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Opening Remarks

Disrupted Cities: Infrastructure Disruptions as the Achilles Heel of Urbanized Societies[1]

Stephen GRAHAM

> "The town exists only as a function of circulation and of circuits ; it is a singular point on the circuits which create it and which it creates. It is defined by entries and exits: something must enter it and exit from it"[2]

On our rapidly urbanizing planet, the everyday life of the world's swelling population of urbanites is increasingly sustained by vast and unknowably complex systems of infrastructure and technology stretched across geographic space. Immobilized in space, they continually bring into being the mobilities and circulations of the city and the world. Energy networks connect the heating, cooling and energising of urban life through infrastructure to both far-off energy reserves and global circuits of pollution and global warming Huge water systems sate the city's insatiable thirst, their waste water and sewerage parallels removing human and organic wastes from the urban scene (at least partially). Within cities, dense water, sewerage, food and waste distribution systems continually link human bodies and their metabolisms to the broader metabolic processes through which attempts are made to maintain public health. Global agricultural, shipping and trade complexes furnish the city's millions with food. Highway, airline, train and road complexes support the complex and multi-scaled flows of commuters, migrants, tourists and refugees, as well as materials and commodities, within and through the global urban system and its links with hinterlands and peripheries. And electronic communications systems provide an universe of digitally mediated information, transaction, interaction and entertainment with is the very lifeblood of digital capitalism and which is increasingly assembled based on assumptions of always being 'on'. The vital material bases for 'cyberspace' are largely invisible and subterranean. They also link intimately both to the electrical infrastructures which allow it to function, and to the other infrastructural circuits of the city as they themselves become organised through digital media.
Whilst sometimes taken for granted -- at least when they work or amongst wealthier or more privileged users and spaces -- energy, water, sewerage, transport, trade, finance and communication infrastructures allow modern urban life to exist. Their pipes, ducts, servers, wires, conduits, electronic transmissions and tunnels sustain the flows, connections, and metabolisms that are intrinsic to contemporary cities. Through their endless technological agency, these systems help transform the natural into the cultural, the social and the urban.

Infrastructural edifices thus provide the fundamental background to modern urban everyday life – a background that is often hidden, assumed, even naturalised. They fundamentally underpin the ceaseless and mobile process of city life in a myriad of ways. This process inevitably works across many geographical scales, from the level of the human body and its metabolisms -- through which the food, water and energy brought to the city through infrastructural

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circulation actually flow – through the city, region and nation to the transnational and even planetary – with its transnational networks of energy extraction and flow, airline travel, electronic communication, food trade, port systems, and the movement of solid, liquid and gaseous wastes. Much-debated processes of 'globalisation' -- beneath the fast-fading hyperbole of the business press -- rely after all on vast and unimaginably complex material circuits of infrastructure within which cities invariably act as the dominant hubs of built networks, the predominant centres of demand (for energy, food, water, transport and communications), and the dominant centres for generating pollution and waste of all forms.

The political, economic, social and environmental importance of the world's lattices of urban infrastructure can only grow as the world becomes more urban. Well over 50% of the world's population lives in cities; 75% of the world's population of over 9 billion people is projected to live in them by 2050.[3] Within just over four decades there will be fully 7 billion people living in the world's cities, 4.75 billion more than in 2007. The overwhelming majority of these will be in the burgeoning cities and 'megacities' of the so-called 'Developing World': in Asia, Africa and Latin America.

As this great demographic and geographic shift continues, humankind will become ever more reliant on functioning systems of urban infrastructure. Indeed, the very nature of urbanisation means that every aspect of people's lives tends to become more dependent on the infrastructural circuits of the city to sustain individual and collective health, security, economic opportunity, social well-being and biological life. Moreover, because they rely on the continuous agency of infrastructure to eat, wash, heat, cook, light, work, travel, communicate, and remove dangerous or poisonous wastes from their living place, urbanites often have few or no real alternatives when the complex infrastructures that sometimes manage to achieve this are removed or disrupted.

What happens when the infrastructural flows or metabolisms of the modern city, that so often come to be considered so 'normal' that urbanites may even come to see them as culturally banal, invisible, even boring, are suddenly interrupted or disturbed? In what ways do technical malfunctions, interruptions in supplies of resource, wars, terrorist attacks, public health crises, labour strikes, sabotage, network theft, extreme weather and other events usually considered to be 'natural' (floods, earthquakes, tsunami etc.) disrupt the flows of energy, water, transportation, communication and waste that are the very lifeblood of the contemporary city?

Ironically, moments of infrastructural statis and disrupted flow as a powerful means of revealing the politics of the 'normal' circulations of globalizing urban life which tend to fall off the radar screen of contemporary political and social-scientific debates. Here we confront a paradox: Studying moments when infrastructures cease to work as 'normal' is perhaps the most powerful way of really penetrating and problematizing those very normalities of flow and circulation to an extent where they can be subjected to critical scrutiny..

In fact, infrastructural disruptions provide important 'heuristic devices' or learning opportunities though which critical social science can excavate the politics of urban life, technology or infrastructure in ways that are rarely possible when such systems are functioning 'normally.' Disruptions and breakdowns in normal geographies of circulation allow us to excavate the usually hidden politics of flow and connection, of mobility and immobility, within contemporary societies. Occasions of immobility and interrupted flow help to reveal urban infrastructure systems to be much more than the technocratic 'engineer's stuff' configured in value-free ways to serve some notional

'public good' often imagined.[4] Instead, they emerge, fleetingly, as materialisations of the starkly contested and divided political, ecological and social processes which tend both to characterize contemporary cities and to shape the configurations of the flows, and immobilities, that sustain global capitalism. Studying infrastructural disruptions critically thus allows us to do much more than learn policy or planning lessons about how to avoid repetitions of such events or how to ameliorate their effects. It also brings major opportunities to re-think and re-theorise the nature of contemporary urban life.[5]

"THE FORGOTTEN, THE BACKGROUND, THE FROZEN IN PLACE"?: INVISIBILITY AND INFRASTRUCTURE

Whilst public commentary may celebrate certain infrastructures as glamorous and worthy of (at least temporary attention), this process often works to render the remainder of a city's infrastructural circuits as curiously invisible and mundane – even boring. Indeed, when infrastructure networks work best, and succeed in reaching mass adoption as the basis for styles of urban life, they tend to become progressively both more 'ordinary' and less and less noticed.[6] Western urban culture, certainly, has often displayed a tendency for the technological circuits of cities to be rendered culturally more invisible – at least to powerful or hegemonic users – as their use has becomes progressively normalized.

