs a memorandum of understanding between ministers, and sometimes between heads of state. Some ministers of health tell their people they cannot talk about diseases – such as the Middle East respiratory syndrome (MERS) coronavirus, which remained hidden from the rest of the world for a long period of time. But CORDS networks operate across borders and even in difficult situations such as the Middle East. Palestine, Israel and Jordan are communicating today through CORDS despite deep political animosities.

We have learned the importance of getting people communicating early, in order to understand what is happening sooner. When there are only a few pieces of information to put together it becomes very difficult to make a decision. At the UK Department of Health, it is called 'the period of uncertainty'. Situational awareness is about gathering information, analysing and assessing it, and then making decisions from it. Gathering information includes what people are saying and doing on the ground. Big events always start as small events locally, and it is important to find out if people talk about those events and whether they pass information to others. Newspapers can help inform what is happening on the ground and often know before anybody else.

Examples of Emerging Infectious-Disease Problems
There are a number of contemporary examples which illustrate deficiencies in the situational awareness of infectious diseases.

SARS Coronavirus

This was present for three months in ministry-of-defence hospitals in China before it was recognised as spreading by which time it was a problem for the wider world.

MERS Coronavirus

The first outbreak happened in northern Jordan in April 2012. A newspaper reported that there had been an outbreak of severe respiratory disease in an accident-and-emergency department of a hospital in Jordan, with a doctor and a nurse dead and five other people seriously ill. That was highly unusual. When asked what the government was doing about it, the relevant minister said it was just pneumonia, and discouraged further discussion. But authorities were persuaded to send samples to the Naval Medical Research Unit Three (NAMRU-3) in Egypt, the US Navy's laboratory. They were tested for everything but nothing was found. Later, when the MERS coronavirus appeared, the samples from Jordan were tested again and all were found to be MERS coronavirus. This was the first outbreak – it could have been kept hidden and it would have disappeared from public view. But the information was there that would have given situational awareness.

H1N1

This pandemic began much earlier than when it was officially identified in April 2009. Argus data suggest that respiratory disease was a topic reported on more frequently in the 2008–09 influenza season than in 2007–08.[1] Reports in the media in the 2008–09 season scored higher in terms of social disruption than reports in the media in the 2007–08 season. Selected examples include:

- 6 March 2009, Querétaro: San Juan del Rio hospitals on alert
- 12 March 2009, Chihuahua: Upper respiratory infections increased 30 per cent recently in Parral
- 16 March 2009, Nuevo Léon: 60–70 per cent occupancy at Monterrey Children's Hospital
- 19 March 2009, Tamaulipas: Seven children under five hospitalised in Nuevo Laredo; 4,000 respiratory consultations in February. This work was undertaken in real-time but reported retrospectively
- 23 March 2009, Tabasco: Consultations increased 30 per cent at Villahermosa Medical Center.

H1N1 was subsequently identified on 21 April 2009.

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1. Project Argus, a bio-surveillance system run from the University of Washington that used CIA software to trawl the world media for information on diseases. See N P Nelson, J S Brownstein and D M Hartley, 'Event-Based Biosurveillance of Respiratory Disease in Mexico, 2007–2009: Connection to the 2009 Influenza A (H1N1) Pandemic?', *Euro Surveill*. (Vol 15, No. 30, June 2010).

Ebola

In early March 2014 there were clues that something different was happening in parts of Guinea. It started small and locally, and continued for over a month before it emerged as a problem. Situational awareness in this case would have meant having information early enough to make a difference.

On 19 March a newspaper in Guinea, *Africaguinea*, published an article about a strange fever that broke out in Macenta (the first case was actually a two-year-old child in December – there is a big gap between something happening and it being noticed). It was initially thought to be Lassa fever and no buttons were pressed. Then people started to move to Conakry 800 km away, where there is a hospital, and stay with family and friends. Many men there have several wives, so there are large extended families and many connections. And there is tremendous poverty in Conakry so it is easy for disease to spread in those areas.

There are enormous problems in Guinea, Sierra Leone and Liberia. They are ravaged by wars and have minimal health infrastructure. In 2012, a laboratory report of Sierra Leone's laboratory capabilities was published. There are just seven laboratories – for a population of six million. Of those seven laboratories, none of them can do more than six of the twelve basic tests as recommended by the World Health Organization.[2] In 2003, a plan to invest in the laboratory infrastructure was put in place, but it never got started. So, a lot of foreign donors have had to come in with laboratories into Sierra Leone and the surrounding countries.

There are very few doctors. Those who want to go back and help left due to the war; some had been imprisoned. Each side puts the other side in prison when there is a power change, so it is natural for the long-term future of the doctors' families to go abroad. The percentage of total GDP spent on health is less than 3 per cent. It is a mammoth task to rebuild infrastructure in such countries. At the time of the conference it was expected that the World Bank would put $602 million into the infrastructure of those three countries. But an effective response needs people, not just briefcases of money.

The Next Viruses

Researchers at the National Institute for Communicable Diseases in South Africa have been going up the Great Rift Valley and trapping bats, looking for Ebola and other viruses. They have isolated several other virus isolates in their laboratory that could possibly transmit to humans and cause the next

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2. Information obtained via personal correspondence with Noel Gill. The author is able to provide further information if required.

outbreak.[3] So it is not a case of 'if' there is another public-health threat to follow Ebola, it is 'when'.

Key Challenges

There is a big gap between something happening and it beginning to be noticed and then acted upon. To this end, CORDS has outlined the following aims:

- Act faster. The first curve on Figure 1 is the infectious-disease curve and the other is the local-intervention curve. The aim is to get that curve closer to the outbreak curve
- Be closer to the outbreak. This means having local people who know about reporting in order to build proper surveillance systems using humans
- Act earlier so that the curve can be pushed back and begin to reduce the impact on the population
- Act smarter, so lessons are learned for better preparation next time. Find a system that gives out the clues that something is happening by communicating with people.

Figure 1: Graph Showing the Rate of Infectious Disease and Local Intervention over Time.
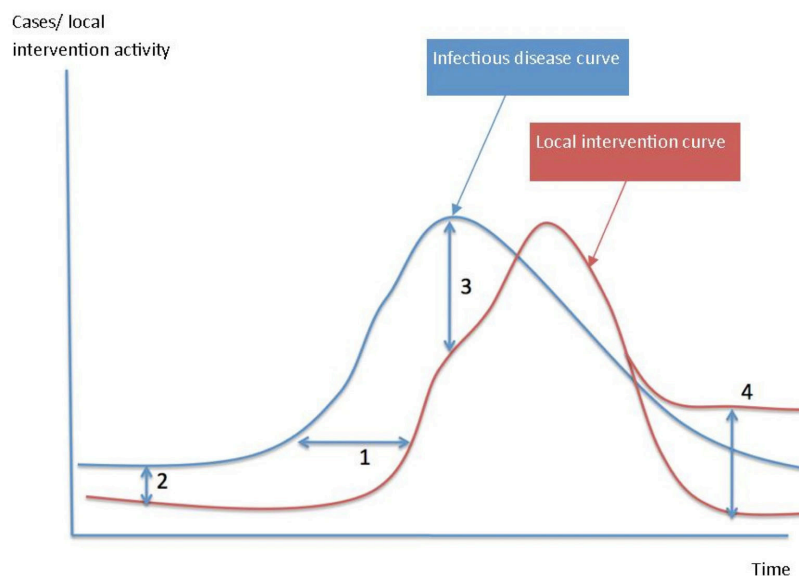
Source: CORDS.

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3. Information obtained via personal correspondence with researchers. The author is able to provide further information if required.

Our concept in CORDS is that we want people to talk to each other before disease is identified. If it is happening in one place, it is likely to happen in another place, and talking is the only way of getting closer, faster and earlier to actually responding.

Improving Awareness

How do we go about improving awareness? We believe local people make the difference, so we start by listening to them. When you work with local communities you realise their key role in combating infectious disease, which is only enhanced by external, professional support. This enables and facilitates these communities to find the solutions they need. That is sustainable.

We do a lot of work in risk management, risk communication and innovative operational research. We do not use PowerPoint presentations. Rather, we give them scenarios and get them to find the solutions to the problems.

The Ebola Intensified Preparedness Programme

CORDS is in the middle of what we call the Ebola Intensified Preparedness Programme, funded by the Rockefeller Foundation, using its local people to do the work. In Dar es Salaam, we put together an emergency workshop with those who know about Ebola, which included people from the University of Kinshasa in the Democratic Republic of the Congo (DRC), and virologists from Uganda. We also had two traditional healers, teachers and journalists, along with experts and policy-makers. We listened to them and asked for their feedback on the programme. They said it is about working within communities, using information that people will understand and using the knowledge of the culture and the anthropology of those areas.

The representatives from the DRC and Uganda explained how they have teams of 100 people in the centre who are sent out if there is an Ebola outbreak. Teams include psychologists, sociologists and anthropologists as well as the necessary medical personnel. They understand that work has to be conducted in local languages. Another important message that came across was not to forget traditional healers. Between 60 and 70 per cent of the population will go to a traditional healer. In the DRC and Tanzania, they have worked with traditional healers and given them some indicators – for example, if they see particular diseases and illnesses – to get patients over to the health system for help.

We found that in the DRC people noticed that in most outbreaks monkeys die first. But it is not practicable to tell them to stop eating monkeys – it is a valuable source of protein for starving people and they have done it for thousands of years. Even the prime minister of Guinea tried to tell people not to eat bush meat but people continued to eat it. So we came up with

plans to help make it safer to eat monkeys and bats. This manages, rather than eliminates, the risk.

Conclusion

There will be another epidemic; researchers continually identify new viruses and there are probably more to be discovered. Any new virus will probably arrive in Africa or Asia and we need to be ready. Western messages do not work and we must listen to and work with the people on the ground. When local communities work together they are very creative and know how to find solutions.

Newspaper reports that get in before anything else does are essential to the analysis and situational awareness. We need systems that pool this information and make it available in an easily digestible format. We are working on a West African infectious-disease surveillance network – the World Bank and Rockefeller Foundation are also going to contribute. At the very least we will get people talking across borders so if it does happen again, they will actually be communicating and improving one another's situational awareness.

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V. Controlling and Managing Infectious Diseases During Armed Conflicts: The Example of Polio in Syria

Balsam Ahmad

On 17 October 2013, a cluster of fourteen acute flaccid paralysis (AFP) cases was reported in the northern Syrian governorate of Deir ez-Zor. The significance of the polio cluster stemmed from the fact that cases re-emerged fourteen years after the World Health Organization (WHO) certified Syria as polio-free.[1]

There is evidence from other countries that have experienced conflict, of an inverse statistical association between armed conflict and low vaccine coverage. This is mainly caused by the breakdown of basic health services and an inability to reach vulnerable populations. For example, a study using retrospective neonatal polio-vaccination histories based on a series of multiple indicator cluster surveys (2000, 2006 and 2011) in Iraq showed that infants living in the central and southern areas affected by conflict were 21.5 percentage points less likely to have received an oral poliovirus vaccination within two weeks of birth compared to those living in the autonomous Kurdish areas which were relatively unaffected by war.[2]

Pre-Conflict Syria: A Changing Context

Up until the conflict and the resulting mass population displacement, Syria was home to a population of around 22 million comprising diverse religious and ethnic backgrounds. The Syrian population is young with more than a third under fifteen years of age in 2010 (37.2 per cent).[3] High unemployment rates were a key challenge in Syria even before the crises. In 2010, the official unemployment rate was estimated at 8 per cent. Unemployment was high and increasing among the youth (the rate of unemployment among the youth was six times higher than that of adults).[4] Gender inequality in terms

1. Balsam Ahmad and Sanjoy Bhattacharya, 'Polio Eradication in Syria', *Lancet Infectious Diseases* (Vol. 14, No. 7, July 2014), pp. 547–58.
2. Valeria Cetorelli, 'The Impact of the Iraq War on Neonatal Polio Immunisation Coverage: A Quasi-experimental Study', *Journal of Epidemiology and Community Health* (Vol. 69, No. 3, November 2013), pp. 226–31.
3. World Health Organization (WHO), 'Syrian Arab Republic Information Sources', 2013, <http://www.emro.who.int/syr/information-resources/information-resources.html>, accessed 12 March 2015.
4. International Fund for Agricultural Development, 'Syrian Arab Republic: A Fact Sheet on Youth Unemployment', 2011, <http://www.ifad.org/events/gc/34/nen/factsheet/syria.pdf>, accessed 5 February 2015.

of education is notable (female illiteracy is 22 per cent compared to just 10 per cent for males).[5]

The health-care system in Syria consists of a government-run public system that provides mostly primary-care services and teaching hospitals attached to the ministries of health or defence. On the other hand, the majority of secondary- and tertiary-care services and facilities belong to the private sector and are mostly concentrated in major urban centres such as Damascus and Aleppo.

The Syrian government pursued economic liberalisation policies over the decade preceding the conflict. Economic liberalisation was mostly notable in the fields of health and education. Such policies resulted in increasing socioeconomic inequity and pushed more people into poverty. Urban-rural inequality in economic and human development was stark, especially in the eastern provinces that have witnessed severe consecutive droughts since 2005, pushing millions into poverty.[6]

For example, the Health Sector Modernisation Programme (2003–10), financed by the EU, promoted the gradual withdrawal of state funding and increased public-private partnerships for the provision of health services.[7] The liberalisation of the health-care system resulted in a widening of inequality in access to care and increased the financial burden of those least able to pay.[8]

In general, many of the health indicators in the country have shown positive trends: infant and maternal mortality rates (IMR and MMR) have declined significantly over the past two decades.[9] On the other hand, like many developing countries, Syria experienced a double burden of disease. Communicable diseases from exposure to traditional health hazards such as lack of safe water, sanitation and indoor air pollution still constitute a major cause of mortality and morbidity.[10] At the same time, the prevalence of risk factors for chronic diseases such as coronary heart disease has been increasing.

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5.   Ziyad Ben Taleb et al., 'Syria: Health in a Country Undergoing Tragic Transition', *International Journal of Public Health* (Vol. 60, Supplement 1, 2014), S63–72.

6.   *Ibid*., S63–72.

7.   Kasturi Sen and Waleed al Faisal, 'Syria: Neoliberal Reforms in Health Sector Financing: Embedding Unequal Access?' *Social Medicine* (Vol. 6, No. 3, March 2012), pp. 171–82.

8.   Kasturi Sen, Waleed Al-Faisal and Yaser AlSaleh, 'Syria: Effects of Conflict and Sanctions on Public Health', *Journal of Public Health* (Vol. 35, No. 2, June 2013), pp. 195–99.

9.   Sen and al Faisal, 'Syria: Neoliberal Reforms in Health Sector Financing', *Social Medicine,* p. 172.

10. *Ibid.*

The Barriers to Polio Immunisation: Using a PESTE Framework

There are a number of barriers to polio immunisation which can be identified through a political, economic, socio-cultural, technological, environmental (PESTE) framework.

