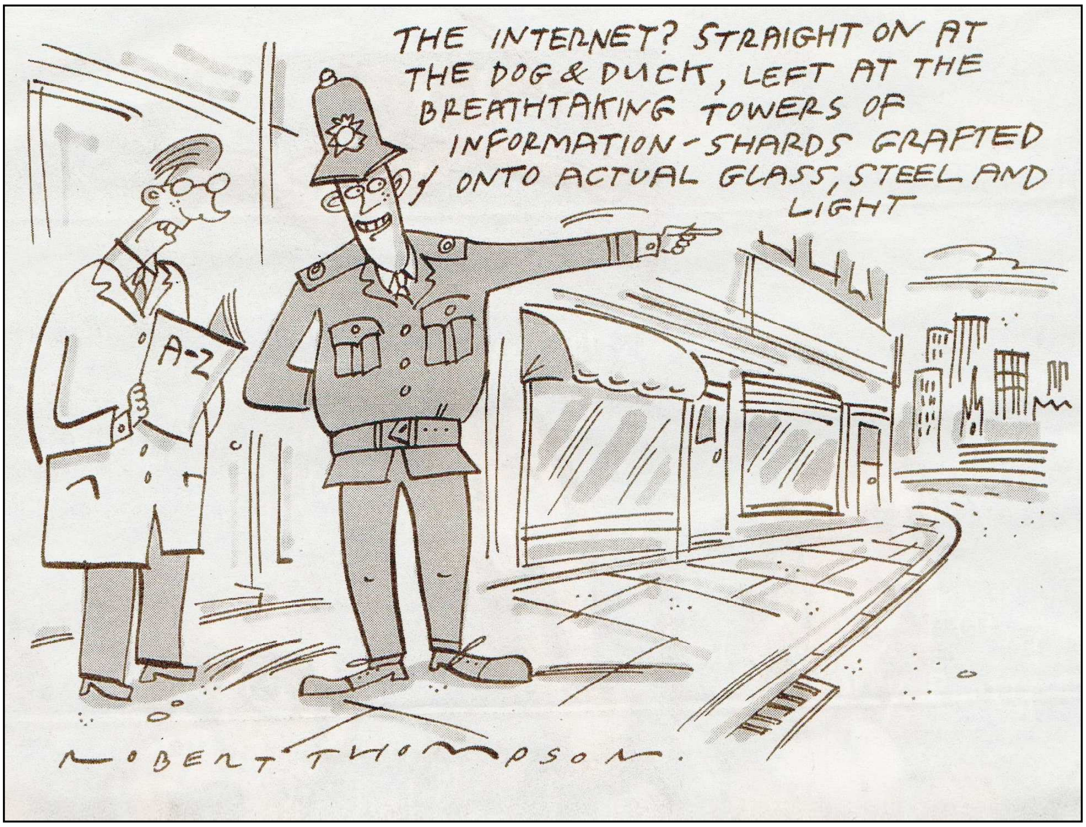
Chapter Four

Imagining Internet Infrastructures: Spatial Metaphors and Scientific Inscription



4.1 Introduction: explaining what the Internet looks like[1]

There are several kinds of spatial imaginings that have been exploited to establish the Internet as something ‘real’ and to prove the ‘matter of fact’ existence of its infrastructure to different audiences by explaining ‘what the Internet looks like’. These are significant in how they work to overcome the problems of the invisibility and intangibility of the Internet as an infrastructure. How do you explain the Internet when you cannot see and touch it?

[1] (Source of cartoon: Robert Thompson, *The Guardian*, Online section, 29 March 2001, page 4.)

Imaginings of infrastructures were particularly prevalent in the first half of the 1990s, when the Internet emerged rapidly as a new social-technical phenomenon in advanced capitalist countries and needed to be 'explained' in accessible ways to the majority of people who had not experienced it for themselves. This was especially because the Internet as a entity has no singular, manifest representation. Unlike transportation and telecommunications there is no one material device that unambiguously signifies the Internet. Further complicating the matter, the Internet is often typified as a place rather than an object or media (as illustrated by the cartoon above). Early in the Internets' entry into the public consciousness, it had an imaginal malleability as people had no fixed conception of what it was, how it worked, whether it was valuable to them, or whether they could trust it. As a result the influence of particular spatial metaphors, geographical representations and scientific inscriptions in shaping perceptions was strong.