When it happens, the very rendering of infrastructural services as virtually ubiquitous and utterly ordinary means that their use can become taken for granted and 'normalised' as an essential, but largely invisible, support to modern urban life. In the language of the sociology of technology, such infrastructures have thus become 'black boxed'[7] by their users who often had no other functional alternative to relying on the networked infrastructure systems whether it was water, sewerage, electricity, the telephone or the automobile system. Mobile and land-line telephones, electric plug sockets, water taps, flushing toilets, Internet computers, and cars are thus tend to be so utterly ubiquitous in advanced industrial societies that these apparently banal artifacts give no hint to the average user of the huge and geographically-stretched infrastructural complexes that invisibly sustain them.

Bruce Mau has argued that "the secret ambition of design is to become invisible, to be taken up into a culture, absorbed into the background." He argues, in fact, that "the highest order of success in design is to achieve ubiquity, to become banal."[8] Taking such a perspective further, Mau reflects that the "automobile, the freeway, the air-plane, the cell phone, the air conditioner, the high-rise – all invented and developed first in the West, but fully adopted and embraced the world over -- have achieved design nirvana. They are no longer considered unnatural. They are boring, even tedious." Most of the time, Mau argues that "we live our lives within these invisible systems, blissfully unaware of the artificial life, the intensely developed infrastructures, that support them."[9]

Anthroplogists, Geoffrey Bowker and Susan Leigh Star, meanwhile, suggest that "good, usable [infrastructure] systems, disappear almost by definition. The easier they are to use the harder they are to see. As well, most of the time, the bigger they are, the harder they are to see."[10] Within social scientific writing about cities, especially, the vast infrastructural circuits of the city have often emerged as little more than "the forgotten, the background, the frozen in place"[11] – a merely technical backdrop that is the preserve of engineer's only. Geoffrey

Bowker and Susan Leigh-Star offer the banal and often universal experience of uninterrupted electricity services to power a simple, reading light as an example of how infrastructures have a tendency to become taken for granted. “Unless we are electricians or building inspectors,” they write, “we rarely think about the myriad of database, standards, and inspection manuals subtending our reading lamps, much less about the politics of the electric grid that they tap into.”[12]

When anthropologists or sociologists define ‘infrastructure,’ the ways in which sometimes attains cultural invisibility over time is one of the key criteria that they settle on. For Bowker Susan Leigh Star, for example, one of the eight defining characteristics of technological systems that achieve the cultural status of ‘infrastructure’ is that they “becomes visible upon breakdown.” They write that “the normally invisible quality of working infrastructure becomes visible when it breaks: the server is done, the bridge washes out, there is a power blackout. Even when there are backup mechanisms and procedures, their existence highlights the now visible infrastructure.”[13]

When infrastructure achieves the status of a ‘black box’, few modern urbanites venture to understand the inner workings of the technology or the giant lattices of connection and flow that link these network access points seamlessly to distant elsewheres. How many of the world’s burgeoning billions of urbanites, after all, routinely consider the extraordinary assemblages of fuel sources, generating stations, transmission wires and transformers that push electrons through the myriad electrical artifacts of contemporary urban life? Or the mass of servers, satellites, glass fibres, routers – and, indeed, electrical systems – that bring our ‘virtual’ worlds of play, socialising, e-commerce or communication into being? Or the globe-straddling systems of communication, data processing, financial transaction, or risk profiling that bring airliners into the sky? Or the vast subterranean worlds that bring the fresh water to the tap or faucet or remove the human waste from the toilet once flushed? Or the global supply chains that populate a supermarket shelves with produce, fill the gas or petrol station with the hydrocarbon products of the decayed forms of billions of ancient life-forms?[14]

Beyond the (usually temporary) celebration of new airports, highways, glitzy fast-rail stations, TGV networks, or broadband telecommunications, the more prosaic and banal underpinnings of modern urban life tend to populate a kind of cultural substrate to the city. Many urban networks in the contemporary city remain "largely opaque, invisible, disappearing underground, locked into pipes, cables, conduits, tubes, passages and electronic waves."[15] Once initially completed and universalized – at least in many western cities – the water, sewerage and electricity systems of the city tended to "became buried underground, invisible, banalised, and relegated to an apparently marginal, subterranean urban world."[16] Often burrowing underground into the dark, dirty and dusty worlds of the subterranean city, such architectures and technologies increasingly became cordoned-off physically as well as imaginatively, abandoned to the engineers, urban explorers or cultural marginals to inhabit, reveal or celebrate the dark labyrinths of the subway, the sewer, the security tunnel, or the historical legacies of earlier systems of movement and mobility abandoned or forgotten below ground.[17] It is not surprising that counter-cultural movements as well as science fictions and urban dystopias routinely delve – quite literally – into the forgotten or abandoned subterranean circuits through which the technologies or circulation burrow and connect. When it occurs, the ‘black boxing’ of infrastructural systems, and the failure of their users to see beyond the flowing tap, the car ignition, the computer screen, the telephone handset, or the

burning stove, to the empire of functions 'behind' the working service, has further important implications for the imaginations of urban infrastructure. Cultures of normalised and taken-for-granted infrastructure use sustain widespread assumptions that urban 'infrastructure' is somehow a material and utterly fixed assemblage of hard technologies embedded stably in place which is characterised by perfect order, completeness, immanence and internal homogeneity rather than leaky, partial and heterogeneous entities.