Political Factors
Syria shows many signs of a failed state. The Syrian conflict is resulting in a fragmented reality on the ground with more than 1000 armed groups being known to be active in the country. Areas controlled by the government and those controlled by various opposition factions are becoming increasingly disconnected from one another and, in some cases, opposition areas have their own autonomous status. The key challenge for public-health efforts is the bleak humanitarian situation that continues to deteriorate with the escalation of violence four years into a complex conflict.

The war in Syria has created the largest mass displacement of population in modern history. According to the UN High Commissioner for Refugees, the number of registered Syrian refugees in March 2015 was approaching 3.7 million.[11] The number of internally displaced persons (IDPs) according to the Internal Displacement Monitoring Centre was estimated to be 7.6 million.[12]

In addition to the challenges to routine immunisation programmes resulting from the large population displacement inside and outside Syria, there is also the problem stemming from limited access to health-care for a large segment of the population. This is due to the wide destruction of health-care facilities, severe shortage in health-care personnel and the lack of security in many areas. According to WHO, by the end of 2013, about 60 per cent of public hospitals and 38 per cent of primary health-care centres had been destroyed or seriously damaged.[13]

Economic Factors
The escalating armed conflict, the sanctions as well as the wide destruction of personal and state property and infrastructure have had devastating effects on the Syrian economy. According to the Economic and Social Commission for Western Asia, Syria has lost thirty-seven years in human development in the first three years of the conflict and has seen a decline across all development

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11. UNHCR, 'Syria Regional Refugee Response: Inter-Agency Information Sharing Portal', <http://data.unhcr.org/syrianrefugees/regional.php>, accessed 12 March 2015.
12. The Internal Displacement Monitoring Centre, 'Syria', <http://www.internal-displacement.org/middle-east-and-north-africa/syria/>, accessed 12 March 2015.
13. WHO, 'Health: Syrian Arab Republic 2013', <http://www.who.int/hac/syria_dashboard_6june2013_final_small_.pdf>, accessed 25 January 2015.

indicators to reach the second-lowest ranking among all Arab countries.[14] Unemployment now exceeds 50 per cent and an estimated half of the population lives below the poverty line. Government subsidies have been removed on many essential goods and food inflation is above 100 per cent. The availability of essential food items and goods is restricted in besieged areas and prices of essential goods have rocketed in most areas of Syria. A war economy is emerging in the country which is flourishing on violence and lawlessness.[15] One in five Syrian families are deprived of food for at least a week every month and malnutrition might be the next epidemic in Syria if no urgent efforts take place to alleviate the situation.[16]

Socio-Cultural Factors
There is a dearth of empirical data from Syria and other Arab countries on socio-cultural factors that influence acceptance of routine immunisation programmes. However, there is no evidence to suggest a lack of acceptance of the routine polio-immunisation programme among the populace on the basis of religious grounds similar to what is seen in countries such as Nigeria. Recent commitments from religious leaders in the Arab world on polio vaccination are likely to have had a positive effect on immunisation efforts. For example, in a communiqué on 26–27 February 2014, the First Global Islamic Advisory Group for Polio Eradication made an appeal to all communities, governments, civil society and religious organisations to ensure that all children have access to the polio vaccine.[17] It is worth noting the meeting was organised by Al Azhar Al Sharif and the International Islamic Fiqh Academy in collaboration with the Organisation of Islamic Cooperation, Islamic Development Bank, WHO and UNICEF.[18]

Evidence from research in developing countries shows that there are numerous socio-cultural factors that influence acceptance and uptake of vaccination programmes in developing countries. Those relevant to Syria include: parental education; perception and attitude of parents towards vaccination; barriers to access vaccination; as well as opportunity costs such

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14. United Nations Economic and Social Commission for Western Asia, 'Syrian Experts Urge Geneva II Parties to Seize Historic Opportunity', press release, 21 January 2014, Beirut, <http://www.escwa.un.org/information/pressescwaprint.asp?id_code=610>, accessed 12 March 2015.
15. Jihad Yazigi, *Syria's War Economy* (London: ECFR, 2014).
16. Taleb et al., 'Syria: Health in a Country Undergoing Tragic Transition', *International Journal of Public Health*, S63–72.
17. Global Islamic Advisory Group (IAG) for Polio Eradication, 'Final Communiqué', First IAG Meeting on Polio Eradication, Jeddah, Saudi Arabia, 26–27 February 2014, <http://www.polioeradication.org/Portals/0/Document/Resources/Declaration_Resolution/Jeddah_Declaration_EN.pdf>, accessed 3 February 2015.
18. Ahmad and Bhattacharya, 'Polio Eradication in Syria', *Lancet Infectious Disease*, pp. 547–48.

as loss of earnings or time.[19] Illiteracy and low educational attainment of mothers may lead to poor knowledge of the vaccine and increased likelihood to accept rumours. Qualitative empirical evidence from Aleppo in Syria shows that health-care providers perceived differences between ethnic communities in the uptake of health services such as contraceptive services and vaccination.[20] For example, there were more barriers to access health services among the tribal Arab communities in the north than the Kurdish population. In a previous study, one of the barriers mentioned as an obstacle to the uptake of vaccination was the difficulty for many women in leaving the home and their reliance on the husband or the mother-in-law to accompany them and their children to health services.[21]

Inside Syria, routine vaccination campaigns are hampered by shifting conflict lines and a lack of access to communities because of high levels of insecurity and violence. There is no indication or evidence to show that IDPs who moved to government-controlled areas, whatever their religious or political affiliation, are denied access to polio vaccination. In fact, evidence shows that vaccination coverage for polio is 100 per cent in Tartus governorate, one of the provinces that received the highest number of IDPs because of its relative safety.

Technological Factors
There are three issues to include under technological factors. These relate to surveillance, the routine polio-vaccination schedule, and challenges to delivery and transport of the vaccine.

It is important that routine and effective surveillance of wild poliovirus take place. This usually occurs through reporting and laboratory testing of all cases of AFP and non-polio AFP immunity-profile monitoring. In September 2012, the Syrian Ministry of Health Early Warning Alert and Response System (EWARS) was established with technical support from WHO to respond early to outbreaks and detect epidemic threats. It reportedly uses health facilities run by NGOs and private hospitals and clinics in provinces most affected by the armed conflict.[22] A parallel system led by the assistance co-ordination unit of the national coalition and technically supported by the US Centers

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19. Mandip Jheeta and James Newell, 'Childhood Vaccination in Africa and Asia: The Effects of Parents' Knowledge and Attitudes', *WHO Bulletin* (Vol. 86, No. 6, June 2008), pp. 417–96; see also Victoria Nankabirwa et al., 'Maternal Education Is Associated with Vaccination Status of Infants Less Than 6 Months in Eastern Uganda: A Cohort Study', *BMC Pediatrics* (Vol. 10, No. 92, December 2010).
20. Balsam Ahmad and Yannick Sudermann, *Syria's Contrasting Neighborhoods: Gentrification and Informal Settlements Juxtaposed* (Boulder, CO: Lynne Rienners, 2012).
21. *Ibid.*
22. Ghada Muhjazi et al., 'An Early Warning and Response System for Syria', *The Lancet* (Vol. 382, No. 9910, December 2013), p. 2066.

for Disease Control and Prevention was set up in opposition-controlled governorates.[23]

According to WHO and UNICEF data on national immunisation coverage of the third dose of polio vaccine, there has been a steady and large decline in the uptake of routine immunisation. According to these sources, vaccination coverage with three doses of oral poliovirus vaccine (OPV) – the OPV3 vaccination – among children aged 12–23 months dropped from more than 80 per cent on the eve of the conflict in 2010 to just over 50 per cent in 2013.[24] Similarly, non-polio AFP immunity-profile monitoring shows an increase in the number of children who have never received polio vaccine or who have not completed the full routine immunisation regime since 2011.[25] WHO and UNICEF maintain that the data underlying these estimates come from data officially reported in addition to data cited in the published and grey literatures as well as consultation with local experts. The effectiveness and neutrality of EWARS in detecting cases of polio in opposition areas was questioned by some authors.[26] Others claim EWARS has succeeded in mitigating the consequences of the polio outbreak.[27]

The current routine schedule of the polio vaccine can be another barrier to achieving adequate vaccine coverage in a conflict situation. Effective immunisation requires several rounds of administering the vaccine. The routine immunisation schedule for polio consists of a dose of OPV at birth followed by three OPV doses at least four weeks apart and a dose of inactivated polio vaccine by injection. According to data by WHO and UNICEF, the bivalent oral polio vaccine (bOPV) was used in Syria for the first time in order to quickly boost the immunity of children and interrupt the poliovirus transmission. In a study in the *Lancet*, the bOPV was found to be superior to the trivalent oral polio vaccine (tOPV) in inducing a higher immune response.[28]

23. Adam Coutts and Fouad M Fouad, 'Response to Syria's Health Crisis—Poor and Uncoordinated', *The Lancet* (Vol. 381, No. 9885, June 2013), pp. 2242–43.
24. WHO and UNICEF, 'Syrian Arab Republic: WHO and UNICEF Estimates of Immunization Coverage: 2013 Revision', <http://www.who.int/immunization/monitoring_surveillance/data/syr.pdf>, accessed 8 May 2015.
25. WHO and UNICEF, 'Syrian Arab Republic: Situation Report No. 1', 7 November 2013, <http://www.rch.org.au/uploadedFiles/Main/Content/clinicalguide/guideline_index/Syrian%20Arab%20Republic%20POLIO%20Sit%20Report%20No%201.pdf>, accessed 8 May 2015.
26. Annie Sparrow, 'Syria's Polio Epidemic: The Suppressed Truth', *New York Review*, 20 February 2014; see also Zaher Sahloul et al., 'Health Response System for Syria: Beyond Official Narrative', *The Lancet* (Vol. 383, No. 9915, February 2014), p. 407.
27. Muhjazi, et al., 'An Early Warning and Response System for Syria', *The Lancet*, p. 2066.
28. Roland Sutter et al., 'Immunogenicity of Bivalent Types 1 and 3 Oral Poliovirus Vaccine: A Randomised, Double-Blind, Controlled Trial', *The Lancet* (Vol. 13, No. 376, October 2010) p. 1682–88.

The delivery of the OPV vaccine is another challenge in a situation where there are severe shortages of fuel, extensive electricity cuts (or even no electricity at all) and a lack of security. The OPV is licensed for pre-administration temperatures of 2–8 degrees for no longer than six months. There are huge challenges to maintain the cold chain, especially with shortages of fuel and electricity.

Environmental Factors
The environmental factors identified here relate to those that facilitate transmission of the poliovirus and to those that determine the susceptibility of the population (children under five years old).

The poliovirus is known to survive for a long time in the environment under suitable environmental conditions. It usually requires high doses of chlorine to kill it in sewage-contaminated water. The poliovirus is highly infectious and is transmitted through person-to-person contact. In endemic areas transmission by contact with healthy carriers is the most frequent type of transmission encountered.

The effective reproduction number (*Re*) for polio can be determined by transmissibility as well as population susceptibility. The former is very much determined by the sanitation level which is dire in many parts of the country, especially since the beginning of the war and the collapse of basic infrastructure such as piped water. Damage to the water, sanitation and hygiene infrastructure is particularly severe in rural Damascus, Idleb, Deir ez-Zor, Homs, Aleppo and Al-Raqqa, as well as many centres in the north where the latest cluster of polio appeared. Additionally, overcrowding, poor hygiene and inadequate facilities, especially in places hosting refugees and IDPs, will facilitate transmission.

Susceptibility is determined by population immunity. In the case of poliovirus, more than 80 per cent of individuals in a population must be fully immunised for the susceptible individuals to be protected by herd immunity. This is not the case in conflict-ridden Syria where data show that polio vaccine coverage has gone down considerably below that in many areas affected by the armed conflict. According to Sahloul et al., the coverage in the governorate of Deir ez-Zor where the cluster of polio reported went down from 50 per cent in 2012 to 36 per cent in 2013.[29] That is significantly below the level needed for herd immunity.

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29. Sahloul et al., 'Health Response System for Syria: Beyond Official Narrative', *The Lancet*, p. 407.

Conclusion

The conflict in Syria has been described as a public-health catastrophe for the country and the region.[30] This has manifested itself in the case of the re-emergence of polio more than a decade after the country being confirmed by WHO as polio-free. As the conflict intensifies and becomes ever-more complex, it is essential to have a clear understanding of the situation on the ground in order to predict and contain the spread of polio and infectious diseases in general. This paper attempted to do that by analysing myriad factors: political, economic, socio-cultural, technological and environmental. It is worth noting that the polio cluster is not the only one that has re-emerged in Syria; others, including measles, gastroenteritis, Leishmaniasis and tuberculosis have all been reported inside Syria and in refugee camps outside the country.

Effective infectious-disease management and control require stability. It is essential that a peace-building approach for ending the violence and bloodshed be prioritised. In the meantime, as the conflict takes its course, it is vital that there are efforts to strengthen and better co-ordinate surveillance for AFP. Equally important are efforts to achieve efficient co-ordination between humanitarian and donor agencies in order to ensure a rapid response to emergencies and outbreaks, especially inside Syria. Every effort should be made to reach the population in conflict areas and there should be mechanisms to monitor accountability and impartiality in delivering immunisation to all Syrian children, irrespective of from which side of the conflict or geographical region their parents come. Perhaps the common desire and need to combat infectious diseases and halt their spread inside and outside Syria can bring opposing sides to the negotiating table and be the first building block to a long-lasting peace.

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30. Coutts et al., 'Response to Syria's Health Crisis—Poor and Uncoordinated', *The Lancet*, pp. 2242-43.

VI. Situational Awareness for Global Immunisation Programmes

William S Schulz

It is imperative that global immunisation programmes maintain keen awareness of the contextual factors that can affect their operation. Key among these contextual factors is public confidence in vaccines. Programmes are at risk when their target populations do not trust the safety and efficacy of a vaccine, and can expose themselves to controversy and even violence when public trust is ignored. It is therefore of great value for programmes to be able to measure contextual factors at a large scale so that they can respond to public concerns, and avoid programmatic disruptions and the public-health damage such disruptions can inflict. This paper presents an overview of available and newly emerging measurement approaches, from the perspective of the Vaccine Confidence Project, a research group at the London School of Hygiene and Tropical Medicine that specialises in engaging publics to build trust and improve health.