In this chapter, I consider how different types of spatial imaginary of the Internet have been deployed to overcome infrastructural invisibility and work to forge the disparate and fragmented networks into a unitary entity that could be trusted. This imaginary is examined in two broad categories. Firstly, for general audiences, the range of verbal and visual metaphors that were deployed is considered. While such metaphors can be dismissed as mundane, Vujakovic (1998, 158, added emphasis) points to their social power, noting the "common acceptance of a *particular* metaphors (propagated or reinforced by the media) may lead to a limited view of an issue and the closure of constructive alternatives."; and I think this is apposite to particular kinds of spatial metaphor than have been applied to the Internet. Secondly, for the research-engineering audiences, I examine the role of scientific inscriptions in constructing facts about the Internet's structure and operations. To begin, I unpack the nature of the Internet's invisibility.

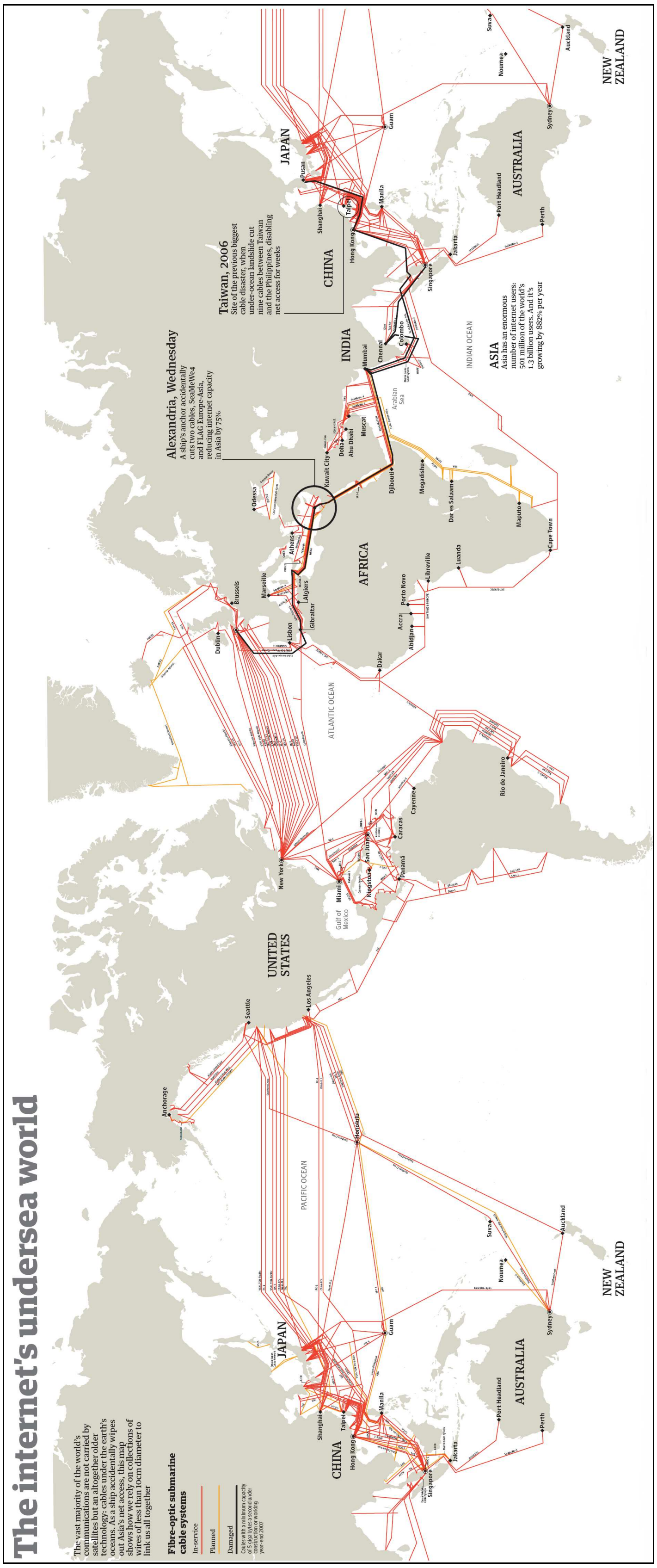


Figure 4.1: Cartography denotation necessary to make invisible Internet infrastructure visible for readers of a newspaper story about cable cuts and their impact on the Internet. (Source: *The Guardian* 2008, 22-23.)

4.2 Internet 'invisibility'

There are several dimensions to the invisibility of the Internet: firstly, the unseen, ignored and hidden material nature of the wires and computers; secondly, the transparency of network activities and lack of tangible experience for users; thirdly, issues of rapid social naturalisation and the 'taken-for-granted' banality of technical systems; and lastly, the conscious occlusion through institutional normalisation within the wider neo-liberal political economy. I outline each of these dimensions in turn.

Figure 4.2: A road junction outside the One Wiltshire building, an internet hub in downtown Los Angeles, that is heavily marked with 'utility graffiti' signifying the location of underground cable routes leading into the building. Such markings are a kind of 1-to-1 map of the complexity of what lies unseen just beneath the surface. (Source: Varnelis 2002, no pagination.)

4.2.1 Materially unseen

The first dimension of invisibility is that network hardware for data transmission is largely unseen in the everyday urban landscape, especially in comparison to the physical presence of other communications systems (roads, railways, airports, postal mail and the like). The Internet as infrastructure is very briefly visible as fibre-optic cables are rolled out in the streets, but is quickly subsumed beneath roads and pavements. The 'wires' of the Internet through cities and across countries are almost universally routed subterraneously (Figure 4.2), and between continents lie along the ocean floors (Figure 4.1). The Internet is also dematerialising further as the actual wires are rapidly being replaced by wireless transmission that invisibly carries data unfelt through buildings and bodies.