The combination of the social normalisation of uninterrupted and ubiquitous service and the cultural invisibility of so many of the subterranean artifacts which bring infrastructural services into being, mean that entire technological systems can effectively become black boxed from the point of view of their millions of users. At the same time, our tendency to take infrastructural complexes for granted still means that, for many western urbanites, at any rate, "technical systems [now] conjure up images of stability and permanence."[19] This is because of their historical evolution from small, fragmented, specialised systems to integrated, often (quasi) universal, and technologically-standardised ones that can be regarded as "functional subsystems of society as a whole." [20]

Because of the apparent permanence of black-boxed infrastructural complexes, infrastructure networks thus retain powerful images of stability. Often, they are regarded as "symbols of the complexity, ubiquity and the embodied power of modern technology."[21] This explains why urban studies, for example, still often uses a language such as 'public infrastructure' or 'public works', that traps these networks within a historically-specific period, so utterly failing to acknowledge radical current shifts in the social organisation of the sectors. Urban studies appears to have difficulties acknowledging the intrinsically dynamic nature of network changes. It, too, has, in effect, tended to 'black box' networks like electricity as permanent, ubiquitous and banal underpinnings to urban life that don't really warrant contemporary attention.

INFRASTRUCTURE AS PRECARIOUS ACHIEVEMENT

Such caveats help hammer home a crucial point : That infrastructure networks, despite their occasional veneer of permanence, stability and ubiquity, are never structures that are given in the order of things. Instead of being static material or technical artifacts to be relied on without much thought, infrastructure networks are, in effect, processes that have to be worked towards. The dynamic achievement of a functioning energy, communications, water or transport network requires constant effort to maintain the functioning system. It is easy to overplay the degree to which infrastructure networks necessarily 'mature' to become socially ignored and 'embedded'. "We sometimes seem to view mature [infrastructure networks] as invulnerable," writes sociologist Jane Summerton, "embodying more and more power over time and developing along a path whose basic direction is as foreseeable as it is impossible to detour [But] systems are more vulnerable, less stable and less predictable in their various phases than most of us tend to think." [22]

When the diverse elements are coupled and interact according to their assigned roles within any given infrastructural networks – allowing the intended effects to be expected with high reliability – sociologist of technology describe the network as stable and closed. Take the 'Large Technical System' of the automobile and its related highways and service infrastructure, for example:

"the techno-structure of automobile traffic is a

striking example of this stability : the strongly-knit relations between automobile manufacturers and suppliers, the close intertwining of transport and taxation policy, the long-lasting tradition of motorcar engineering and the mass myth and mass practice of automobilism. Each of these relations guarantees the continuation of a technological trajectory, although the automobile traffic system has been deeply shaken by the crisis of oil supply, air pollution, and urban traffic jams. This close coupling of things, people, and signs and its continuous production by routines are the social base of the technological momentum and the myth of technics-out-of control."[23]

Despite such occasional veneers of permanence, closure and stability, infrastructure networks are always precarious achievements. The links between nodes do not last by themselves ; they need constant support and maintenance. For many of the world's urbanites, indeed – especially those in the burgeoning informal settlements which dominate many cities in the global south – achieving an electricity, water or communication service is the result of a constant process of improvisation.[24] For such urbanites, infrastructure networks are far-from being black boxes that almost miraculously and invisible bring electricity, internet connections, water or food to any point or space. Instead, they are highly politicized assemblages of artifacts and practices within which continuous efforts at agency, or resistance may – just may – allow services to be improvised, often beyond the bounds of markets and strict legality.

But even in cities where infrastructure services are associated with a veneer of stability or permanence, a vast and hidden economy of repair and maintenance is continually at work to allow infrastructural circuits to actually work.[25] Constituting at least 10% of most urban economies, this economy of repair and improvisation is almost invisible within the debates of urban studies. The sheer amount of economic activity generated by repair and maintenance I notable, even though it is almost completely ignored in accounts of the economies of contemporary cities. In the United States, for example, there were fully 5.82 million people engaged in 'Installation, Maintenance and Repair' (IMR) occupations in 2000. This figure was expected to rise to 6.48 million by 2010, a growth rate of 11.4%. These jobs constituted 4% of all jobs in the USA, making the sector one of the six most important service industry occupational groups.[26] "Think only of some of the familiar sounds of the city as an instance," write Stephen Graham and Nigel Thrift, "from the sirens denoting [automobile] accidents, to the noises of pneumatic drills denoting the constant upkeep of the roads, through the echoing clanks and hisses of the tire and clutch replacement workshop, denoting the constant work needed just to keep cars going."[27]

UNDERSTANDING INFRASTRUCTURE DISRUPTIONS

"City-dwellers are particularly at risk when their complex and sophisticated infrastructure systems are destroyed and rendered inoperable, or when they become isolated from external contacts" [28]

The continuous reliance of urban dwellers on huge and complex systems of infrastructure stretched across geography creates its inevitable vulnerabilities. When infrastructure services have become taken for granted, paradoxically, as we have seen, it is often the moment when the blackout occurs, the server is down, the subway has a strike, or the water pipe ceases to function that the dependence of cities on

infrastructure networks becomes most visible. In such circumstances, "for most of us," writes Bruce Mau, "design is invisible. Until it fails."[29]

Sudden disruptions to the complex and 'cyborgian' assemblages that sustain infrastructure networks brings with it the startling paradox with which we started this essay: The unexpected absence of functioning infrastructure works to underline the very (albeit useless) presence of the vast stretched-out system that usually remains so invisible.[30] When they have become stable and taken for granted, interruptions in power, clean water supplies, the arrival of fresh food, the ability to move commuters, tourist or business travelers, the means of flitting electronic data, money, communication or video around the planet at the speed of light, or the means of shifting waste and sewerage away from teeming cities, immediately work to make the vast complexes of infrastructure on which urbanites continually rely starkly visible – if only until normal services are resumed. Sociologists of technology call this a process of 'un-blackboxing': a social process, the opposite of 'black boxing' process discussed above, through which the complex system and technologies upon which everyday life relies , which are normally kept within a 'black box' within which only specialist engineers and policy makers penetrate, are suddenly clearly revealed.[31]