Defining the Problem: Three Examples
Vaccines encounter controversy in many different environments. The recent outbreak of measles in unvaccinated populations in the US illustrates the concrete damage that can follow from a seemingly ephemeral problem like 'distrust in vaccines', and also the long incubation period that can lead to a vaccination crisis. The seeds of distrust in this case were sown over a decade ago when Andrew Wakefield published a paper alleging a link between the measles-mumps-rubella vaccine and autism spectrum disorder,[1] which has since been retracted.[2]

Another recent example comes from Kenya: since October 2014, Catholic bishops in Kenya have taken a stand against the tetanus vaccine, claiming it is laced with sterilisation hormones as part of a secret population-control scheme.[3] In fact, this rumour is a very common one: in 1995 the exact same claim about tetanus vaccine shut down immunisation

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1. Andrew Wakefield et al., 'Ileal-Lymphoid-Nodular Hyperplasia, Non-Specific Colitis, and Pervasive Developmental Disorder in Children', *The Lancet* (Vol. 351, No. 9103, February 1998), pp. 637–41.
2. The Editors of The Lancet, 'Retraction—Ileal-Lymphoid-Nodular Hyperplasia, Non-Specific Colitis, and Pervasive Developmental Disorder in Children', *The Lancet* (Vol. 375, No. 9713, February 2010), p. 445.
3. John Nalianya and John Muchangi, 'Kenya: Catholic Church Opposes Tetanus Vaccination of Women Aged 19-49', *Star*, 10 October 2014.; see also Abby Ohlheiser, 'The Tense Standoff Between Catholic Bishops and the Kenyan Government over Tetanus Vaccines', *Washington Post*, 27 November 2014.

programmes in the Philippines, Tanzania, Mexico and Nicaragua.[4] In 2003, similar sterility allegations led to a boycott of polio vaccine in northern Nigeria – arguably the most damaging vaccination stoppage in history, spreading the Nigerian polio strain to countries around the world.[5] When the consequences of confidence are global, situational awareness needs to be global as well.

Perhaps the most daunting challenges have occurred in Pakistan, where polio vaccinators have been subjected to violent attacks. Since 2012, vaccination teams across the country have been targeted by militant assassins.[6] Most victims have been gunned down by men on motorcycles, although there have been a few cases of kidnapping and, in one case, attackers stormed a programme office, ordered out the women and children, and fatally shot a specific vaccination official.[7] Any tools to help explain and prevent such events are of immense value to public health, and to all other humanitarian disciplines that face these challenges.

Framing the Problem: Vaccines under Attack?
There are a number of theories about why vaccination runs into so many problems. In recent years, vaccines have arguably become 'victims of their own success', since by decreasing the rates of disease they decrease people's awareness of the importance of immunisation.[8] The advent of the Internet has also exacerbated the spread of anti-vaccine rumours.[9] These are reasonable points, but there is also a much simpler explanation for the prevalence of vaccine controversies: there are simply so many vaccines being administered that controversies are just inevitable.

4. World Health Organization (WHO), 'Reports of Contaminated Tetanus Toxoid Vaccine Are False, Says WHO', press release, 19 July 1995.
5. Isaac Ghinai et al., 'Listening to the Rumours: What the Northern Nigeria Polio Vaccine Boycott Can Tell Us Ten Years On', *Global Public Health* (Vol. 8, No. 10, December 2013), pp. 1138–50.
6. Seye Abimbola, Asmat Malik and Ghulam Mansoor, 'The Final Push for Polio Eradication: Addressing the Challenge of Violence in Afghanistan, Pakistan, and Nigeria', *PLoS Medicine* (Vol. 10, No. 10, October 2013), pp. 1–4.
7. Amirzada Afridi, 'Warning Shots: Polio Vaccinator Shot Dead in Khyber Agency', *Express Tribune*, 22 December 2013.
8. Heidi J Larson et al., 'Addressing the Vaccine Confidence Gap', *The Lancet* (Vol. 378, No. 9790, August 2011), pp. 526–35.
9. Anna Kata, 'Anti-Vaccine Activists, Web 2.0, and the Postmodern Paradigm – an Overview of Tactics and Tropes Used Online by the Anti-Vaccination Movement', *Vaccine* (Vol. 30, No. 25, May 2012), pp. 3778–89.

Figure 1a: Global Coverage Rates of Original New EPI Vaccines.

Figure 1b: Vaccination Coverage Compared to Employment and Voting.
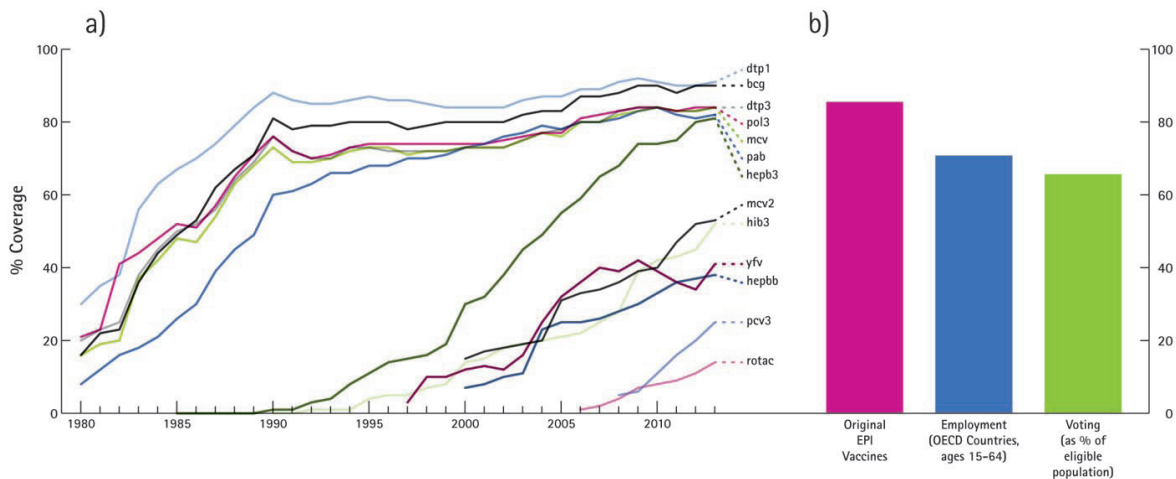
Source (Figure 1a): WHO, 'WHO/UNICEF Estimates of National Immunisation Coverage', <http://www.who.int/immunization/monitoring_surveillance/routine/ coverage/en/index4.html>, accessed 9 March 2015.

Source (Figure 1b): OECD, 'LFS by Sex and Age – Indicators', OECD iLibrary Database, <http://stats.oecd.org/Index.aspx?DatasetCode=LFS_SEXAGE_I_R>, accessed 15 March 2015; Rafael L Pintor et al., Voter Turnout since 1945 *(Stockholm, Sweden: International Institute for Democracy and Electoral Assistance, 2002).*

Indeed, vaccination rates have increased dramatically since the beginning of the Expanded Programme on Immunisation (EPI) in 1980. As illustrated in Figure 1a, the original EPI vaccines have now reached very high coverage – up to 80 or 90 per cent global coverage for some vaccines. Although these figures might well be considered insufficient for disease-control purposes, from a political perspective it is nothing short of remarkable to see coverage of some vaccines surpass rates of labour-force participation,[10] and voting (see Figure 1b).[11]

Vaccination is one of the most common, shared experiences in the world. It enters – if only momentarily – into almost every life on the planet, and each one of these lives has its own sensibilities and suspicions. Such large vaccination programmes cut across a great diversity of situations. Naturally, they become drawn into the countless struggles playing out around the

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10. OECD, 'LFS by Sex and Age – Indicators', OECD iLibrary Database, <http://stats.oecd. org/Index.aspx?DatasetCode=LFS_SEXAGE_I_R>, accessed 15 March 2015.
11. Rafael L Pintor et al., *Voter Turnout Since 1945* (Stockholm, Sweden: International Institute for Democracy and Electoral Assistance, 2002).

world, and get entangled in their politics. This is especially true in polio eradication, because eradication requires vaccinators to go everywhere, into the most challenging environments in every corner of the earth.

So although the multiplying controversies can make it feel like vaccination is increasingly under attack, it is perhaps more accurate to imagine immunisation as the instigator – actively expanding into new localities, and intersecting (predictably) with local issues. Seen in this light, situational awareness for immunisation programmes depends principally on understanding the conflicts playing out in the target population, and attempting to adapt the programme to fit comfortably into that environment.

For example, when the polio-eradication programme began operating in Afghanistan and Pakistan in the early 2000s, it adapted reasonably well to the two environments, specifically in terms of its public association with the national governments of those two countries. Polio eradication is, at least in theory, owned by the national government wherever it operates, but there is some flexibility in how much it broadcasts this ownership. In Afghanistan, where an armed insurgency held considerable territory and political influence, the programme was distanced from the government, and, in practice, the Taliban were allowed to carry out vaccinations in its areas and take credit for the health-care and jobs created through the programme. This has made polio-vaccination activities fairly resilient to Taliban challenges.[12]

Pakistan, in the early 2000s, was not facing such an insurgency, and so the programme was strongly associated with the government, which allowed politicians to use it to improve their image and have high-profile meetings with international philanthropists, which is often effective at increasing their commitment to making the programme run well.

Ten years later, though, Pakistan had developed a thriving cohort of anti-government militant groups, and the polio programme's long-established association with that government became a liability.

It is not absolutely certain that the attacks on polio workers were motivated by the programme's association with the government – with few exceptions, nobody has claimed responsibility for these attacks. Then again, it is unusual for militants in Pakistan not to claim responsibility for their strikes, which suggests that their purpose was not to advance a specific agenda, but rather to create a general climate of fear and make the government look weak.

The attacks may be symbolic, since the Global Polio Eradication Initiative is a Western-backed initiative, which makes it the epitome of what Pakistani

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12. Yaroslav Trofimov, 'Risky Ally in War on Polio: The Taliban', *Wall Street Journal*, 9 January 2010.

militant groups oppose: Pakistan bending to the Western will. On the other hand, the militants may see the vaccinators as actual enemies: the CIA used a fake vaccination campaign as cover in its hunt for Osama Bin Laden, and this has raised suspicions that any vaccinator could be a Western spy.[13]

The suspicion of espionage was certainly invoked by Hafiz Gul Bahadur, a Pakistani militant leader who banned polio vaccinators from North Waziristan in summer 2012. Although this was around the time of the first targeted strikes against vaccinators, Gul Bahadur is unlikely to be involved in these attacks, being an isolationist who almost never fights the government. Rather, Gul Bahadur made the argument that US drone strikes harm his people more than polio does, and offered to allow vaccinators back in if the drone strikes were stopped.

Thus, the Polio Eradication Initiative did a reasonably good job of assessing the Pakistani context at the beginning, but contexts change, and global programmes need the capacity to respond to these changes. They need to know when important events happen, how they influence peoples' attitudes and what to do about it.

Measuring Confidence
There are a variety of tools available to support this capacity for situational awareness, including surveys, media monitoring, epidemiological data, and qualitative research. In general, these tools are characterised by tradeoffs between depth, breadth and speed: faster measurements provide less detail, and detailed insights are easier to acquire for narrow subsets of the population.

Surveys
Surveys are the most traditional technique for gauging public sentiments. Surveys are most often used to directly measure respondents' attitudes towards vaccination and vaccination programmes.[14] In more-complex scenarios like the case of violence in Pakistan, surveys can also be useful for understanding public support for vaccine opponents. One survey of university students in Islamabad and Rawalpindi found that 32 per cent replied either 'yes' or 'don't know' to the question: 'do you think killing of polio vaccinators is justified?'[15] The prevalence of support for the killings has strategic implications for those attempting to end the attacks.

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13. The Editors of The Lancet, 'Polio Eradication: The CIA and Their Unintended Victims', *Lancet* (Vol. 383, No. 9932, May 2014), p. 1862.
14. Douglas Opel et al., 'Development of a Survey to Identify Vaccine-Hesitant Parents', *Human Vaccines: The Parent Attitudes About Childhood Vaccines Survey* (Vol. 7, No. 4, April 2011), pp. 419–25.
15. Masood Ali Shaikh, Anila Kamal and Irum Naqvi, 'University Students Perspective on Polio Vaccination – Ruse or Realistic Need for Pakistani Children?', *Journal of Pakistan Medical Association* (Vol. 64, No. 6, June 2014), pp. 694–96.

Epidemiological Data
Epidemiological data, like disease incidence, are the furthest 'downstream' indicator of an immunisation programme's performance. Although these figures cannot provide detailed information about public sentiments, a sudden spike in cases should prompt further investigation of potential issues.

The Vaccine Confidence Project is also currently preparing a study for publication, in which vaccine coverage rates were analysed over several decades, using coverage stability as an indicator of immunisation-programme resilience.

Qualitative Research
Qualitative information is invaluable, but commensurately costly. While there has been a number of insightful qualitative analyses produced in the aftermath of confidence crises, it is not possible to conduct continuous qualitative research in all immunisation programme settings.[16]

That being said, it is possible to continually collect and operationalise qualitative insights (of a sort) from programme workers on the ground, through strong management structures and innovative communication technologies. The Global Polio Eradication Initiative (GPEI), for example, sits at the top of a vast system of politicians, philanthropists, health workers, and social mobilisers. In Nigeria, the polio programme is currently piloting a mobile-phone based system for social mobilisers located in their home villages to update the national and international levels of the programme on their progress and challenges, and any emerging opponents or allies in promoting immunisation.

At the same time, this human network helps resolve issues when they arise. For example, apart from militancy problems in Pakistan, there have been numerous instances in which a specific community has strategically refused to admit vaccinators, demanding infrastructural repairs or additional health services. Having recognised that polio eradication is an international priority, communities use it to bargain for services they themselves deem more important. In those situations, the programme's social mobiliser is often able to act as an intermediary to identify the community's demands and reach an agreement.

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16. Ebenezer Obadare, 'A Crisis of Trust: History, Politics, Religion and the Polio Controversy in Northern Nigeria', *Patterns of Prejudice* (Vol. 39, No. 3, August 2005), pp. 265–84; see also Elisha Renne, 'Perspectives on Polio and Immunization in Northern Nigeria', *Social Science and Medicine* (Vol. 63, No. 7, October 2006), pp. 1857–69.

Media Monitoring

Media monitoring refers to an emerging set of technologies that trawl the vast oceans of publicly available data on the Internet, in search of useful insights on a particular topic. Its outputs can be broadly grouped into two categories: sentiment analysis and event detection.

In sentiment analysis, large volumes of user-generated content (such as posts on social-media sites) are processed to identify comments on a particular topic (such as vaccination), and then these comments are analysed to determine the author's sentiment with regard to that topic (positive, negative, or neutral towards vaccination). Although relatively new, such systems show considerable promise in quickly assessing vaccination sentiments. For example, data from the Twitter social-media service have been used to study the evolution of public sentiments relating to the 2009 H1N1 'swine flu' pandemic, and were found to be in good agreement with actual vaccination rates, indicating that sentiment analysis can correctly predict a population's willingness to be vaccinated.[17]

Event-detection systems, meanwhile, can alert programme managers to the occurrence of events that might threaten public confidence, such as a reported adverse event following immunisation, or more general changes in context, like a political power shift, that could impact a programme. These systems work by monitoring fluctuations in the public's interest in different topics, for example, through search-engine activity: if there is a sudden spike in searches containing 'tetanus vaccine', and 'sterilisation', in a particular country, it is likely that a specific event has occurred that inspired people to search for these topics.[18] A similar method has also been successful in monitoring and forecasting infectious-disease trends worldwide.[19] If applied to the detection of 'prompter' events, these event-detection technologies could alert public-health authorities to a looming crisis of confidence, before the story even appears in the news.