The infrastructure at the ends of the wires, the network switches and computer servers, have a small physical footprint, and are usually hidden away in unmarked service spaces and anonymous secure, windowless buildings. Other supporting hardware elements vital to ongoing Internet production, such as air-conditioning and backup power supplies, are separated from people by being located in basements or on roof tops. For all the hype surrounding the Internet and the billions in capital investment, it has remarkably little visual impact on the urban landscape. Other tangible or noxious externalities of the Internet are minimal because it does not produce noise or other noxious pollution[2].

In addition to being out-of-sight and relegated to non-human serving spaces, other elements of the network hardware that are manifestly visible in the landscape are effectively made invisible because they are mundane ('invisibility by being ignored') or because they are not associated with the operation of the Internet ('invisibility by misconception'). For example, the wiring cabinets[3] aggregating customer telephone lines, which are now vital to broadband Internet distribution, are a common sight on pavements but are an anonymous and unmarked part of street furniture.

The material invisibility of the Internet is being actively encouraged in some quarters as part of more recent cybersecurity initiatives in which critical and

[2] Moreover, the negative externalities of manufacturing I.T. hardware are concentrated and largely remote from the affluent places of Internet consumption as a consequence of global supply chains. The disposal of computing equipment is also highly polluting, but again is hidden from the view of most people (see BAN 2002).

[3] In the UK, British Telecom has some 90,000 such 'primary cross-connection point' cabinets. They are usually painted an unassuming green colour, see <www.btplc.com/Thegroup/Networkstory>.

vulnerable elements of the infrastructure are thought to be best protected by being kept anonymous and secret (Gorman 2004). Such 'security through obscurity', leaving important places deliberately undocumented, has a long tradition, including in the production 'rules' of state cartography (Board 1991).