Interconnection and Cascading Effects

During infrastructural disruptions within contexts where infrastructure has become taken for granted, to adopt Irving Goffman's terms, the built environment's "backstage' becomes momentarily "frontstaged."[32] But because infrastructures that are usually considered separate are actually woven together in all sorts of mutually dependent ways[33] – as with the Internet/electricity example already discussed -- disruptions to one infrastructure quickly cascade through other systems in unpredictable ways. [34] As Charles Perrow's highly influential book Normal Accidents35 demonstrates, tightly interconnected infrastructures "predictably fail but in unpredictable ways."[36] Crucially from the point of view of this book, disruption or destruction in one point in a water, transport, communication or energy grid tends to move through the whole system. And because these systems are densely interlinked and mutually dependent -- or are 'tightly coupled' in engineering parlance -- disruption in one tends to cascade to others very quickly. Thus, when the baggage handling facilities at Heathrow's new terminal 5 failed to keep up with passenger throughput in March, 2008, cascading effects quickly disrupt the entire planet's airline system. When thieves literally cart off electrical copper networks – affected by the high price of the metal – as has been common in China, Europe, Russia or the Global South within the lest decade, complex chains of de-electrification can quickly paralyse the multiple electrical circuits and digital or physical circulations of urban life.

Given that all of the 'Big Systems' of infrastructure that sustain advanced, urban societies are profoundly electrical, city residents become, in particular, "hostages to electricity."[37] This is because it is very difficult to store large quantities of electricity. In an electrical blackout it is not just electric lighting that fails. Electrically-powered water and sewerage systems tend to grind to a halt. Public transportation stops. Food processing and distribution is disabled. Health care becomes almost impossible. Even the Internet ceases to function.

Large scale, cascading infrastructure failures, particularly between electricity and transport outages and other systems, demonstrate, can have many orders of cascading effects. For example, Richard Little recounts how, in May 1998, the failure of just one satellite terminated the operation of 80%

of all US pagers, disrupted ATM and credit card transactions systems, interrupted emergency health care communications systems, and brought chaos to the complex, Just-in-Time systems in place in health care systems.[38]

From Apocalyptic Fears to Cultures of Repair

Just as cultural debates about infrastructure tend to privilege glitzy and glamorous infrastructural edifices, cultural commentaries about infrastructural disruptions tend to be with the spectacular collapse of whole cities, societies or civilisations, rather then the mundane interruptions and repairs and improvisations that constitute the quotidian existence of urban dwellers.[39] As we have seen, in many cases, infrastructural services do not become blackboxed and taken for granted because their use is always precarious and unreliable. This point is especially important in the parts of global south cities where rudimentary or improvised access to power, water, fuel, food, or sanitation, beyond the limits of 'formal economies,' is all that is possible.[40]

Rather than swarming masses of repair workers or urbanites tinkering with the prosaic technicalities of urban life, or dealing with cascading infrastructural disruptions, though, we find that films, video games and novels are endlessly preoccupied with fantasies of complete societal or urban collapse replete with annihilated cities and complete societal breakdowns.[41] We have mass disasters, wholesale loss of life, the repeated end of cities per se,[42] and reversals to pre-industrial existence for small bands of hardy survivors, rather than the improvised coping strategies of users and providers in dealing with day-to-day infrastructure disruptions. We also encounter widespread social and political discussions of how past societies have collapsed[43] and how contemporary civilization is facing a future wholesale collapse characterised by resource exhaustion, runaway climate change, growing demographic pressure, and spiraling warfare, rather than the prosaic experiences of sewer overflows, transport disruptions, or energy blockades.[44] And we rehearse the millennial speculations of endless predictions of apocalypse by 'cyberterror'[45] or malign software running out of control -- think of the debates that surrounded the Y2K problem in the run up to the year 2000 -- rather than the endless and deeply prosaic software glitches, crashes and the continuous repair necessary to run a simple Windows PC, a city electrical system, or an organizational computer network.[46] In addressing the infrastructure disruptions in this book, therefore, we need to be especially mindful of the continuous, invisible work necessary to being about infrastructural circulation even when infrastructural assemblages are working 'normally.'[47]

Of course, fear, apocalypse and catastrophe sells; routine portrayals of prosaic improvisation don't. Disaster genres in film, video games and novels, after all, tap into widespread sense of apocalyptic dread about the fragility of urban life in times of growing environmental stress, burgeoning populations, and the growing sense of imminent or existing resource exhaustion, catastrophic climate change, or biodiversity collapse. More generally, there is a widespread cultural sense of the flakiness of many of the essential infrastructural services organised through often unreliable 'kludges' of myriads of software fudges lacing together massive computer communications systems.[48] "Fear of the dislocation of urban services on a massive scale", writes Martin Pawley, is now "endemic in the populations of all great cities", simply because contemporary urban life is so utterly dependent on a huge range of subtly inter-dependent and extremely fragile computerized infrastructure networks.[49]

Disruption and Digitality

Such is the cyborgian nature of computerized infrastructure systems that disruptions to normal services are sometimes moving from the status of inconveniences to that of life-threatening events. Taking an unusually reflective and critical stance for a software engineer, Bill Joy, co-founder of Sun Microsystems, caused a furor back in 2000 amongst readers of the bible of the high-tech elite, Wired. He suggested that the mediation of human societies by astonishingly complex computerized infrastructure systems will soon reach the stage when "people won't be able to just turn the machines off, because they will be so dependent on them that turning them off would amount to suicide."[50] Such concerns fuel an entire publishing industry emphasizing that the lurking actions of distant 'cyberterrorists' could bring an 'electronic Pearl Harbor' to the US nation by sewing mass destruction and death by bringing paralysis to air traffic control, logistics, electricity, water or other critical systems through the use of malign code .[51]

Computer worms and viruses are often deemed by US security commentators to be mere trial runs for such mass, digital paralysis. The 'I Love You' or 'Love Bug' virus, launched by a college student in the Philippines on May 3rd 2000, remains powerful example here. This virus moved to infect 45 million computers in at least twenty nations across the world within three days, clogging and destroying corporate e-mail systems in its wake. Overall damage was estimated at well over $ 1 billion and many Fortune 500 companies were substantially affected. The virus also exposed some of the transnational tensions and inequalities that surround corporate IT. Some newspapers in the Philippines, for example, expressed national pride that the country could spawn a hacker that could bring the highly fragile computer communications systems of Northern corporations to an (albeit temporary) collapse.