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17. Marcel Salathé and Shashank Khandelwal, 'Assessing Vaccination Sentiments with Online Social Media: Implications for Infectious Disease Dynamics and Control', *PLoS Computer Biology* (Vol. 7, No. 10, October 2011).

18. Marek Ciglan, Kjetil Nørvåg, 'WikiPop – Personalized Event Detection System Based on Wikipedia Page View Statistics', conference proceedings of the 19th ACM International Conference on Information and Knowledge Management, New York, 2010, pp. 1931–32; see also Martin Holaker and Eirik Emanuelsen, 'Event Detection Using Wikipedia' (Master's Thesis, Norwegian University of Science and Technology, June 2013); Miles Osborne et al., 'Bieber No More: First Story Detection Using Twitter and Wikipedia', conference proceedings of the Workshop on Time-Aware Information Access, TAIA 12, Portland, Oregon, August 2012.

19. Nicholas Generous et al., 'Global Disease Monitoring and Forecasting with Wikipedia', *PLoS Computational Biology* (Vol. 10, No. 11, November 2014).

The first limitation of these media-monitoring systems is that they rely on people using the Internet, and internet usage is not uniform worldwide: as illustrated in Figure 2, there are great disparities in internet usage between low- and high-income countries, and less than half of the world population uses the Internet, according to World Bank estimates.[20] This limits the utility of media monitoring in low-income settings, since findings are less likely to be representative of the general population. However, internet penetration is increasing in these settings and technologies for monitoring internet activity may become viable in the near future.

Figure 2: World Bank Estimate of Internet Use Showing Discrepancies in Internet Users Throughout the World and Future Utility of Media Monitoring.
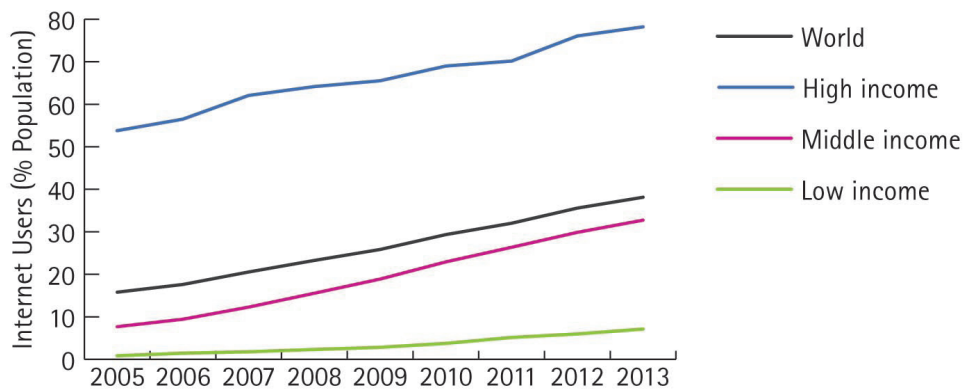
Source: World Bank, 'World DataBank', <http://databank.worldbank.org/data/home.aspx>, accessed 15 March 2015.

The second limitation relates to the raw complexity of the social events being studied. Qualitative factors, such as political motives and historical prejudices, simply cannot be captured usefully in quantitative data. This means that 'big data' cannot replace traditional forms of social science. Rather, quantitative tools must be allowed to evolve into their natural niche in the analytical toolbox, and will likely supplement qualitative situational awareness in new and unpredictable ways.

Returning to the Pakistan Example

Figure 3 illustrates how multiple forms of quantitative data can be used to contextualise and investigate complex situations like the recent militant opposition to polio vaccination in Pakistan. This timeline was compiled retrospectively from databases, not in real time, but could conceivably be updated continuously using the technologies outlined above.

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20. World Bank, 'World DataBank', <http://databank.worldbank.org/data/home.aspx>, accessed 15 March 2015.

Figure 3: Contemporaneous Graph of Wild Poliovirus Type 1 Incidence, Drone Strikes in North Waziristan and Instances of Attacks on Polio Workers and Other Humanitarian Workers, and News Media Salience in Pakistan.

* Colour-coded by readership zone, grouped by week. Charts show geographic distribution of attacks on polio workers and incident cases of WPV1, grouped by region.

Source: Poliovirus type 1 incidence adapted from GPEI status reports and polioeradication.com; drone- strike data in North Waziristan, adapted from dronestrea.am; data on instances of attacks on polio workers and other humanitarian workers adapted from UNOCHA dataset; results of Nexis UK query for 'polio* AND eradicat* AND pakistan*'. See Will Schulz, 'The Politics of Polio in Pakistan' (MSc Project Report, London School of Hygiene and Tropical Medicine, 2014), available in the library of the London School of Hygiene and Tropical Medicine.

The first row of the timeline tracks weekly incident cases of polio, according to region.[21] It is easy to observe the large, sustained outbreak in North Waziristan, which started in April 2013, when poliovirus was introduced to a population whose children had been denied vaccination by Hafiz Gul Bahadur's ban.

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21. WHO et al., 'Global Polio Eradication Initiative (GPEI) Status Report', 2nd Joint Report of the GPEI, 29 April 2013; see also WHO et al., 'Global Polio Eradication Initiative (GPEI) Status Report', 3rd Joint Report of the GPEI, 27 September 2013; WHO et al., 'Global Polio Eradication Initiative (GPEI) Status Report', 4th Joint Report of the GPEI, 30 April 2014.

The second row tracks US drone strikes in North Waziristan, which Hafiz Gul Bahadur named as the motive for his ban.[22] The fact that he maintained his ban during a five-month lull in strikes may suggest his motivations were not as simple as he claimed.

The third row tracks Pakistani militant attacks: the darker shade indicates that the targets were polio workers; the lighter shade shows other humanitarian workers.[23] Although this illustrates the pattern and distribution of attacks, it also raises the question of how to distinguish polio-focused attacks from more generalised violence against humanitarian workers. Importantly, there is no indication that attacks on polio workers occurred as retribution for drone strikes.

The fourth row of the timeline represents English-language news articles pertaining to polio eradication in Pakistan, acquired from the Nexis UK database. It illustrates well the limitations of a simplistic media-monitoring system: the beginning of the ban on polio vaccination in North Waziristan would not have been detected at all, and the killings of polio workers only received attention after several attacks had already occurred. Media attention is a major goal of using violence as a terrorist tactic, so it is also noteworthy that attacks received more coverage when multiple strikes occurred within a short timeframe, and when major public figures issued condemnations of the violence.

This example suggests that quantitative data can be useful in analysing complex social events to improve situational awareness. It can be used to view events through a high-level lens, and to compare patterns across very different phenomena. This remains far from an automated situational-awareness system, but may be useful for exploring the role and possibilities afforded by 'big data' in this arena.

Conclusion
This paper has discussed how various sources of data can provide big-picture situational awareness for large health initiatives such as a global immunisation programme, concluding with an example of how different types of quantitative data can be used together to describe an evolving situation over time. New and emerging sources of data can help programme managers maintain awareness of key contextual factors with greater speed and global reach.

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22. Josh Begley, 'Dronestre.am: Real-Time and Historical Data About Every Reported United States Drone Strike', <http://dronestre.am>, accessed on 8 May 2015.
23. Based on unpublished work, used with permission, from the United Nations Office for the Coordination of Humanitarian Affairs, 'Aid and Polio Worker Data 2014'. The author can provide further information if needed.

However, these quantitative data sources still require qualitative minds to interpret data and draw practical insights. Figure 3, for example, would have little meaning to a reader unfamiliar with the basic dynamics of militant violence against the Pakistani polio programme. New data sources should, therefore, be seen as an input to be used by social scientists, not as a replacement for human capital. If public-health actors are to take advantage of these new data sources, they must also increase their investment in analytical expertise.

William S Schulz is a social researcher with an interdisciplinary background in politics, psychology and public health. He holds an MSc in Public Health from the London School of Hygiene and Tropical Medicine, as well as a BA in Political Science from Swarthmore College. His research interests include political psychology, public trust, community engagement, international development, medical anthropology, wellness and happiness studies and rhythms of social life. He is currently a Research Assistant with the Vaccine Confidence Project at the London School of Hygiene and Tropical Medicine.

VII. The Spatial Dimension to Situational Awareness

Steve Wallace

Envitia, a spatial-information systems specialist, leads a programme for the UK Ministry of Defence's Defence Science and Technology Laboratory, looking at advanced geospatial information services. One element of the research is investigating the human domain, which has been undertaken by Helyx SIS Ltd, a consortium partner. One area of this research is seeking to understand the human dimension. Here I will explain how it works and look at future requirements.

Jennifer Cole's article in the *RUSI Journal* talks about the requirement for better situational awareness at the beginning of outbreaks and the fact that cultural, economic and societal information is fundamental in being able to understand the context of what is going on.[1] It lists some interesting examples, including in Sierra Leone where there was widespread unwillingness among parts of the population to believe official statements regarding the outbreak of Ebola, based on political tensions between the ruling All People's Congress (APC) party and the Sierra Leone People's Party – the main opposition party. The latter draws greater support in the region in which the outbreak originated and some among the population see Ebola as the APC's sinister ruse to kill those with supposed Ebola symptoms once they present themselves at government-run health centres.

Approaches that have focused more on the social and cultural aspects of disease control have experienced success. A good example of this was the World Health Organization's Global Polio Eradication Initiative which worked with the Organisation of the Islamic Conference to counter the Islamist narratives by issuing fatwas in support of polio vaccination.

It is important to be able to map beliefs, behaviours and likely compliance as well as recognising and mitigating likely barriers.

The Human Terrain System
The US Human Terrain System developed from the deteriorating situation in Iraq and Afghanistan during 2005–06 as the improvised explosive device (IED) threat continued to cause significant damage and casualties to US ground forces.[2] Combat commanders did not have a good understanding of the cultural and social implications of military operations in urban environments.

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1. Jennifer Cole, 'Conflict, Post-Conflict and Failed States', *RUSI Journal* (Vol. 159, No. 5, October 2014), pp. 14–18.
2. See US Army, 'The Human Terrain System', <http://humanterrainsystem.army.mil>, accessed 25 April 2015.

The result of conducting operations without local socio-cultural knowledge produced negative effects among the local populations.

Research from the Joint Improvised Explosive Device Defeat Organization indicated that many of the IED attacks against US and coalition forces were a result of military actions that violated local and national socio-cultural values, which led to violent retaliation. Socio-cultural understanding and knowledge was believed to provide a unique method to help combat commanders consider the effects of military operations on local populations and engage local leadership to build trust, understanding and co-operation to non-violently engage the enemy and reduce the number of violent attacks against US and coalition forces.

Challenges in Developing an Equivalent Human-Domain System
There are many interrelated disciplines that use different terms; they overlap and often work at different scales. In this case, we have people who generate human-geography products that map tribal, religious and cultural areas, but it is typically done at a very coarse resolution.

There is also another challenge of working with people on the ground who are acting at the individual level. How do we manage the process of collecting that data in a coherent way that can be analysed, maintaining a consistency throughout, particularly where there are people rotating in and out? We want to be able to maintain the understanding of those people and capture the information in a coherent way.

Data Collection
There are a number of significant challenges when considering the data collection, analysis and visualisation of these pieces of information. The creation of location-specific geosocial models and patterns of life is not easy to do. Factors to consider include:

- Capturing and mapping religious, ethnic and dynamic factors
- Assessing local norms and potential deviations from these
- Understanding and capturing the effects of scale and time (nation to neighbourhood, tribe to individual). You might be working both at a national level as well as an individual level. How do you put a framework in place that enables you to capture that information and analyse it in context?
- Visualising motives, intentions, reactions, rumour, emotions; how do you capture and visualise it in association with these other, more static and concrete pieces of information?
- Understanding human behaviour to enable insight.

A key, initial aspect of the work was the assessment of a taxonomy, developed at a number of levels. Terms and definitions helped us to look across different disciplines and see what those terms are and define them – from cultural geography to human terrain, rumour, opinion, among others.

The Importance of Scale

Levels-of-detail (LOD) specifications were used as a means of distinguishing between model areas that require low- or high-resolution data. The benefit of using LOD was the ease with which users could express requirements in terms of geography (area) and resolution (detail) of data required.

This simple technique was implemented to allow requirements for human-domain visualisations to be articulated at the macro to micro levels providing a useful basis for linking requirements to scale, use and data availability.

An Analytical Framework

The primary purpose of an information framework is to identify 'what' information is required. The weakness in the way information frameworks are used is that they treat all information equally, failing to distinguish between information 'themes' of greater or lesser importance or the effect of geography or time. Provided this weakness is recognised, they continue to provide a useful tool for identifying or describing information themes during a formal planning process.

Political, military, economic, social, infrastructure and information (PMESII) , and diplomatic, informational, military and/or economic (DIME) systems are key concepts in irregular warfare and effects-based operations simulations. PMESII describes the foundation and features of an enemy (or ally) state and can help determine the state's strengths and weaknesses, as well as help estimate the effects various actions will have on states across these areas.

Eight types of human-domain data were explored, each with different challenges for collection, interpretation and use. The challenges include how to choose from a wide range of collection methods that can be applied in different circumstances; or the difficulties with geospatial referencing for some data types.

Best Practice for Capturing and Representing Information

To process the information, you need to work out what different data types are needed, from observed to interaction, opinion, sentiment, among others. It is then necessary to decide what methods are going to be employed to collect these: for example, a questionnaire, interview, census or multimedia analysis. There are multiple ways of collecting things with the associated tools. It was important that the data model provided consistency and showed the relationships between those pieces of information. Again,

there are a number of data models which the military use, such as the NATO Geospatial Information Framework and the NATO Geospatial Interoperability Framework.

The following is the framework within which we worked. In terms of scale, we came up with four levels of detail (which is a standard way of doing things):

- The types of data required, whether static – refering to things unlikely to change such as tribal areas, religion, language at a regional scale – down to the dynamic – individuals whose locations, actions and beliefs can have influence
- How it might be collected
- The data type
- The collection methodology.

We developed a way of placing the most important terms within a human-domain continuum that spans the strategic to tactical levels of command.

Some Useful Definitions

There are some key definitions used in the approach:

Human Geography: The study of spatial patterns of interactions between humans and their physical environment.

Human Terrain: The characterisation of cultural, anthropological, and ethnographic information about the human population and interactions with the joint operational area.

Human Domain: The totality of the human sphere of activity or knowledge.

We held visualisation workshops that considered the challenge of identifying and integrating the following factors:

- Human-domain data types (objective or subjective)
- Levels of detail (0–4) and the relationship between human geography and human terrain
- Operational level (for example, strategic and tactical)
- Whether static or dynamic information is used
- Any spatial and temporal factors
- Uncertainty or level of confidence (more to less confident)
- Visualisation technique, for example maps, network analysis, charts/graphs, animations/interactive visualisations, infographics and graphical models.