It is not only the ongoing hardware production of the Internet that is unseen; at the infrastructural level what is carried by data networks is entirely invisible in a phenomenological sense. Unlike cars on the road, trains on the track, or letters in the mail, the packets of data flowing through the Internet do not exist at the analogue scales of human senses. Bits (binary digits) of data are composed of discrete states of energy propagated at various wavelengths (light, radio, microwave, and so on) and have "no colour, size, or weight, and can travel at the speed of light ... [they are] a state of being, on or off, true or false" (Negroponte 1995, 14). While the bits are easily interpreted by software, they must be rendered through interfaces for people to comprehend. It is, therefore, not possible to observe the operation of the Internet unmediated. This is problematic, in particular, for companies selling Internet network services who need to make their infrastructure into something potential customers can trust. As a consequence they have to construct a connotation of infrastructure in a way people expect it to look using a range of visual metaphors, of which world maps showing the geography of routes is a primary vehicle (see case study analysis in chapter six).

4.2.2 Transparent in use

At a higher level than traffic flows, the Internet is also 'invisible-in-use' because data networks are intangible in terms of consumer experience. In conventional transportation infrastructures, passengers and drivers have innate and phenomenological knowledge of the networks through the journey experience. They comprehend the physical nature of the infrastructure by kinaesthetic interaction with cars, trains and planes - the direct 'seat of the pants' feel of the network. Telecommunications, in their inherent virtuality, are completely lacking such experiential comprehension. The *lack* of human touch defines *tele*-communications.

No knowledge of the Internet as infrastructure is gained from browsing the Web for example, it gives off no physical sensations. The majority of people on the Internet are never aware of the vast infrastructure they are utilising because it is consciously hidden from them, behind software interfaces. (Again, as noted above this is problematic for companies in the actual business of Internet infrastructure, who commonly use deploy market maps to give potential customers a visible sense of how extensive and powerful their network is; see discussion in chapter six.) Such infrastructural concealment is seen as a good thing by the industry - it is described as the 'network being transparent to the user'[4]. A key part of the power of the Internet has been its ability to provide seamless, end-to-end, communications services so that users do not have to worry about the structure of the underlying networks and the complex ways in which traffic is transmitted. Indeed, one might argue that the Internet could only become such a successful and widely used media of communication once its arcane technicalities were rendered sufficiently invisible to users, through developments such as the Web browser.

Moreover, a large cadre of computer science researchers, network engineers and industrial designers are striving to greatly increase the degree to which computers and the Internet fade into the fabric of everyday activities. Working under the banner of pervasive computing they are striving for systems that are "so imbedded, so fitting, so natural, that we use it without even thinking it" (Weiser 1991, 94). Scholars in this area argue that current ICT use, is in fact, not transparent enough, requiring too much cognitive effort to achieve the desired results (cf. Norman 1998). The promise of nomadic, always-on access through wireless networks will, advocates argue, make the Internet as invisible and ubiquitous as air.

4.2.3 Disappearance by social naturalisation

> The conduct of daily life surely demands a tactical lack of curiosity! But that lack of curiosity carries costs and overhead expenses as well as benefits. (Bijker and Law 1992, 2.)

[4] Transparency in this sense means that infrastructure "does not have to be reinvented each time or assembled for each task, but invisibly supports those tasks" (Star and Bowker 2002, 152); the archetypal of this, in developed countries, is domestic electricity supply.

As well as being materially unseen and intangible in use, probably the most effective way that Internet infrastructure is made invisible is through its subtle disappearance from people's consciousness. As is well noted by scholars interested in the social shaping of technology, once an infrastructure becomes commonplace, people do not much care for how it is produced, for they exhibit "a tactical lack of curiosity" according to Bijker and Law (1992, 2). It becomes a 'taken-for-granted' feature, fading into the background of everyday life. Infrastructure is something you notice more by its absence than its presence.

From being a novelty in the mid 1990s, the Internet has quickly become culturally naturalised, with email addresses and websites part of common vernacular. Concerns about 'digital divides' notwithstanding, many businesses and government agencies now presume that *all* people have Internet service and are sufficiently conversant with it to obtain information and perform transactions online. (Arguably, connotations of ubiquity and universality is, in part, constructed through the particular kinds of worldwide mapping of Internet penetration statistics by some organisations; see analysis in chapter five.) Such everyday social-cultural familiarity is clearly bound-up with transparency in use. As infrastructures become more transparent (and more reliable, affordable and universally available), so they morph in character from desired conveniences to a necessary and seemingly naturally-given part of the lived environment.