On 1st February 2008, meanwhile, just off the coast of Alexandria, Egyptian fishing trawlers inadvertently sever the optic-fibre lines which work to continually bring the 'virtual' interactions of global finance, global telephony and the Internet into being – as happened. In an instant, entire portions of the planet – on this occasion, India and the Middle East – suddenly experience 'network unavailable' signs on their computers, the collapse of stock markets, or the disappearance of their telephone call tone. Again, flurries of media reports momentarily expose the geographies and politics through which glass strands are weaved together at the bottom of the world's oceans to sustain burgeoning electronic interactions between global archipelagoes of high-tech cities and urban economies. For a day or two, the serious newspapers are full of detailed maps of the world's optic fibre networks. Once the crisis is over, these geographies sediment back into the collective unconscious until another interruption occurs.

The reorganization of every circuit and aspect of modern urban life through incredibly complex digital control systems[52] clearly adds a new and vital twist to discussions about the politics and impacts of infrastructure disruptions. Crucial within such debates is the growing awareness that, far from being rational, orderly, or even explicable, digital systems often display a kind of vitalism and non-linear complexity that it can be difficult even for experts to explain how they work (or, equally, don't work).

Beneath the techo-boosterism of the 'digital' or 'networked society,' then, and far removed from the rapidly receding utopianism of the likes of Michael Benedikt discussed above, the prosaic and everyday realities of using contemporary computer systems is, in many ways, constituted through continuous repair and maintenance. Ellen Ullman stresses that the Y2K 'crisis,' in particular, hammered home the fact that

contemporary ICT systems are not "shining cities on a hill – perfect and ever new – but something more akin to an old farmhouse built bit by bit by non-union carpenters."[53] "Glitches, patches, crashes", the crisis revealed, were "as inherent to the process of creating an intelligent electronic system as is the finely tuned program, the gee-whizz pleasure of messages sent around the world at light speed. "[54]

During the Y2K crisis, even computer and software engineers often had little idea of the full archaeological sedimentation of decades worth of software within their computer networks underlined what Ullman calls the "near immortality of computer software" – the way new software often merely aggregate around the kernels of very old systems. Resulting systems are thus inevitably going to be unreliable to an often unknown extent. In the event, only one of the largest concerted repair operations in human history, in the years leading up the turn of the millennium, was able to avert the mass failure of a whole host of transnational ICT systems, and the interdependent infrastructures that they sustain.

Large amounts of any investment of time and money in keeping an IT system running is inevitably spent confronting the need for continuous software and hardware upgrades and maintenance; installing software patches to iron-out a continuous stream of identified flaws; addressing the malignant code that is continually unleashed into the world; organizing secure back-up systems to maintain data in the event of a major crash; and training and equipping the staff, facilities and services to offer such continuous repair services. To take just one example, within Metropolitan Chicago in 2003, 'computer maintenance and repair' constituted 4% of all jobs in the city (5, 679 jobs in all).[55] Moreover, a burgeoning universe of software support and call centre help-lines, spread right across the world to service the major markets of northern metropolitan areas, constitutes one of the world's fastest-growing industries. Here we confront transnationally configured networks, organised through computer systems, which link consumers in the global north to advisors in the global south, and whose very raison d'êtré is the continual requirement of users to deal with the mass, routine, failure in computer systems. Spurred on by 9/11, new urban landscapes of repair and maintenance have even started emerging around the cores of the world's great cities, as emergency computer centres, hardened and windowless like Cold War bunkers, are built to be occupied within minutes in the event of a major disruption or crisis.

Fears of the complete collapse of digital circulations are paralleled by updated variations of long-standing fears of autonomous or cyborgian technics running amok. Events where largely autonomously software, linked into cyborgian infrastructural assemblages, automatically triggers devastating actions – such as with the shooting down of Iran Air flight 655 by the automated computer systems of the US Navy's USS Vincennes – add a new twist to such risks.[56] The interdependence inking electronic communications infrastructures and other infrastructural assemblages also means that electronic disruptions and signals are likely to unpredictably disrupt flows of more prosaic and less glamorous infrastructural circuits, as they themselves become organized through networked computer systems. In February, 2006, for example, the cars of drivers on a coastal road in Norfolk, England, started to mysteriously grind to a sudden halt. Local mechanics were completely flummoxed ("It's like the X-Files, isn't it?" one was reported to have said). Eventually it became clear that the control systems latest computer-controlled cars were being disrupted by powerful radar signals from a nearby early-warning station. (These very means of electronically disabling modern infrastructures are at the heart of emerging military doctrine surrounding

electronic pulse weapons[57]).