There was also a need for macro to micro levels of human-domain information:

Objective Macro: Information in this concept relates to observable aspects of regional and national detail that are more static and spatially orientated. Maps would be appropriate for visualising observable behaviour and interaction data at higher LODs where spatial variation needs to be communicated and could be complemented through animated maps or infographics to provide temporal insights if required.

Subjective Macro: Information in this concept relates to qualitative aspects of regional and national detail that are more static and spatially orientated. Again, even for subjective concepts, maps would provide suitable visualisation tools for spatial factors. However, for specific concepts such as emotion and rumour it may not be appropriate to map these aspects at higher LODs.

Objective Micro: Information in this concept relates to observable aspects of local and individual detail that are more temporal and dynamically orientated. Charts and graphs support temporal variation and can be useful in illustrating trends and identifying anomalies. They are not suited for representing spatial aspects or defining fuzzy boundaries in data.

Subjective Micro: Information in this concept relates to qualitative aspects of local and individual detail that are more temporal and dynamically orientated. Charts and graphical techniques would be appropriate for visualising these concepts.

Concepts and Scale Interaction
It is quite a challenge to be able to manage the collection and expression of information from the strategic to the tactical, so we have come up with a methodology of being able to represent that and capture it at various levels of detail. We try to recognise whether it is a subjective or objective piece of information and whether we are confident in the evidence.

Methodology
Our methodology has three key steps.

Direct: The term 'direct' refers to the ability to articulate and manage human-domain requirements prior to tasking. This could be as part of a formal planning process or could be used to support standing requirements such as routine maintenance.

Collect and Process: Proposes a more standardised approach to the management of the five components of human-domain information. If formalised, the five components would support a more standardised

approach to the discovery and re-use of human-domain information over time. The benefit of this approach is the increased likelihood that information would be retained as specialist staff members rotate between operational deployments; it would also support the analysis of trends and temporal changes.

Disseminate: Considered only the visualisation aspect of dissemination and does not consider the wider aspects of dissemination such as system or bandwidth issues. Based on academic study and some stakeholder engagement, it provides guidance on the most appropriate visualisation technique for human-domain information from the 'macro/strategic/static' levels of data to the 'micro/tactical/dynamic' levels. The output is guidance, with the potential to support future specifications, templates and standards for novel visualisation techniques.

Future Research Requirements
Our methodology is quite easily translatable to the kind of epidemiology in the serious infectious-disease area. But we need to know what types of information might be needed, and how might these be collected and put within that framework.

We look at how to handle uncertainty, trust and sentiment. These are not easy concepts to express, capture and visualise. We need to look at how to visualise motives, intentions, reactions and interactions.

How do you manage authoritative and non-authoritative information to provide that situational awareness? You typically need to combine a number of types of information in order to do that.

Lastly, how do you derive location from non-traditional sources? Again, if you are looking at open sources – whether these be tweets, blogs or audio streams – there is a lot of content out there but how do you derive location at multiple scales and capture that as part of the process?

This paper was compiled from a verbal presentation delivered at the conference. Steve Wallace is a Business Development Manager at Envitia, responsible for the development of its defence-research and consulting business. Prior to joining Envitia, he spent eighteen years with QinetiQ and its predecessor organisations. He holds an MSc in geographic information science from University College London and has a strong background in geospatial interoperability. He has worked extensively with the Defence Geospatial Information Working Group in collaboration with NATO. He also operated as QinetiQ's technical representative to the Open Geospatial Consortium for seven years.

VIII. Emerging Public-Health Threat Intelligence

Tobias Lightfoot

This paper will explain how my organisation, New Light Intelligence (NL Intelligence), is able to put the most significant emerging public-health threat news into people's inboxes every morning, what it has learned in doing this and where it would like to develop its capability further.

About New Light Intelligence
NL Intelligence was formed with the aim of providing timely threat intelligence to decision-makers on emerging public-health threats. It covers infectious diseases of humans, animals and plants; chemical, nuclear and biological contamination; accidental and deliberate release; food; and consumer products.

The organisation uses a set of internet applications and a defined process to collect public-domain data on threats, filters that data into information, puts it in front of the experts for analysis and then creates intelligence alerts that are delivered to clients. It has global coverage.

The organisation has a small and diverse team consisting of public-health, risk-assessment, technology and communication expertise. Output comprises e-mailed alerts containing information and analysis delivered to subscribers' mailboxes both on a schedule and, for the most significant threats, on an ad hoc basis.

This is what is stated at the top of every daily alert produced by NL Intelligence:

> NL Intelligence maintains a constant watch on news from around the world and brings you an expert summary of emerging and ongoing public health threats, direct to your inbox. Our intelligence team monitors hundreds of stories each day on global health threats, bringing you breaking news and relevant and developing stories from around the globe.

Data Collection
The process begins with the collection of data from a broad range of sources. The data is aggregated, cleaned and categorised.

A combination of machine and human filtering is used to turn this data into information. Machine filtering allows a large amount of data to be sifted – in the region of tens of thousands of items per week.

Human filtering allows the most significant data to be identified. We use a two-stage process: the first is through an intelligence-analyst role that reviews thousands of items per week; the second is through a panel of public-health and risk-assessment experts that reviews hundreds of items per week.

The last step in the process is to apply focus. We select items for inclusion in alerts based on specific client needs and interests and provide analysis based on knowledge of their business.

The process is relatively cheap to run and maintain and produces top-quality output combining focused information and expert analysis to a wide audience.

Data Sources
Our current sources can be divided into three broad groups: the public sector, news media and social media.

Public Sector: There are two sub-groups here. The first is aggregators such as Healthmap and ProMed with which many people are familiar.[1] Healthmap provides a large volume of reasonably cleaned data items; ProMed provides a curated stream of academically focused items. We work with these providers, have access to their data streams and incorporate them into our own aggregation tool.

The second sub-group of sources is governmental and non-governmental website news feeds, for example, the World Health Organization, the Centers for Disease Control and Prevention in the USA, the Food Standards Agency and Public Health England in the UK, and the Centre for Health Protection in Hong Kong.

News Media: These include outlets such as the BBC, the *Washington Post* and numerous local media and newspaper websites in countries around the world.

Social Media: These include blogs and Twitter.

Each type of source has its advantages and disadvantages: for example, the public sector tends to be slow to report and social media can be less reliable. Often, cross-correlation can be an important tool in verifying a story.

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1. Boston Children's Hospital, 'HealthMap', <http://www.healthmap.org/>, accessed 8 May 2015; see also International Society for Infectious Diseases, 'ProMED-Mail', <http://www.promedmail.org>, accessed 8 May 2015.

The next stage in the process is filtering. These sources generate a huge amount of data which has to be sifted to find the significant information. This is done in two ways:

Machine Filtering: Some of this is implicit as our sources are selected for their relevance or perform searching, cleaning and categorisation before we receive the feed. Some of this is explicit in that we run our own key-word and Boolean searches to identify potentially significant information. Criteria have been built up over time and are derived from expertise, experience and client feedback.

Human Filtering: We believe that this is the most important stage in the process. An intelligence analyst will review machine-filtered items to identify those that are within the context for which we are looking and, in particular, to identify new or existing threats that are doing something new. For example, they might affect a new location or present more-severe symptoms. An expert panel looks for significance by asking questions concerning causes, sources and impacts.

Data are turned into information by filtering these and finally we turn information into intelligence by analysing and presenting it.

This last step in the process involves selecting the right information for the right person at the right time.

E-mail Alerts
The output is e-mailed alerts. We produce an all-risk and global daily alert, and a weekly summary. This is free to subscribe to, and is intended as a demonstration of our capability. The real value is in our customised client-focused alerts. We work with our expert panel to identify the items that will go in each alert and to add analysis specific to their business.

Included below (Figure 1) is an example of a recent daily alert to give a sense of what our alerts look like. They have a standard brand but can be adjusted specifically for clients. They are organised into logical sections. Every item has a headline, a sub-headline and a body text, and always includes a source link. The example given is a daily alert that goes out on a Monday and also includes a review of the latest information on seasonal influenza.

Figure 1: An Example of a NL Intelligence Alert.
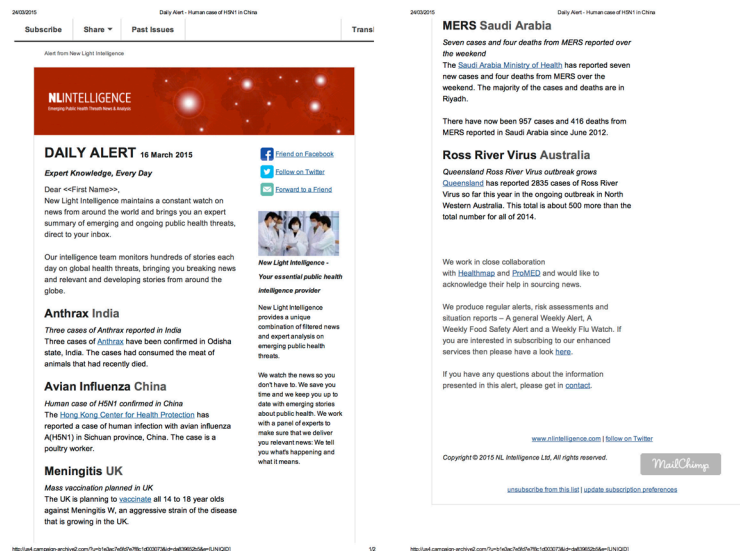
Source: NL Intelligence.

We have created a prototype system and a full-business process. We are growing our audience for our Daily Alerts and work with private clients to create and deliver bespoke alerts.

Key Areas for Development

We have learned a lot and there are a number of key areas for development including crowdsourcing, technology, smartphone app, SMS and process.

Crowdsourcing: We would like to develop a crowdsourcing capability. This is much more than passive social-media searches and I call it '360 degree surveillance'. The idea is to have a network of people that interact with the alerting service so it is not just a push of information but also a pull.

The network would provide local input on emerging threats and the alerts would redistribute this to a wider audience, creating an information flow that is faster and more discerning than what is currently available. Such a model is particularly suited to the public sector, in organisations like Connecting Organizations for Regional Disease Surveillance, which already has established networks and is looking for ways to encourage information sharing.

Technology: We would like to develop more machine-filtering and algorithm encoding. Examples would be duplicate-link removal; and country, threat and species categorising.

We would like to consolidate our systems and automate more of our processes. At the moment, we use one system for collating sources, another for collecting, categorising and sorting significant items, and another for alert creation and distribution.

Smartphone App: We would like to be able to distribute alerts and collect input via a smartphone app.

SMS: We would like to be able to send out links to ad hoc alerts and to collect input automatically via SMS.

Process: We would like to develop our capability for risk assessment, signal recognition and situational awareness. We are currently working on developing a foresighting capability.

Tobias Lightfoot is the founder and Managing Director of New Light Intelligence, a provider of intelligence on emerging public-health threats. Prior to this venture, Toby worked in the IT and financial-service industries in the UK and Singapore for more than ten years.

Surveillance and Modelling

IX. Genomics in Low-Tech Environments

Carl Mayers

The Potential of Genomics

An organism is defined by its complete set of nucleic-acid sequences, which is known as the genome of the organism. A genome can be made of deoxyribonucleic acid (DNA), used by the majority of organisms, or ribonucleic acid (RNA), used by some viruses. An organism's genome encodes the characteristics (the phenotype) of an organism, and can be seen as the ultimate source of biological information about that organism. Genomics is simply the study of the structure and function of these genomes. If the sequence of nucleic acid in an organism's genome is known, it becomes possible to predict whether the organism is a harmless environmental species, or a human pathogen that can cause disease. Genomics can provide a rich collection of information about an organism in a very short time, and has now advanced sufficiently to be useful in the field in the middle of a disease outbreak.

The field of genomics has advanced considerably since the Human Genome Project was completed in 2003. From early discussions to completion, the Human Genome Project spanned approximately nineteen years, and cost in the region of £2 billion.[1] Much of the DNA-sequencing work in the Human Genome Project was carried out using gel electrophoresis, a process that separates radioactively or fluorescently labelled DNA fragments in a gel using an electric field.[2] In the mid-2000s, a rapid advancement in DNA sequencing speed (and a consequent reduction in cost) was brought about by using instruments that could sequence thousands of DNA strands at the same time.[3] This parallelisation of DNA sequencing (known as 'high-throughput', or 'next-generation' sequencing) led to six orders-of-magnitude improvement in DNA sequencing in a decade.[4] Due to this astonishing advance in technology, a human genome can now be sequenced for a few thousand pounds in a modest-sized genetics laboratory. This improvement in technology provides us with a vastly richer understanding of samples that we process.

1. National Human Genome Research Institute, 'The Human Genome Project Completion: Frequently Asked Questions', <http://www.genome.gov/11006943>, accessed 23 January 2015.
2. Frederick Sanger et al., 'DNA Sequencing with Chain-Terminating Inhibitors', *Proceedings of the National Academy of Sciences USA* (Vol. 74, No. 12, December 1977), pp. 5463–67.
3. Jay Shendure et al., 'Accurate Multiplex Polony Sequencing of an Evolved Bacterial Genome', *Science* (Vol. 309, No. 5741, August 2005), pp. 1728–32.
4. National Human Genome Research Institute, 'DNA Sequencing Costs: Data from the NHGRI Genome Sequencing Program (GSP)', <http://www.genome.gov/sequencingcosts/>, accessed 19 March 2015.

Preparing DNA for Sequencing
The process of sequencing samples remains largely the same regardless of the type of sample being sequenced. A DNA sequencer is ambivalent about the source of its DNA; the same four DNA bases (A, C, T, G) are used in all organisms with a DNA genome. The process begins with the collection of a sample; in clinical cases this may be a blood, serum or plasma sample, a swab or other body-fluid sample. If water- or food-borne pathogens are suspected, environmental or food samples will often be used in addition to clinical samples. Samples must be stored once taken; this is normally a trivial exercise in a clinical laboratory where samples can be refrigerated or frozen, but is much more problematic in the field where there may be few cold-storage facilities. A well-proven alternative for the field is the Flinders Technical Associates (FTA) card, which can safely store blood, serum, plasma and buccal (mouth) samples on chemically treated paper for several years at room temperatures.[5] Some pathogens may remain infectious even in preserved samples.