This is often conceived of as a process of 'black-boxing' in which infrastructures are "treated by users as unproblematic and 'closed' sociotechnical artefacts that [can] be relied on without much thought" (Graham 2000, 184). One might argue that the best infrastructures are those that are so 'black-boxed' they are not noticed at all; they are also the most powerful, able to affect deeper or wider ranging reorganisations of socio-spatial relationships without scrutiny or resistance (again, electrical power supplies serves as an archetypal case). Indeed, one way of assessing the extent to which technologies, including the Internet, have moved 'backstage' and been 'black-boxed' is by measuring the degree of dependency people are willing to place on them. Such dependency is exposed in the disruption caused when infrastructures temporarily fail, for whatever reason (e.g., the large degree of inconvenience to everyday activities caused by power cuts).

4.2.4 Occlusion through institutional normalisation

Large infrastructures are produced by institutions and their ongoing production requires huge amounts of mundane, easily-overlooked organisational work (construction plans and maintenance schedules, operational staffing arrangements, business processes, financial management, technical standards, and so on). Internet networks are as much an outcome of the institutional practices as they are the result of physical wires.

Yet this kind of institutional work tends to become normalised, bureaucratic and anonymous. Infrastructure invisibility is manufactured institutionally then, by obscure regulatory structures that make it hard to discern sources of decision-making power, by complex pricing models that hide real costs and deliberately opaque ownership structures which make it unclear who controls companies. Ultimately, the complex institutional power structures underlying the supply of the Internet into people's homes contributes to making the infrastructure invisible. (Many of the companies examined in chapter six who run large parts of the Internet networks are obscure because they do not sell services to end-customers.)

Institutional working is itself is bound within the prevailing political-economic structures. Through much of the second half of the twentieth century utility infrastructures (electricity, water, telephone, transportation networks) were operated within monopolistic state ownership structures. Generally, these had clearly established remits and strong public identities for the infrastructure they managed (even if they were not well liked, e.g. British Rail). Since the 1980s, this institutional unity in provision has been deliberately broken apart - so called 'unbundling' or 'deregulation'- through processes of marketisation, privatisation and regulatory liberalisation. Such fragmentation means there is a lack of a constituted, agreed institutional identity for utility providers. In the case of the Internet, whose job is it to keep the infrastructure running? Graham and Marvin (2001) characterise this shift as a 'splintering urbanism', arguing that it is giving rise to "'premium networked spaces' that are customised precisely to the needs of powerful users and spaces, whilst bypassing less powerful users and spaces" (Graham 2000, 185). Internet provision is a prime example of such premium networked spaces, with its pricing, quotas and differential bandwidths.

Another significant element in this invisibility of institutions owning and running the infrastructures of the Internet is the obscurity of the workers who do this work. The skilled labour force required to build and operate the Internet is largely invisible, and when acknowledged they are often denigrated as just 'technicians' in comparison to other more attractive occupations associated with the creative industries of new media. This aspect of the 'hidden' workforce in information infrastructures is not new, as Downey (2001) shows in relation to the telegraph era.

4.2.5 Implications of infrastructure invisibility

> Infrastructure can be dullest of all topics. It can also be the most important. Infrastructure defines the basis of society; it is the underlying foundation of the facilities, services and standards upon which everything else builds. (Norman 1998, 55.)

The above dimensions of infrastructural invisibility have consequences, both pragmatic and political, for understanding the nature of the Internet. Firstly, from a practical point of view it means infrastructures tend to be little studied within social sciences. They are easily overlooked by scholars and deemed to be insignificant elements in wider analysis or are seen as 'mere' technicalities with little scope for socially informed research. Hillis (1998, 544), for example, argues that infrastructure invisibility across several registers has been the key reason why telecommunications have received scant attention by the human geography discipline[5]: "[f]or a discipline firmly rooted in an empirical and visually dependent understanding of the facts, too often, if it can't be seen 'it's not geography'."