Conversely, disruptions in physical transport infrastructures can have far-reaching effects on electronic communications circuits. This is because, at least within cities, these circuits are invariably layed within conduits that parallel physical roads, subway tunnels or rail systems to minimize costs. In July, 2001, a fire on a train in tunnel beneath central Baltimore, for example, brought network disruptions to email and Internet traffic in places as distant as Atlanta, Seattle, Los Angeles and even Lusaka, Zambia.[58] The fire revealed the continuing role of key US metropolitan areas as the hubs of the vast majority of the world's electronic traffic – a legacy of the military and Cold War origins of the system, and the global commercial dominance of US telecommunications and Internet firms. Against the rhetoric of step-like shifts toward a dematerialized 'information society' demonstrated by writers like Michael Benedikt, discussed above, events like the Baltimore train fire hammer home, rather, that "new infrastructures do not so much supersede old ones as ride on top of them, forming physical and organizational palimpsests -- telephone lines follow railway lines, and over time these pathways have not been diffused, but rather etched more deeply into the urban landscape."[59]

Disrupted Cultures

Recent efforts by the artistic world to represent threats of infrastructure disruption have recently received a great deal attention, most notably through the work of French theorist Paul Virilio on the links between speed, modernity, and the rapid or instantaneous diffusion of technological 'accidents' through global reliance on interlinked digital control systems.[60]

Perhaps more surprisingly, popular music has also started to develop some of the most powerful representations of experiences of infrastructural disruption. Members of Canadian band, the Arcade Fire, for example, personally experienced the huge power collapses which impacted on Eastern Canada's main cities in January 1998 because a massive ice storm led to the widespread collapse of the power transmission system.[61] Some of the five million people affected were without power for five weeks within one of the coldest Canadian winter's on record). As Jacques Leslie recounts, classic cascading effects quickly brought a state of emergency to the area:

> "People without power discovered just how many facets of their lives depended on electricity. Their stoves, appliances, and heating didn't work, and many telephones went out. In eastern Ontario, where 50,000 phones went dead, the electric utility, Ontario Hydro, was doubly confounded, since it depended on customers' phone calls to alert it to power failures. Throughout the affected region, all financial transactions had to be in cash, since credit card swipes and ATMs were useless. And even if drivers could find highways free of tree limbs and power lines, they could go only as far as the gas in their tanks would take them, because gasoline pumps didn't work. Most disturbing of all, at 12:20 p.m. on the 9th, the two water filtration plants that served 1.5 million people in the Montreal region went down, leaving the area with a 4- to 8-hour water supply."[62]

Arcade Fire's song, "Neighborhood #3 (Power Out)" provides a visceral reflection of the experience, and hammers home the sense of modernity unraveled, lives threatened, and norms abandoned amidst darkness and cold that few had experienced before.[63]

Disruptive Politics

Finally, it is useful to stress the growing centrality

of deliberate infrastructural disruption to the political strategies of dissenters, protestors, states and non-state fighters alike. Public protest in cities, for example, increasingly eschews traditional mobilizations in city centers, concentrating instead on disabling or occupying the most strategically important infrastructural hubs of a city. In November and December, 2008, for example, thousands of activists of Thailand's main opposition, the People's Alliance for Democracy (PAD), occupied Bangkok's two main airports, preventing at a stroke their 125,000 daily passengers of from traveling. A powerful demonstration against Prime Minister Somchai Wongsawat, whom they argued was merely a puppet of the previous ousted President, the occupation was an effective siege which completely disrupted lucrative tourist economy of the whole of Thailand.

State military theorists, are also all too aware of the debilitating cascading effects of interrupting infrastructural flows, especially electricity supplies. They have developed a range of military doctrine which legitimizes the destruction of urban societies' electrical systems as means of reducing societies deemed adversaries to a state of 'strategic paralysis.' The US and Israeli armies, amongst others, have carefully developed a range of weapons – from giant 60-ton bulldozers equipped with claws designed to destroy roads, water systems and power lines to 'soft' bombs which rain millions of graphite coils onto electrical sub-stations, 'de-electrifying' entire adversary societies in an instant. Indeed, a complex body of military theory legitimatizes such attacks as a necessary and supposedly 'non-lethal' means to coerce highly urban societies by bringing about complete infrastructural disruption or devastation, By generating huge public health crises, as electrically powered water and sewerage systems grind to a halt and repair becomes impossible because of sanctions, such targeting actually leads to very large numbers of civilian deaths, usually amongst the old, the young and the ill.[64]

Non-state fighters and insurgents, meanwhile, have moved well beyond the long-term staple of the car bomb.[65] They now attempt to appropriate airliners, subway cars, railway carriages and buses as means, paradoxically, to devastate and interrupt the circulations of cities.[66] Infrastructures and technologies of circulation are pre-eminent amongst the myriad of 'soft targets' that constitute contemporary cities in the eyes of such movements. They symbolize the purported arrogance of technocratic western nations or the transnational reach and power 'global' cities.[67] They provide opportunities to engineer massive media events and extraordinary levels of devastation without the use of any military weapons whatsoever. And they help generate incalculable economic costs as 'normal' circulations and flows sustaining globalised capitalism are interrupted by cascading disruptions unleashed unpredictably in space and time.

In India, for example, terrorists have targeted the electrical infrastructures sustaining the country's burgeoning high-tech enclaves.[68] In Iraq, Saudi Arabia and Nigeria's Niger Delta, meanwhile, a whole spectrum of insurgents work to destroy oil pipelines, targeting the distant supply lines of fossil-fuels as a means to bring economic and political pressure on distant cities. In all these examples, perversely, "the space of the city, orchestrated by the organizational logics of infrastructure, is… precisely revealed in its destruction."[69] Political violence against infrastructure is perhaps the ultimate way of forcibly 'unblackboxing' infrastructures that have managed to achieve the status of perceived stability, invisibility or permanence.

Geopolitical power, finally, increasingly centers not merely on the use and deployment of military

power but on the control of the energy, water and food resources which must continually be imported to sate the appetites of rapidly urbanizing societies. Vladimir Putin's resurgent Russia, for example, is emerging one again as a 1st order power largely through its continual threats and disruptions to the gas supplies that it pipes Westward toward the Ukraine and Eastern and western Europe.

Notes

1 This article is an altered version of "When infrastructure fails," in *Disrupted Cities: When Infrastructure Fails*, ed. Stephen Graham, New Yorkn: Routledge.

2 Gilles Deleuze and Félix Guattari, (1997) ' City/State' *Zone* 1/2 195-199, pp. 196.

3 United Nations Habitat Program, *State of the World' s Cities*, United Nations Habitat program: Nairobi, 2007, pp 4

4 See Olivier Coutard (ed.)(1999), *The Governance of Large Technical Systems*, London : Routledge.

5 See, for example, Phil Steinberg and Rob Shields (Editors)(2008), *What is a City? Rethinking the urban after Hurricane Katrina*, Athens and London: University of Georgia Press.