A key decision that must be made early in the design of a field laboratory is whether samples will be inactivated as they enter the laboratory, allowing further analysis on the open bench without hazard to operators, or whether they will be handled in bio-containment, protecting operators from infection. Bio-containment work is slow, logistically expensive and requires well-trained staff, so there is a significant advantage in inactivating the agent as soon as possible in a field genomic lab. Inactivation techniques useful in the field include the use of heat (pasteurisation, boiling, autoclaving), and chemical treatment with chaotropic agents such as guanidinium salts and ionic detergents. Care must be taken with inactivation methods to ensure that substances in the sample do not interfere with inactivation; the process must be validated carefully with reference to the sample types expected. A safe method of inactivation that is easy to operate in the field is autoclaving; the combination of high pressure and temperature will inactivate most pathogens, and yet preserve DNA for sequencing.[6]

Once the sample is safely inactivated, the DNA from the sample must be extracted. There are a number of well-proven commercial technologies that are suitable; in the past the Ministry of Defence (MoD) has used manual techniques based on affinity purification,[7] and automated equipment such as

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5. GE Healthcare Life Sciences, 'Sample Collection Cards and Kits', General Electric, <http://www.gelifesciences.com/webapp/wcs/stores/servlet/catalog/en/GELifeSciences-UK/products/AlternativeProductStructure_21465/>, accessed 20 March 2015.
6. Emma McCarter et al., 'Autoclaving as a Rapid Method to Shear DNA for Sequencing' (working title), manuscript in preparation, 2015.
7. See, for example, MO BIO Laboratories, 'PowerSoil® DNA Isolation Kit', <www.mobio.com/soil-dna-isolation/powersoil-dna-isolation-kit.html>, accessed 20 March 2015.

the Qiagen EZ-1.[8] Automation is of great advantage, as it reduces the risk of manual errors and reduces the number of personnel needed in a laboratory. Where sample volumes are small, it is often necessary to amplify the trace amounts of DNA present. Modern amplification chemistries now allow direct amplification, where a sample is directly added to an amplification reaction without needing DNA extraction or purification.[9] Such chemistries can overcome inhibitors present in the sample, speed up the analysis of trace samples, and reduce the risk of losing valuable sample DNA during purification. Once extracted or amplified, the DNA must finally be sheared to a suitable length, and have DNA sequences enzymatically attached to the sheared fragments. At this stage, the DNA is known as a library of sequences, and is ready for sequencing.

Sequencing DNA in the Field
The latest generation of high-throughput DNA sequencers are the very first that can be easily used in the field. Of particular note are the Illumina MiSeq, which has no requirement for laboratory gases and has simple, rapid chemistries, and the Ion Torrent Personal Genome Sequencer, which has a robust, non-optical detection system but requires a gas supply and additional lab instrumentation.[10] Both are desktop instruments but are laboratory based. In the past year, nanopore sequencing has become an exciting prospect with the launch of the Oxford Nanopore Technologies MinION sequencer.[11] The MinION is the size of a USB stick and has the potential to offer truly portable, field DNA sequencing, but like other DNA-sequencing technologies, it currently requires sample-processing steps in a laboratory before sequencing. Sequencing technology is rapidly changing; it is realistic to expect a fully automated, field-portable instrument to be available within the next five years. Until then, compromises must be made.

Depending on the platform, the high-throughput DNA sequencer takes between three to forty-eight hours to turn a DNA library into a data file containing billions of bases of genomic information. This information must then be subjected to quality control, assembly and analysis by comparing

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8. QIAGEN, 'EZ1 Advanced XL', <http://www.qiagen.com/gb/products/catalog/automated-solutions/sample-prep/ez1-advanced-xl-instrument/>, accessed 20 March 2015.
9. Timothy Minogue et al., 'Cross-Institute Evaluations of Inhibitor-Resistant PCR Reagents for Direct Testing of Aerosol and Blood Samples Containing Biological Warfare Agent DNA', *Applied Environmental Microbiology* (Vol. 80, No. 4, February 2014), pp. 1322-29.
10. Kenneth Frey et al., 'Comparison of Three Next-Generation Sequencing Platforms for Metagenomic Sequencing and Identification of Pathogens in Blood', *BMC Genomics* (Vol. 15, No. 96, February 2014).
11. Oxford Nanopore Technologies, 'The MinION Device: A Miniaturized Sensing System', <https://nanoporetech.com/technology/the-minion-device-a-miniaturised-sensing-system/the-minion-device-a-miniaturised-sensing-system>, accessed 20 March 2015.

it with known sequences. These steps are carried out using software tools; at present this requires users to have a detailed understanding of bio-informatics and access to high-performance computer hardware. In many cases, it is best to return this data for processing in a dedicated facility; this is greatly hindered if mobile data services or internet access are not available.

Establishing high-bandwidth communications is a priority for a field genomics lab and enables rapid sharing of data as it is generated. The entire process from sample collection to data analysis currently takes between twelve and forty-eight hours depending on the technology used, but will likely be possible within six to eight hours in the next two years. Eventually, it will be possible to sequence DNA in real time, as single-molecule sequencing technologies, such as nanopore sequencing, mature. The field genomic lab will become an information portal at the frontline of an outbreak, providing actionable information to understand an outbreak at source.

Designing and Equipping Field Genomics Laboratories
The design of a field genomic laboratory is constrained by the challenges it will face. The field laboratory and its staff could be subject to attack, looting or other hostilities. The field location may lack running water, electricity and fuel supplies may be irregular. The environment may be harsh, with extreme temperatures, dust or sand storms, torrential rain and flooding. There may be limited accommodation for lab workers, and local health-care provision may be limited or non-existent. Communication networks may be poor, with no internet or cellular-phone access, and it may be difficult to maintain a cold chain to ship consumables to the laboratory.

Many of these challenges can be overcome by engineering solutions, and experience has shown that these environmental challenges usually pose more problems than the genomics technology used in the laboratory. At present, a cold chain is critical to operating a genomics capability in the field, and this requires considerable logistics effort to maintain.

In most outbreak situations, a field genomics capability will not add sufficient operational value to justify this logistics burden. Where the causative agent (virus, bacterium) of an outbreak is known, the optimum field capability will usually be based on a nucleic-acid amplification technology, such as real-time polymerase chain reaction (real-time PCR). PCR assays are available for the majority of infectious agents, and can be carried out quickly and at high throughput with minimal logistics burden.

The major benefit of a field genomics capability is only realised when the causative agent of the outbreak is unknown, or when extremely detailed information on the causative agent is needed for epidemiology or to guide treatment. High-throughput sequencing excels at identifying unknown

biological agents in clinical matrices.[12] A targeted sequencing approach can amplify regions of a large number of pathogens and sequence them to identify pathogens from a large panel of suspects.

Alternatively, all of the nucleic acid in a clinical sample can be sequenced and any non-human sequence investigated by comparing against all known sequences from pathogens. This allows discovery of previously unknown pathogens, and operates without any bias or preconception as to the likely cause of disease. If sufficient sequence from the pathogen can be found in the sample, a pathogen can be 'deep sequenced', where large amounts of sequence are generated from the same sample, allowing the investigation of different variants of a pathogen in the same host.[13] This helps to investigate the epidemiology of an outbreak, allowing closely related variants or strains of pathogen to be identified and grouped into clusters, identifying patterns of infection and transmission.

Genomics in the Future
In the next decade, it will become commonplace to use genomics in the field. The technologies at the vanguard of this advance are currently still in development. It is now feasible to take current DNA sequencers into the field, but their sensitivity to environmental changes, and their high commissioning and servicing burden still require technical experts to deploy to the field with them. Advances must be made to simplify the use of genomics; self-collimating optics or non-optical sequencing techniques will be needed to deploy equipment far off the beaten track.

The Defence Science and Technology Laboratory has experience of using these technologies in the field, and deploying duplicates (even triplicates, in some cases) of key items of equipment has proved essential to survive instrument failure. When instruments can cost hundreds of thousands of pounds, this level of redundancy carries a high penalty. All sequencing technologies currently require a laboratory process to prepare DNA for sequencing (library generation); this remains true for room-sized Illumina HiSeq instruments down to pocket-sized Oxford Nanopore MinIONs. The reagents needed for these steps must be stored cold, or frozen, requiring freezers and/or refrigerators in the field. The processes involved in library generation require pipettes, thermocyclers and centrifuges. While the *instrument footprint* of DNA sequencers is currently shrinking, the *laboratory footprint* remains large, due to this extra equipment needed. Whoever develops either a

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12. Justine Cheval et al., 'Evaluation of High-Throughput Sequencing for Identifying Known and Unknown Viruses in Biological Samples', *Journal of Clinical Microbiology* (Vol. 49, No. 9, September 2011), pp. 3268–75.
13. Stephen Gire et al., 'Genomic Surveillance Elucidates Ebola Virus Origin and Transmission During the 2014 Outbreak', *Science* (Vol. 345, No. 6202, August 2014), pp. 1369–72.

simple process for library generation that uses reagents that can be shipped without a cold chain, or a new breed of sequencer that does not require *any* library generation will truly empower the next generation of field genetics laboratories. In the next decade, we are likely to see real-time DNA sequence data being streamed from the source of an outbreak, providing the biological information needed to respond, both locally and internationally. These are exciting times for genomics.

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X. Monitoring and Influencing Situations

Simon Smith

The scale and availability of data on the Internet has increased dramatically in recent years.[1] Handling this quantity of data poses many engineering problems,[2] but once these are overcome, views of the world can be created with more detail than ever before – views that adapt in real-time as events emerge and unfold.

The focus of this paper is on the implications that large-scale data-analysis technology has for both the monitoring of infectious-disease outbreaks and influencing behaviours during such a time. Specifically, Ebola and avian influenza are used as case studies to look at how this technology impacts three different areas: monitoring news, viral marketing and population movement.

Monitoring News
This has been transformed with the advent of the Internet and social media. Most news outlets have an online presence and actively promote their material immediately after publishing. This allows news all around the world to be monitored in real-time, including smaller, regional-news producers.

Viral Marketing
Viral marketing is the art of using a network (usually an online social network) to propagate a message. Analytics running on online social networks allow the structure of the network to be characterised. In the event of a disaster, such as an outbreak of an infectious disease, this information could be used to more effectively spread a sanctioned message and limit the impact of disinformation.

Population Movement
Smartphones containing global positioning system (GPS) tracking chips have become ubiquitous in the West and are increasingly popular in the developing world.[3] A proportion of this data is exposed through social

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1.   Internetlivestats.com, 'Total Number of Websites', <http://www.internetlivestats.com/total-number-of-websites/#stats>, accessed 19 March 2015; see also James Manyika et al., 'Big Data: The Next Frontier for Innovation, Competition, and Productivity', McKinsey Global Institute, 2011; Internet World Stats, 'Internet Growth Statistics', Miniwatts Marketing Group, <http://www.internetworldstats.com/emarketing.htm>, accessed 19 March 2015.
2.   Adam Jacobs, 'The Pathologies of Big Data', *ACM Queue* (Vol. 7, No. 6, July 2009).
3.   International Telecommunication Union, 'The World in 2014: ICT Facts and Figures', April 2014, <http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2014-e.pdf>, accessed 19 March 2015.

media. This allows real-time insights into where a population is. Being able to spot congregations of people during a disease outbreak could be a useful new ability.

These three areas are discussed in turn, with simple experiments/ demonstrations to illustrate each one. The majority of the work was performed using Ripjar's analysis software.

Monitoring News

Data relating to Ebola and avian influenza was obtained from a wide variety of news, social-media and blogging sites from the Internet (more than 50,000 sources in total) using a keyword search for the following terms:

- **Ebola:** *ebola*
- **Avian influenza:** *bird flu, birdflu, H5N2, H5N8, avian flu*

No attempt was made to translate any of the terms into other languages, as such, the following analysis focuses on English-speaking media – it should be noted that this is a failing of this study and not the underlying system. The following tables show the quantity of data collected over a ten-day period:

Ebola		Avian Flu	
Twitter	520,000	Twitter	24,000
Tumblr	42,000	Tumblr	3,900
News	23,000	News	1,500
Wordpress	22,000	Wordpress	590
Other	13,000	Other	1,000
Total	620,000	Total	31,000

Tumblr and Wordpress are blogging sites. There are some sources not listed above that made smaller contributions to the total count. Looking at that data over a seven-day period we see the following patterns as outlined below.

Figure 1: The Quantity of Documents on a) Ebola and b) Avian Influenza.
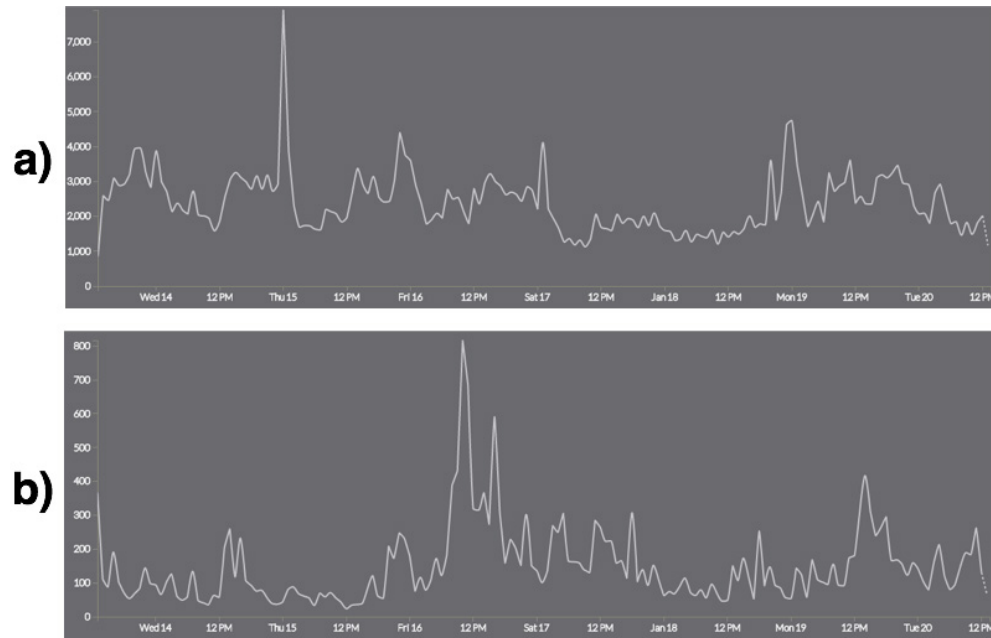
Source: RipJar Ltd.

Looking at Figure 1, the Ebola line (Graph a), there is an evident periodicity to the data. This is loosely aligned with North American office hours. It is possible to see the weekend when there is a lower quantity of data produced. There is a very evident and dramatic spike on Thursday 15. The following news article headline is typical of the data underneath that spike:

> '[Northampton] Hospital testing woman for Ebola', *Chichester Observer,* United Kingdom

This also demonstrates the sort of local-news providers that are monitored by this tool. Focusing on the avian-flu trend (Graph b), there is a large spike on Friday 16 due to the breaking of the following story:

> 'Panic as bird flu hits Lagos', *Daily Post*, Nigeria

In addition to detecting stories as they emerge, it is possible to locate from where the data is coming, allowing a geographically contextualised news analysis to be performed. Figure 2 shows where discussions of Ebola were taking place in the UK and northern France.

Figure 2: Map Showing Where Discussions of Ebola Have Been Taking Place in the UK and Northern France.

Source: RipJar Ltd.