[5] There have been some noteworthy academic attempts to understand the physical construction and geographical embeddedness of network infrastructures, in spite of the varying dimensions of invisibility, e.g., Board *et al.* (1970); Gottmann (1961);Graham and Marvin (1996, 2001); Hugill (1999); Mitchell (1995); Townsend (2003).

The failure of much of the social sciences to take a serious interest in infrastructures is compounded by the lack of published and comprehensible documentation of them. This is particularly the case with the Internet, with available data being partial, spatially incomplete, fragmented organisationally and often held to be commercially confidential (cf. Grubesic and Murray 2005; Jordan 2001). In relation to network maps for commercial promotion, chapter six discusses the impacts of partial and missing traffic data for misunderstanding the nature of Internet infrastructure growth. Furthermore, as an infrastructural entity, the Internet is essentially made intractable because of its undocumented presence in standard government statistics and on general reference mapping. For example, the terrestrial fibre-optic cable systems which sustain the Internet are not present as a layer in published topographic map databases (e.g., in Ordnance Survey's MasterMap product in the UK)[6]. Being unmapped in this way is, in many respects, tantamount to being invisible for analysis[7].

From a political perspective, critical studies of infrastructures are made harder because of the ways in which institutions deliberately keep them as 'black-boxed' systems, to keep people from easily observing (and questioning) their design and operational logics. Invisibility of the infrastructure provides an effective cloak under which dubious or iniquitous practices can be safely carried out by institutions owning and operating them. The lack of critical studies of Internet infrastructure mean intensifying bias in the ongoing production of networks that widen social difference and inequalities across space are unchallenged. It also precludes informed discussion of ways to build and operate infrastructure differently.

[6] Utility engineering departments do have facilities maps showing pipe and cable routes but these are typically not available to the public and in many cases are incomplete and of varying degrees of accuracy.

[7] As noted in chapter six, this limit has meant some academic and policy analysts have been overly reliant on the vagaries of network marketing maps produced for commercial promotion as their source of primary data on the extent of Internet infrastructures.

4.3 The role of verbal and visual metaphors

The generation of popular explanations of the Internet involves the classification and conceptualisation of an unfamiliar phenomenon (i.e., extensive but invisible infrastructures which support novel forms of interactive media) into a set of well-known categories. This process can be effectively accomplished using metaphors, which constitute an important and pervasive form of figurative speech, fundamental to human language and which structure cognitive experience (Lakoff and Johnson 1980). Here I consider verbal metaphors first, followed by a discussion of common visual spatial metaphors, used to represent, imagine and 'explain' Internet infrastructures, thus, at least in part, overcoming its multidimensional invisibility.

4.3.1 Linguistic spatial metaphors

> The expanding lexicon of the Internet ... is not only replete with, but actually *constituted* by, the use of geographical metaphors. (Graham 1998, 166.)

Metaphors are linguistic tools that facilitate understanding of a unfamiliar subject by bringing another, more familiar, concept in conjunction with it. According to Lakoff and Johnson (1980), metaphorical schemas ground the conceptual structures of a novel domain (target) to a known, physical one (source). The metaphor works as a transfer of concepts from source to target, in which the transferred, familiar concepts interact with the new unfamiliar context, highlighting its nature and producing effects in terms of potential shifts in meaning. As Sawhney (1996, 292) argues, metaphors "create a 'stereoscopic vision' which allows for simultaneous viewing of an idea from two or more points of view." The unfamiliar motorcar when it first appeared in 1880s, for example, was explained as a horseless carriage, thereby grounding the unknown by proposing that it can be seen as being like the common horse and cart. The insight generated by a well-chosen metaphor comes from the point of *interaction* between familiar concepts and unfamiliar contexts. Metaphors create an image that is usually far from the actuality of the subject; for example, the reality of Internet access via dial-up modems in the early 1990s was at odds with 'highway' metaphors, and yet effective metaphors can pervade the popular imagination through reproduction in the media, being endlessly circulated and refined, so that they become a natural and invisible part of language and thought. Furthermore, metaphors become part of defining the cultural contexts of communication and play a major role in the legitimisation of certain social values and in the denial of others. The choice of metaphors can reveal as much about the speaker as what they are actually talking about.