6 David Perry (1995), "Introduction". In D. Perry, (1995), *Building the Public City: The Politics, Governance and Finance of Public Infrastructure*, London: Sage. 1-20.

7 Steve Hinchliffe defines black boxes "as settled items whose users and colleagues (human and non-human) act in ways which are unchallenging to the technology". Steve Hinchcliffe (1996), "Technology, power and space – the means and ends of geographies of technology", *Environment and Planning D: Society and Space*, 14, 659-682. Pp 665.

8 Bruce Mau, *Massive Change*, London Phaidon, 2003. pp. 3-4..

9 Bruce Mau, *Massive Change*, London Phaidon, 2003. pp. 3-6...

10 Geoffrey Bowler and Susan Leigh Star (2000), *Sorting Things Out: Classification and its Consequences*, Cambridge, Ma.: MIT Press.

11 Susan Leigh-Star (1999), "The ethnography of infrastructure", *American Behavioral Scientist*, 43(3), 377-391. 379.

12 Geoffrey Bowler and Susan Leigh Star (2000), *Sorting Things Out: Classification and its Consequences*, Cambridge, Ma.: MIT Press. pp. 33

13 Bowker and Leigh-Star use seven other characteristics to define 'infrastructure.' To them, infrastructure is embedded (i.e. "sunk into other structures); transparent ("it does not need to be reinvented each time or assembled for each task"); offers temporal or spatial reach or scope; is learned by its users; is linked to conventions of practice (e.g. routines of electricity use); embodies standards; is built on an installed base of sunk capital; and is fixed in modular increments rather than being built all at once or globally (Bowker and Leigh-Star, 2006, 335).

14 See Aihwa Ong and Stephen Collier (2005)(Editors), *Global Assemblages: Technology, Politics, and Ethics as Anthropological Problems*, Oxford: Blackwell.

15 Maria Kaika and Eric Swyngedouw (2000), "Fetishising the modern city: The phantasmagoria of urban technological networks", *International Journal of Urban and Regional Research* , 24(1), 122-148, pp. 122.

16 Maria Kaika and Eric Swyngedouw (2000), "Fetishising the modern city: The phantasmagoria of urban technological networks", *International Journal of Urban and Regional Research* , 24(1), 122-148, pp. 122.

17 See, for example, David Pike (2007), *Metropolis on the Styx: The Underworlds of Modern Urban Culture, 1800-2001*, New York: Columbia.

18 See, for example, Julia Solis (2007), *New York Underground*, Routledge: New York.

19 Jane Summerton (ed.) (1994), *Changing Large Technical Systems*, Boulder: Westview Press, pp. 1.

20 Renata Mayntz, R. (1995), "Technological progress, societal change and the development of large technical systems". *Mimeo*. Pp. 5.

21 Jane Summerton (ed.) (1994), *Changing Large Technical Systems*, Boulder: Westview Press, pp. 1.

22 Jane Summerton (1994), "Social shaping in large technical systems", *Flux*, 17, July-September, 54-56. Pp. 56.

23 Werner Rammert (1997) "New rules of sociological method: Rethinking technology studies." *British Journal of Sociology*, 48: 171-191.

24 Colin McFarlane (2010), "Infrastructure, interruption, and inequality: Urban life in the Global South", Stephen Graham ed. *Disrupted Cities: When Infrastructure Fails*. New York: Routledge.

25 See Stephen Graham and Nigel Thrift (2007), "Out of order: Understanding maintenance and repair", *Theory, Culture and Society*, 24(3), 1-25.

26 DPE (Department for Professional Employees) (2003) *Current Statistics on White Collar Employees*. Washington, DC: DPE.

27 Stephen Graham and Nigel Thrift (2007), "Out of

order: Understanding maintenance and repair", *Theory, Culture and Society*, 24(3), 1-25. Pp. 2.

28 Seymore Barakat, 'City war zones, *Urban Age*, Spring, 11-19. pp. 12.

29 Bruce Mau, *Massive Change*, London Phaidon, 2003. pp. 3-4..

30 Heideggerian philosophy and phenomenology is particularly helpful in explaining how the apparent failures of infrastructure systems work to render them visible. Such events "disclose a world," writes Peter-Paul Verbeek. "When somebody uses a tool or piece of equipment, a referential structure comes about in which the object produced, the material out of which it is made, the future user, and the environment in which it has a place are related to each other. But that this is so, according to Heidegger, generally appears only when a handy or ready to hand tool or piece of equipment breaks down. When this happens, the tool suddenly demands attention for itself. The reliable dealings we are used to having with the tool are ruptured, and instead of withdrawing from our attention the tool suddenly forces itself upon us. Someone sits at a word processor focused on the text at hand and all of a sudden the computer freezes. The trustworthy world that developed around the computer – the open book, the keyboard, the screen, the cup of coffee; in short, the entire mutually referring network that Heidegger calls a world – is abruptly destroyed." (Peter-Paul Verbeek, (2004) *What Things Do. Philosophical Reflections on Technology, Agency and Design*. University Park, Pennsylvania State University Press. pp 79-80. Cited in Stephen Graham and Nigel Thrift (2007), "Out of order: Understanding maintenance and repair", *Theory, Culture and Society*, 24(3), 1-25.)

31 See Leigh Star, S. (1999), "The ethnography of infrastructure", *American Behavioral Scientist*, 43(3), 377-391.

32 See Erving Goffman, (1959) *The Presentation of the Self in Everyday Life*. New York: Doubleday, and Henke, C.R. (2000) 'The Mechanics of Workplace Order: Toward a Sociology of Repair', *Berkeley Journal of Sociology*, 43: 55–81. Rather than focusing on material infrastructure networks, Goffman worked within an ethnomethodological tradition, discussed the way 'repair' operated as a kind of interactional maintenance of order in everyday encounters and conversations.