Perhaps as expected, the geographical distribution of the data is aligned with population density; large cities are evident on the map.

Viral Marketing

Viral marketing has emerged as a useful marketing technique for many companies since the advent of social media. It is a popular idea because a recommendation from a friend for a product is the best form of advertising you could hope to achieve. On social media, it is possible to observe how information spreads and determine who is influential with different groups of people. This has given advertisers the chance to tailor their message to hard-to-reach audiences, for example, teenagers. Key tweeters and bloggers in certain networks have enormous influence and can be paid large sums of money ($13,000–20,000 per tweet has been reported) to refer to a product in their content.[4] It is, perhaps, a justifiable cost given the reach of such tweets; Katy Perry, the most followed person on Twitter, has 64 million followers.[5]

In the advent of an infectious-disease outbreak, these techniques must be considered to convey official messages to a population and to quash misinformation. On the Ebola stream, the most influential actors were computed by considering how many times a message is passed on by users (re-tweeted) and how influential those people that re-tweet the messages are. The top ten most influential actors for Ebola are identified in Figure 3.

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4.   Liat Kornowski, 'Celebrity Sponsored Tweets', *Huffington Post*, 30 May 2013.
5.   Twitter Counter, 'Twitter Top 100 Most Followers', <http://twittercounter.com/pages/100>, accessed 4 February 2015.

Figure 3: The Top Ten Most Influential Actors Regarding Ebola.

Source: Ripjar Ltd.

Many of the organisations heavily involved in dealing with and reporting the Ebola crisis are represented in the list, which shows they are controlling the story effectively. The @bilal_shah512 and @consipiracyimage accounts both had one extremely popular tweet each, the former relating to how scary Ebola is, the latter on how suspicious it was that Ebola had disappeared from the news. The final individual on the list is Hans Rosling, the famous Swedish doctor and statistician, who was in Liberia fighting Ebola.

The messages that propagated the fastest on Twitter relating to Ebola (during the time frame considered) are shown below:

> Ebola has disappeared, gas low AF, US & Cuba good now...am I the only one that think it's some weird s*** going on...

> Ebola is gone, gas is at 1.60, US & Cuba good now.. and I still can't get a text back smh

> A plane passenger was hospitalised after landing in Newarsk from an '#Ebola-affected country.' http://t.co/CTS0ic95zV http://t.co/Pa6ysFXauH

The first two are somewhat-frivolous tweets that suggest how good life is in the US now that Ebola has gone. The third tweet is from CNN with some news that a patient in the US had been admitted to hospital after visiting an Ebola-infected country. While these tweets are not particularly interesting

in themselves, they become interesting due to their popularity – they give a flavour of US sentiment towards the Ebola outbreak.

Finally, it is possible to look at the network structure of Twitter directly. Figure 4 shows the main component of the accounts discussing Ebola:

Figure 4: Visual Representation of the Twitter Accounts Discussing Ebola.


Source: RipJar Ltd.

In this case, the tightly knit group of accounts indicates that most of the main accounts are in contact with one another.

Population Movement

The final area, upon which this sort of data-analysis impacts, is the location of populations. Smartphones can provide a latitudinal/longitudinal co-ordinate that is accurate to within metres of the true location. Twitter users can provide this precise location information when they submit a tweet, giving large-scale, real-time information as to where people are. In the event of an infectious-disease outbreak, people's behaviour could change and such capability might help find large gatherings of people.

To illustrate the nature and scale of this data, Figure 5 shows a map of the world with the locations of six billion tweets shown.

Figure 5: Data from the Twitter Streaming API.
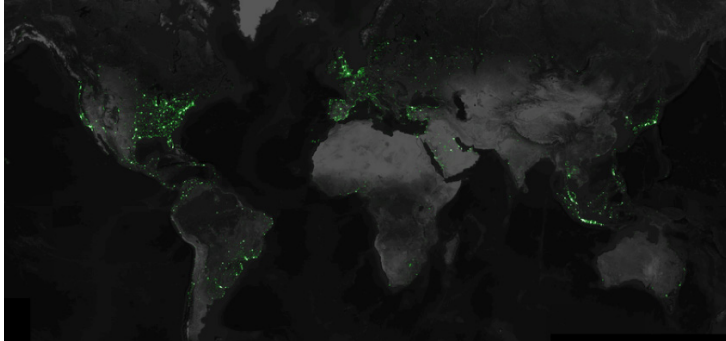
Source: Mapbox OpenStreetMap, <https://www.mapbox.com/about/maps/>, accessed 11 May 2015.

The brighter areas in Figure 5 indicate that tweets have been located at that position. The map shows where Twitter data are abundant. Evidently the Western world is a big user of Twitter, but there are some countries that are more surprising: Indonesia and Malaysia, for example, have a large presence. Saudi Arabia has the highest proportion of Twitter users in the world.[6]

Twitter currently sees around 500 million tweets per day,[7] and around 0.5 per cent of these data have the precise location information on them (a larger proportion has less accurate geographical information). This gives about 2.5 million positional points per day.

Figure 6 demonstrates the fine-grain detail that is evident in these locations (image taken from the same six-billion tweet map).

Figure 6: Data from the Twitter Streaming API.

Source: Mapbox OpenStreetMap, <https://www.mapbox.com/about/maps/>, accessed 11 May 2015.

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6. *The Economist*, 'Social Media in Saudi Arabia', 13 September 2014.
7. Richard Holt, 'Twitter in Numbers', *Daily Telegraph*, 21 March 2013.

Figure 6 is a zoomed-in image of London. It is possible to see the city centre and the main arteries serving the city. A sharp eye can just see the river in the bottom right-hand corner of the image with bright spots at Canary Wharf and the O2 Arena. Towards the top right-hand corner there is a bright spot that is the Olympic Park. The stadium is even evident as a small oval ring.

Figures 5 and 6 show data collated over several years – but even by looking at the data over a few hours it is possible to spot gatherings of people.

Conclusion
The purpose of this paper has been to highlight the availability of large, real-time data sets and their potential applications to monitor and influence situations involving an outbreak of disease. Software tools exist that handle the scale of this data to make such analyses possible by non-technical individuals. In particular, it is hoped that this paper has motivated the use of this approach to news monitoring, viral marketing and also population-movement tracking.

Simon Smith is a Data Scientist at Ripjar, a data-analytics startup focusing on extracting and presenting insights from social media, news and other publicly available data. Previously, he worked in a variety of research positions in cryptography, machine learning and visual analytics. He has a particular interest in natural-language processing and enabling computers to understand human language.

Discussion Groups

During the afternoon, the conference broke up into focused discussion groups, the outcomes of which are presented over the following pages.

Discussions were without attribution. The information presented here seeks to represent the discussions that took place; there is not always robust academic referencing to support the views offered, but it has been assumed that if comments made by individual delegates were not credible, they would have been rejected by the other members of that group during the discussions. Views presented are therefore assumed to be broadly supported by the majority of those present.

There was, inevitably, some crossover of subject matter and topic discussion between the groups, and where this occurred, comments have been amalgamated under one heading to avoid repetition.

Discussion Group 1: Surveillance and Modelling of Emerging Diseases

Chair: Adam Kucharski, Research Fellow, Centre for the Mathematical Modelling of Infectious Diseases, London School of Hygiene and Tropical Medicine.

Rapporteur: Sara McDonnell.

Key Issues and Challenges
- Which techniques and tools can help with spotting problems at the pre-epidemic stages?
- What might help situations once an outbreak has already been detected?
- What data/techniques do we need to design a strategy post-outbreak?
- Can social-media data be used to measure trends?

There will always be background noise that makes it difficult to spot an emerging outbreak. In the case of Ebola, the area was subject to Lassa fever and malaria, for example, which also have high mortality rates and make infants sick. In the UK, there is a lot of respiratory disease. When do we realise it is a pandemic? Could we detect anthrax in London? The challenge is identifying the signal from the noise and spotting abnormalities.

The group acknowledged that there has been an exponential growth in the data available. In bio-informatics, for example, there are now hundreds of sequences detectable from a single swab. Whereas before, we struggled to acquire data, now we have a tsunami of it. This means we need to be specific about what information we want and for people to be 'the intelligent customer' – to ask the right questions. Data collection needs to be consistent and we need to have an idea of how a 'normal society' works so we can spot abnormalities.

Sometimes there are too many data, sometimes too little, and in some places it is difficult to obtain data, so we need alternative ways of filling gaps in current knowledge. Can we find proxies or indirect measures where data is scant, such as understanding outbreaks in animal populations?

There are many different factors at play that we don't see – 'epidemiological dark matter' – of which wild animals are one such type. Data from wild animals can be useful, such as when birds are dropping out of the sky. We have well-established systems for cattle, but it is more difficult working out systems for wildlife.

However, there are alternative ways of looking at it; for example, if a community relies on bush meat and that source disappears we might look at what is being eaten instead in the event of an outbreak. Biologists and economists could work together more closely on this.

The problem with previous outbreaks is that by the time you realise something has happened it is too late. How can we use the benefits of hindsight? Perhaps we can work out which people get sick before they go to the doctor by monitoring chemists and what pharmaceuticals are being purchased, or how many ambulance callouts there have been in an area and if water usage goes up. Indicators such as these cannot be taken in isolation, but together they can be significant pointers. We need the statistical tools to measure how patterns are changing.

How can we understand the impact of luck? Separating correlation from causation is important – a link might be serendipitous or might be potentially harmful if that correlation doesn't actually exist. But we might be able to monitor a sudden change in *x* and *y* which could mean that there is something going on.

What Might Help Situations Once an Outbreak Has Already Been Detected?

Intervention can affect situations and data sources. Control measures can change the way people behave, and not always in the way you would expect. They may stop people reporting their illness, for example. When trying to stop mass panic, a decision-maker might think that it is a rational response to turn off mobile signals, but this loss of infrastructure can change behaviour and affects the monitoring of it. Similarly, a sudden emergency situation can seize up communication channels, such as when phone networks went down during the Boston marathon bombings in April 2013.

We need to take into account how people communicate in particular communities and how we can reach far-flung villages. An example was given of a network of displaced men who formed their own communication network on motorbikes.

Understanding the knock-on effects that outbreaks can have is important, and how those chain reactions can impact data. Actions such as closing schools during pandemics, for example, have their own knock-on effects and unintended consequences,[1] of which we have an incomplete sense. There may be cases when no action is actually the best course to take.

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1.   Thomas House et al., 'Modelling the Impact of Local Reactive School Closures on Critical Care Provision During an Influenza Pandemic', *Proceedings of the Royal Society B: Biological Sciences* (Vol. 278, No. 1719, August 2011), pp. 2753–60.

The so-called 'worried well' phenomenon, where people are worried they are affected when in fact they are not, can have a big impact on how a disease transmits. It was pointed out that 50 per cent of people attending Ebola centres didn't have the disease. A greater understanding is needed of these types of models. In underdeveloped countries the 'worried well' is not thought to be such a problem, but the evidence from the Ebola centres would suggest otherwise.

During an outbreak, politicians want certainty and often it is difficult to give certainties. 'It depends' is a stock answer in many cases. Being able to quantify risk, in a reliable sense, would be powerful.

Social media emit lots of data – can this be integrated into measuring qualitative trends? Visualisations can help to convey information so that people just 'get it'. They also help to capture multiple dimensions as well as 'fuzzy' data. But while graphic representations were generally acknowledged to be better at conveying information than tables, it was pointed out that they can cause people to make wrong connections.

What Data/Techniques Do We Need to Design a Strategy Post-Outbreak?
In an ideal world we should be able to predict long-term effects of these problems. For example, HIV has very long-term effects, affecting whole lifecourses. Vaccines can have non-linear responses because there are other factors at play. Understanding these would be helpful.

Crowdsourcing information could be a good way of tracking outbreaks. Twitter, Streetmap and Wikipedia are all examples of where crowdsourcing information can be successful as a way of keeping information up to date. There are already people doing this: Flu Near You (<https://flunearyou.org>) by HealthMap asks users how they feel then aggregates crowdsource data. Google Flu Trends (<http://www.google.org/flutrends/>) is often ahead of some public authorities responsible for disease monitoring. There are other data sources that can be utilised and integrated with this information, and this could be researched further. Getting the right data from Google can be difficult however.

Getting a balance between qualitative and quantitative data is important. Flusurvey scientists at the London School of Hygiene and Tropical Medicine are analysing swabs sent to participants to monitor how flu takes hold over the winter months.[2] However, the number of responses would affect the statistical integrity of the data (there were 5,000 participants last year).

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2. London School of Hygiene and Tropical Medicine, 'Free Home Flu Test Kits for Flusurvey Participants', News, 19 November 2014, <http://www.lshtm.ac.uk/newsevents/news/2014/flu_home_tests.html#sthash.aCmkpkmw.dpuf>, accessed 28 March 2015.

Summary
We now have a tsunami of data available from different sources; we now have to decide on which data to focus, how best to utilise these data and how to communicate them in the event of an outbreak. We also need to establish what kinds of data we have, where there are gaps in the data and how we might use alternative sources to discern a signal from the noise. Once an outbreak is determined, we then need to understand how interventions might work and their potential 'ripple effects'. Modelling and visualisation techniques can help understand these effects.

Suggested Research Topics
- How to establish consistent data-collection systems to ensure we have an idea of how a 'normal society' works and ways of spotting abnormalities relating to a serious infectious-disease outbreak. For example, in wildlife it would be useful to establish systems for spotting outbreaks in wildlife as we currently do for cattle. Also investigating the use of proxy sources of information to establish warning signs and how these early indicators might be used in conjunction with other pointers to understand how patterns of behaviour are changing
- Utilising suitable statistical tools to measure how patterns change and understanding the impact of coincidence so that correlation can be separated from causation
- Understanding the knock-on effects of an outbreak, and how interventions can change patterns of behaviour. How, for example, does society's reaction to the outbreak of disease (including the 'worried-well' phenomenon) affect disease spread in different societies?
- Studying how 'big data' obtained from social media/search engines could be utilised to measure trends and how visualisations can be best used to communicate those trends that might have multiple dimensions, as well as 'fuzzy' data.

Discussion Group 2: Genomic Sequencing and Analysis of Early Cases

Chair: Sterghios A Moschos, Reader in Industrial Biotechnology and Biochemistry and Director of Westminster Genomic Services at the University of Westminster.

Rapporteur: Heidi Chung, RUSI.

Key Issues and Challenges
The group discussed aspirations for the next twenty-five years of genomic sequencing regarding serious infectious diseases. Themes discussed were:

- Screening for infectious diseases
- Technology platforms
- Utilising mobile technology
- Developing protocols and policy that can enable this technology to work and address any ethical concerns that may arise.

First, the group looked at how infectious disease could be detected early to allow intervention before it becomes beyond the point of control. Meaningful screening is essential to enable early intervention. An inadequate screening measure gave a negative result of Ebola with the Scottish nurse, Pauline Cafferkey, who expressed worries that she had the disease as she worked at the Ebola Treatment Center in Sierra Leone. As a result, her treatment for Ebola was delayed.