Metaphors can work as self-fulfilling prophecies in which the phenomena so described gets progressively remade to fit its dominant metaphor. “The metaphors that are used to study an emerging technology”, Sawhney (1996, 293) notes, “usually end up influencing the shape it takes.” This can be seen for example, in the legal frameworks enacted to regulate the Internet, which are based, in significant part, on metaphors from a transportation context relating to physical movement of goods (see below). The conceptual framework from which particular metaphors are drawn is important because they impart certain properties and favour certain implications. Contrast, for example, conceptualising Internet infrastructure as media with the associated range of broadcasting metaphors, instead of the more utilitarian transportation one.

Metaphors must, therefore, be read as political because their linguistic power can effect social change in terms of the way a new phenomenon is perceived, in the service of certain interests. Adams (1997, 156) calls this effect a “cognitive jolt” that makes people stop and think in a new way, and it can be used to destabilise accepted norms. Metaphors can also be deployed persuasively to contain and normalise threats to powerful interests from new phenomena, such as a disruptive technology like the Internet. Metaphors, then, are a contested domain of political action because they affect how people talk about the world which, in turn, affects the way they relate to it.

In circumstances where there is “high uncertainty, missing data, unclear goals and poorly understood parameters” (Klein 1987 quoted in Sawhney 1996, 292), the most productive means of explanation of a new technology can often be through metaphors and analogies. This was the case with the Internet in the early 1990s when it was in its social ‘discovery’ phase of development in Western consumer societies. It is important to think about the politics lying behind the work metaphors were being employed at this time.

Metaphors from many different conceptual frameworks have been actively deployed to characterise the Internet. For example, the Internet as a living organism (such as a tree, a body or brain); the Internet as a city (with streets, towns halls and suburbs); the Internet as a marketplace (with online shops, virtual money, and e-trading); the Internet as written text (with its letter metaphors of web pages email, addresses and signature files). The map and mapping practices related to navigation were themselves also a prime source of metaphors for explaining the Internet. Metaphors from multiple domains were employed simultaneously, often in competition to dominate a discourse. The result was a confusing ecosystem of metaphors (see Palmquist 1996), being combined together and clashing against each other in confusing, sometimes creative ways (e.g., the notion of information presented as a 'Web page' combines the organic framework with a book-bound analogy).

Each of these metaphorical domains highlights certain aspects of the Internet, downplays some and hides others. Some clearly owe allegiance to U.S.-centric domination of the Internet's infrastructure development and media-driven popularisation; for example, the large number of 'frontier' related metaphors. This metaphorical domain is seen as foundational to many American cultural myths, pregnant as it is with complex connotations of social autonomy and political conquest (cf. Adams 1997; Yen 2002). As example in 1990, Mitch Kapor and John Perry Barlow, co-founders of the Electronic Frontier Foundation, a U.S. interest group that works for Internet free speech, wrote: "In its present condition, cyberspace is a frontier region, populated by the few hardy technologists who can tolerate the austerity of its savage computer interfaces, incompatible communications protocols, proprietary barricades, cultural and legal ambiguities, and general lack of useful maps...". The nature of social and spatial relations implied by this kind invocation of the frontier (zone beyond legal control, self-reliance, boundless opportunities for risk takers and so on) are seen as ideals, by some, for the kinds of new technological opportunities the Internet promised in the early 1990s. It also "supports an often-made claim that cyberspace is different from real space, and that government should generally refrain from regulating the Internet" (Yen 2002, 3). Yet the frontier is as much a romantised myth of progress that consciously elides the very detrimental experiences for many living on the frontier, with its profiteering, rough justice, racial prejudice and casual violence.