33 See Rae Zimmerman (2001), "Social implications of infrastructure network interactions," *Journal of Urban Technology*, 893), 97-119.

34 Richard G. Little (2002), Controlling cascading failure: Understanding the vulnerabilities of interconnected infrastructure," *Journal of Urban Technology*, 9(1), 109-123. See Richard G. Little (2010), "Managing the risk of cascading failure in complex urban infrastructures", Stephen Graham, ed. *Disrupted Cities: When Infrastructure Fails*. New York: Routledge.

35 Charles Perrow (1999), *Normal Accidents: Living With High-Risk Technologies*, Princeton, New Jersey: Princeton University Press.

36 Richard G. Little (2002), Controlling cascading failure: Understanding the vulnerabilities of interconnected infrastructure," *Journal of Urban Technology*, 9(1), 109-123. pp. 113.

37 John Leslie, ' Powerless, *Wired*, April, 1999, 119-183.

38 Richard G. Little (2002), Controlling cascading failure: Understanding the vulnerabilities of interconnected infrastructure," *Journal of Urban Technology*, 9(1), 109-123.pp.112.

39 See, for example, Lawrence Vale and Thomas Campanella, (Editors)(2005) *The Resilient City: How Modern Cities Recover From Disaster*, Oxford: Oxford University Press and In Jane Schneider and Ida Susser, (eds.) *Wounded Cities: Destruction and Reconstruction in a Globalized World* . London : Berg. 25-46.

40 Colin McFarlane (2010), "Infrastructure, interruption, and inequality: Urban life in the Global South", Stephen Graham ed. *Disrupted Cities: When Infrastructure Fails*. New York: Routledge.

41 See, for example, Claire Sponster (1992), "Beyond the ruins : The geopolitics of urban decay and cybernetic play", *Science Fiction Studies*, 20(2), 2251-265.

42 See, for example, Max Page, (2008), *The City's End, New haven*, Yale, and Stephen Graham (Ed.)(2004), *Cities, War and Terrorism*, Oxford: Blackwell. NY book

43 See Jared Diamond (2006), *Collapse: How Societies Choose to Fail or Survive*, London: Penguin.

44 See, for example, Roy Woodbridge (2004), *The Next World War: Tribes, Cities, Nations, and Ecological Decline*, Toronto: University of Toronto Press.

45 William Mitchell and Anthony Townsend (2005) 'Cyborg Agonistes: Disaster and Reconstruction in the Digital Era'. In Lawrence Vale and Thomas Campanella (eds) *The Resilient City: How Modern Cities Recover from Disaster*. Oxford: Oxford University Press. pp.313–24

46 See Ellen Ullman (1999) "The myth of order," *Wired*, 7(4), at http://www.wired.com/wired/archive/7.04/y2k.html

47 Susan Leigh Star (1999), "The ethnography of infrastructure", *American Behavioral Scientist*, 43(3), 377-391, pp. 385.

48 See Stephen Graham and Mike Crang (2008), "Sentient cities: Ambient intelligence and the politics of urban space", *Information, Communications and Society*,

10(6) 789-817.

49 Martin Pawley (1997), *Terminal Architecture, London*: Reaktion Books. pp. 162

50 Willaim Joy (2000), "Why the future doesn't need us", *Wired*, April, 238-260, pp. 238.

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discussion of the way fears of 'cyber-terror' attacks are manipulated and exaggerated, see François Debrix (2008), *Tabloid Terror: War, Culture and Geopolitics*, New York: Routledge, 2008, chapter 1.

52 Stephen Graham and Simon Marvin(1994), "Telematics and the convergence of urban infrastructure: Implications for contemporary cities", *Town Planning Review*, 65 (3), 227-242.

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54 Ellen Ullman (1999), "The myth of order", *Wired*, April, 126-187., pp. 126.

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Report for the Chicago Metropolitan Region. Chicago: WBMC.

56 Gene Rochlin (1997), Trappe uption by design: Urban infrastructure and political violence", Stephen Graham ed. *Disrupted Cities: When Infrastructure Fails*. New York: Routledge.

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59 See Kazys Varnelis (2004), "The Centripetal City: Telecommunications, the Internet, and the Shaping of the Modern Urban Environment," *Cabinet Magazine*, 17, Spring, available at http://varnelis.net/articles/centripetal_city.

60 See Steve Redhead (2006), "The Art of the Accident: Paul Virilio and accelerated modernity," *Fast Capitalism*, 2 (1). At http://www.uta.edu/huma/agger/fastcapitalism/2_1/redhead.htm and Paul Virilio (2003), Unknown Quantity, London: Thames and Hudson.

61 See Jacques Leslie(1999), "Powerless", *Wired*, April, 119-183.

62 Jacques Leslie (1999), "Powerless," *Wired* 7(4), available at http://www.wired.com/wired/archive/7.04/blackout_pr.html

63 For full lyrics of the song "Neighborhood #3 (Power Out)", from the album Funeral, see http://www.metrolyrics.com/neighborhood-3-power-out-lyrics-arcade-fire.html

64 Stephen Graham (2010), "Disruption by design: Urban infrastructure and political violence", Stephen Graham ed. *Disrupted Cities: When Infrastructure Fails*. New York: Routledge.

65 See See Mike Davis (2007) *Buda's Wagon: A Brief History of the Car Bomb*, London: Verso.

66 See John Robb's influential global guerillas blog at http://globalguerrillas.typepad.com/ as well as his 2007 book *Brave New War: The Next Stage of Terrorism and the End of Globalization*, New York: Wiley.

67 See Stephen Graham (2009), *Cities Under Siege: The New Military Urbanism*, London: Verso.

68 See Vyjayanthi Rao , (2007), "How to Read a Bomb: Scenes from Bombay's Black Friday," *Public Culture*, 19(3), 567-592.

69 See Vyjayanthi Rao , (2007), "How to Read a Bomb: Scenes from Bombay's Black Friday," *Public Culture*, 19(3), 567-592. pp.572.