Better screening systems would not only enable appropriate diagnosis and trigger timely treatment, but ensure intelligent decision-making. There is also a need to consider what is a meaningful scientific outcome and what additional information is required. Blood sampling is considered to potentially be a better test material than body temperature and may improve the accuracy of the screening result.

Another way of improving the effectiveness of the screening system could be to split it into two stages. Primary screening should be simple and seek to identify irregularity such as high body temperature; identified cases can then be filtered by secondary screening with more complex testing to ensure targeted treatment.

The US Department of Defense has invested heavily in its research of technology platforms. Similar research is also being conducted in the UK; however, the research groups are scattered. There is a need to gather all the separate research groups to ensure a collective effort.

These efforts could be used to develop devices that measure bio-markers indicating the need for the user to seek medical consultation. Wearable technologies provide platforms through which this could be realised. The necessary step-change challenge centres on how to make this technology available to the general public, not just the wealthier population – and to encourage self-monitoring for wellbeing, disease monitoring and disease prevention, in a positive way.

Similarly, smartphones could be a cheaper and more deliverable solution to allow timely medical consultation. Coupled with energy sources, connectivity and computational power, they could enable communication via Skype, for example, instead of face-to-face consultations. Implementation would reduce waiting times, accelerate response and contain the spread of disease.

The group felt it was important to establish a simple and robust platform that allows prompt responses to an outbreak of disease and can put patients into different groups according to their illness.

Anonymous sampling was raised as a potentially useful way to detect diseases in a timely manner; however, there is an associated ethical concern with using this kind of sampling. Development of effective protocols and policy are far more complex than developing the applicable technology.

Emerging sequencing technologies could mature into continuous environmental monitoring solutions in, for example, transportation hubs. The ethical advantage such an approach would provide is balanced by several substantial technological, analytical and computational-power challenges; there is also a need for clear actionable outcomes to enable containment.

The group felt that, currently, profit is the main driver of medical production. This would need to change if sufficient medical countermeasures are to be produced to prepare for an outbreak. Alternatively, the commercial-development opportunities offered through the need to mitigate outbreaks can be used to leverage interest and commitment from industry.

Summary
Screening systems need to be improved. They need to be faster and more efficient and could benefit from being split into two stages. UK research into technology platforms needs to be consolidated and consideration as to who is able to access this technology is also needed. Mobile-internet devices might provide a way around limited access to face-to-face consultations but interventions such as sampling raise ethical concerns.

Suggested Research Topics
- Improving screening processes beyond simple temperature measurement to include point-of-need methods such as blood sampling and analysis, creating a two-stage process
- Joining up research on technology platforms, such as wearable technology, to develop devices that provide bio-markers that indicate when a user should seek medical help. How this technology might be made available for the general public also needs researching
- Establishing a simple and robust platform that can put patients into different groups according to their illness
- Investigating how smartphones/mobile technology might be able to help deliver medical consultations and how to encourage self-monitoring.

Discussion Group 3: Cultural and Environmental Risk Factors in Disease Spread

Chair: Jennifer Cole, Senior Research Fellow, Resilience and Emergency Management, RUSI.

Rapporteur: Philippa Morrell, Beaver Training & Technical Ltd.

Key Issues and Challenges
- Understanding the cultural aspects of a particular region that may affect disease spread and how an intervention might work
- Understanding the physical and environmental aspects of a region that may hinder aid efforts
- Building relationships with people who can influence behaviour.

Before international actors go in to provide aid, it is important to understand the cultural aspects of a particular region. Just because two countries are in the same part of a continent does not mean the same approach will work in both. An example was given of how an approach which works in Ghana will not work in Nigeria. Factors that need to be considered include the degree to which the local population trusts the government; cultural mores and any taboos around treating disease; attitudes to asking for overseas help; and environmental aspects. This last factor includes: deforestation (which may move potentially disease-carrying animals closer to human populations); population movements, which may differ significantly by season; and international travel of urban populations that risks spreading the disease further.

More qualitative data and analysis is needed, for example, on behavioural aspects – how is the West, which has gone into Africa to help, seen by those in the affected countries?

NGO workers, who had recently been interviewed by RUSI, expressed concern that the feeling among the population in Liberia, in particular, was that the government had held off acting until the epidemic became an international issue. This was because of that country's particular history of relying on international aid: does it recreate a culture of dependence in which a country is no longer able, nor willing, to act on its own?

Another cultural aspect to consider is the role of natural healers. In Sierra Leone there are two distinct types. The first are what the West would see as herbalists, who use natural medicines that can be made using local ingredients. The second are spiritual healers, who use prayer and magic to drive out illnesses that are seen as curses or demonic possession by the local

population. The tendency in the West is to disregard the spiritual healers and try to work with the natural herbal healers. However, many herbal healers see Western medicine as direct competition and therefore are less likely to recommend that a patient seek help from a medical clinic. Spiritual healers, on the other hand, are often moral advisers and will recommend a patient go to a doctor in much the same way as a Christian priest will not see medical aid and prayer as incompatible.

There needs to be strong cultural understanding at a very local level. It is necessary to learn who the affected people are, what local health-care is available to them, who the key influencers in their communities are, and build a network around them. If there is a failure to understand the culture of a place, it is difficult for Western actors to create something that will actually work. Religion, history, and geopolitics all play a strong part and must be fully understood.

Future campaigns to assist with disease should change from being 'this is what we will do' to 'how can we help?'

The group felt that what is required for those going out to provide help is a series of 'recipe cards' that outline the culture of the area to where they are being sent and what will be seen as acceptable practices there. As an example, in the Ebola crisis, disease has often been spread at funerals, where a strong local tradition is to massage the body of the deceased; unfortunately, with Ebola, the viral load is still high following death and this presents a particular risk. Attempts to 'ban' funerals or important funeral rites, and to stop people from touching the bodies altogether, created resentment and resistance. Enabling the families of the deceased to perform the rites, but with the bodies of Ebola victims touched through body bags rather than directly, was accepted.

Culture and environment are flowing and dynamic; so, as important as the recipe card in this approach, is the chef. We need to find out how to build relationships with people who can and will influence behaviour. This could be done via an international network of social scientists and clinicians who can build up a network that would be able to quickly advise on cultural practices in any region when and as an outbreak occurs. Some work is already progressing in this direction: The Institute of Development Studies at Sussex University has set up the Ebola Anthropology Platform funded by The Wellcome Trust and Department for International Development.[1] Equivalent platforms now need to be developed for other regions.

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1. Ebola Response Anthropology Platform, <http://www.ebola-anthropology.net/>, accessed 25 March 2015.

Programmes should focus on people, building networks and promoting research of value to those communities. Work does not necessarily need to be on disease-control programmes only. A list of the roles, and what to look for, can be put together and then information on how to reach these people provided to those going into the region.

Another aspect of research is a strong understanding of the policy for running these operations – how do organisations go into other countries, how effective is this, and how does it affect local response efforts – combined with research into finding the contacts in the appropriate ministries, which may not always be just the ministry of health.

What Is the Measurement of Success?
The group felt that adherence to the international health regulations of the World Health Organization cannot be used to measure success because they are completely subjective.[2] Research needs to be done to find measurement tools that can be used as indicators of success following an international event. The nuclear industry has devised such measurements, for example, and these could be used as a basis.

'How can we help?' is a good formula but it does not always work because sometimes the answer is: 'what can you do for us?' There is a difference between being proactive and reactive and many countries in Africa are still reactive to events. More needs to be done to create the right conditions for them to be proactive and to support them through implementation.

A further suggestion for study was risk perception and the communication of it. This would be a large piece of work; it is not helped by the fact that there is no strong consensus on how risk can be properly communicated in the West. A lot of the information that was provided locally about Ebola, particularly at the beginning of the crisis, had been based on myths and conspiracy theories rather than science. Such narratives may, however, contain important pointers for understanding cultural factors, and should not be dismissed out of hand. They can provide strong clues as to whether governments are generally believed; the importance of religion in positive narratives; and who the most influential individuals or organisations may be. The public and media perception needs to come from the correct person – but who is that correct person and how can they be identified?

Political continuity is also important. For example, in countries like Nigeria, which is a democracy, people are learning how to ask the correct questions of those in authority. It was not long ago that people who asked too many

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2.   World Health Organization, 'Alert, Response and Capability Building under the International Health Regulations (IHR)', < http://www.who.int/ihr/procedures/pheic/en/>, accessed 25 March 2015.

questions were regarded as controversial and so were actively encouraged not to do so. How willing a country's ruling elite is to engage in debate and listen to its citizens will have a strong influence on how likely those citizens are to believe what they are told.

It is necessary to create a proactive attitude in the people and rulers in affected countries. One way to do this is to build a network that is seen as politically neutral, which can work with both the government and opposition so that any work begun while one party is in government continues should the opposition gain power. The group asked whether academic links might be able to best serve this purpose. In countries where social inequality is marked, the academic community may be simply an extension of the ruling elite, however, and offer no greater access to the grassroots communities. Another area could be looking at how to bridge the gap between the elite and the grassroots in networks where it had been agreed that such a network needs to be built.

For some developing countries, particularly those where tourism is a big part of the economy, announcing that there is a health risk or a disease outbreak can have severe economic consequences. An area for research funding could be an examination of the main drivers regarding public-health concerns in that country. For the above reasons, international organisations with reach into Africa, such as the World Bank or the Rockefeller Institute, may be more appropriate in building a network.

Another issue the group felt was a challenge was that as health always attracts NGO funding there can sometimes be little incentive for the countries themselves to invest as they know any shortfall will be bridged by international aid. There might be very good private hospitals for the rich but nothing for the rest of the population: the care pathway may be completely different for different social groups.

A dichotomy was seen between disease control, which the group described as 'sick care' (in other words, it comes into play once people are already infected), and true health-care, which includes preventative measures as well. There is a massive void between the experts and lay people and we need to understand how all parties can practice better risk management. Proactive procedures needed to be understood at the grassroots – would that then help them to be self-sustaining? There must be continuity between what is happening at the policy level and what can be enacted on the ground.

We need a better understanding of what health-care in these countries actually looks like – in many cases, it is a mixture of traditional healers, plus doctors and nurses as the West would recognise them. This raises questions over what kind of training is most appropriate and necessary at the grassroots? Local healers may not need to able to do much more than set broken bones, recognise what

diseases they can treat locally and do so where appropriate, and advise patients to seek further medical help where necessary, referring them to more Western-style health-care clinics. These local health-care practitioners would not be recognised internationally as nurses or doctors, but may be most appropriate for the local region. A valuable research project would focus on how this training could be done in-country, and how much it would cost. The group felt there might be particular merit in this approach as, if such local health-care practitioners did not hold internationally recognised qualifications, it would prevent their leaving the local community to work in the health-care sector in richer countries. The movement of qualified medical staff out of Africa has been a particular drain on African countries' health-care sectors.

Summary

There is clearly more work that can be done to not only assist international aid efforts in countries affected by a serious infectious-disease crisis but also to help the countries in question be better prepared. As well as cultural and environmental awareness, having ready-built networks and trained members of the community would go a long way to help aid efforts, as would communication of risk and measurements of success.

Recommendations

- More qualitative data and analysis are needed on behaviour and attitudes towards the West in the affected countries. Those going out to provide help would benefit from 'recipe cards' outlining the culture of the area to which they are being sent. What practices are seen as acceptable there and what are the priorities driving health-care?
- How an international network of social scientists and clinicians – who are able to quickly advise on cultural practices in any region when and as an outbreak occurs – can add value to any response effort and needs to be better understood. NB: work is already progressing in this area (see above)
- Research is needed to find measurement tools that can be used as indicators of success following an international public-health emergency event. This needs to include long-term indicators that suggest how the local health sector can be strengthened and sustained, as well as just indicators of what happened in the last outbreak
- A valuable exercise would be to look at how strengthening the training of more appropriate local health-care workers (including natural healers) could be done in-country, and how much it would cost. The focus should be on strengthening existing established local health-care approaches, not replacing them with more-Westernised models, which may be dependent on drugs and equipment local populations cannot afford
- Further research into risk perception/management and the communication of it, to local and international populations, is needed.

Conclusions and Summary

Research Themes Identified

Discussion Group 1: Surveillance and Modelling of Emerging Diseases
The first discussion group identified the establishment of consistent data-collection systems as a key research theme with the aim of ensuring that we have an idea of how a 'normal society' works and ways of spotting abnormalities relating to a serious infectious-disease outbreak. For example, it would be useful to establish systems for spotting outbreaks in wildlife as we currently do for cattle. Also, it would be worthwhile to investigate the use of proxy sources of information to establish warning signs and how these early indicators might be used in conjunction with other pointers to identify how patterns of behaviour are changing.

Other lines of research could be investigations into the use of suitable statistical tools to measure how patterns change and further understanding of the impact of luck so that correlation can be separated from causation.

Understanding the knock-on effects of an outbreak, and how interventions can change patterns of behaviour is also important. How, for example, can the 'worried well' phenomenon affect disease spread in different societies?

Finally, the group highlights how the 'big data' obtained from social media/search engines could be utilised to measure trends and how visualisations could be best used to communicate those trends that might have multiple dimensions, as well as 'fuzzy' data.

Discussion Group 2: Genomic Sequencing and Analysis of Early Cases
The second group suggested that improving screening processes such as blood sampling and creating a two-stage process could be a useful research line.

In addition, future work could focus on joining up research on technology platforms to develop devices that provide bio-markers – indicating when a user should seek medical help – such as wearable technology. How could this technology be made available to the general public?

Establishing a simple and robust platform that can put patients into different groups according to their illness could be a further area of analysis.

Finally, future work might focus on investigating how smartphones/mobile technology might be able to help deliver medical consultations and encourage self-monitoring.

Discussion Group 3: Cultural and Environmental Risk Factors in Disease Spread

The third discussion group emphasised that more qualitative data and analysis is needed on behaviour and attitudes towards the West in the affected countries. Those going out to provide help would benefit from 'recipe cards' outlining the culture of the area to which they are being sent. What practices are seen as acceptable there and what are the priorities driving health-care?

How an international network of social scientists and clinicians, who are able to quickly advise on cultural practices in any region when and as an outbreak occurs, needs to be better understood. NB: work is already progressing in this area (see above).

Research is also needed into finding measurement tools that can be used as indicators of success following an international public-health emergency event. This needs to include long-term indicators that suggest how the local health sector can be strengthened and sustained, as well as just indicators of what happened in the last outbreak.

A valuable exercise would be to look at how strengthening the training of more appropriate, local health-care workers (including natural healers) could be done in-country, and how much it would cost. The focus should be on strengthening existing, established local health-care approaches, not replacing them with more Westernised models, which may be dependent on drugs and equipment that local populations cannot afford.

Further research into risk perception/management and the communication of it, to local and international populations, is needed.

SERIOUS INFECTIOUS DISEASE

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