The notion of a frontier also has direct and significant connections to cartography. The act of mapping frontiers begins to render these uncertain spaces as definite lines (a classic example from history being the Tordesillas line that divided the New World for Portuguese and Spanish conquest). Inscribing the frontier begins to formalise its existence and representations necessarily fix its position. Mapping as an act of enclosure transforms frontiers into known borders, able to separate inside from outside, to determine who belongs and those who do not. In some senses all that world maps are semiotically is just frontier signs, but quite problematic for all their connotations of solidity and reality; as Black (2000, 218) observes: "[c]learly contrasting primary colours and firmly delineated frontier lines do not describe adequately or accurately problems of multiple allegiances, overlapping jurisdictions and complex sovereignty…". Also, on the ground, at the frontier line there is often no physical trace to be seen yet the map has real force in construction of territory.

Besides the 'frontier' metaphors, another noteworthy collection of spatial metaphors applied to the Internet uses familiar architectural places (e.g., library, shops, farms, etc). Others characterise the Internet in terms of container-like space (e.g., rooms, sites, malls, communities, cities, spheres, worlds and, of course, cyberspace itself). The metaphors in the container-spaces framework are somewhat more abstract than others, but have nevertheless proved to be particularly potent in defining the Internet as a territorial system, with discrete locations and a bounded sense of inside / outside.

Metaphors built around architectural places are also very common, subtly suffusing throughout Internet imaginary. Familiar domestic environments of the home and work have been metaphorically co-opted to give concrete cognitive forms to invisible Internet infrastructures and their intangible media (homepages, digital libraries, virtual classrooms, server farms and so on). There are almost endless combinations of them and they have been nested together by function or linked thematically. Internet evangelist, Howard Rheingold, who was the lead propagator of the 'virtual communities' movement (itself a potent metaphor), gave a vivid description in the early 1990s of the social forms of part of the Internet, by mixing together multiple architectural-place metaphors:

> "… a place for conversation or publication, like a giant coffee-house with a thousand rooms; it is also a world-wide digital version of the Speaker's Corner in London's Hyde Park, an unedited collection of letters to the editor, a floating flea market, a huge vanity publisher, and a collection of every odd special-interest group in the world." (Rheingold 1993, 130.)

The coffee house is particularly interesting as a spatial metaphor with assorted meanings. It is applied to describe the social nature of cyberspace, imagining the Internet as an ideal venue for particular kinds of discourse and discussion. The coffee house has many connotations in European intellectual thought and public life, being regarded in the eighteenth century as one of the wellsprings of the Enlightenment, a place from which new ideas in science and politics emerged and could be openly debated. It was a place to meet like minded thinkers, share scholarly gossip, read political pamphlets and hear about new scientific discoveries from the men themselves. The coffee house was a public place where you could be seen to be in serious conversations, yet it also offering room for private dialogue (but with the risks of being overheard). Besides discourse, it was also a space for where business could be conducted, and contributed to the raise to form new forms of capitalism and entrepreneurship which were distinct from traditional sources of wealth and power – the church, the king and landed aristocracy.

Yet for all the progressive idealism bound-up in the notion of coffee house culture – which obviously made it an apposite metaphor to apply to mould the, then, formless Internet for 'cyber-utopianists' like Rheingold – it implies certain kinds of acceptable context and social relations. The most obvious being around class and gender. The coffee house was not welcoming to all, it was only a convivial space only for certain class of men engaging in serious talk. It was distinct from the ribald alcoholic atmosphere of the (working class) public house or the trivialities of chatter of the (feminine) tea shop. While the coffee house metaphor connotes openness, it has distinct social and material boundaries that create categories of insiders and outsiders. It was also a space of labour relations with people serving and people being served. It was only democratic for those on the one side of the counter and with the level of income to be able to afford to indulge in the new taste for coffee, an expensive luxury, indicative of sophistication and certain social status. Even today coffee drinking implies a different set of behaviours and identities to, say, lager drinking, as does the use of the Internet which for some is about edification but it also offers prurient recreation for others.

A thorough application of architectural imaginary to metaphorically 'explain' the nature of Internet infrastructures is given in the writings of William Mitchell (professor of Architecture and Media Arts at MIT). His influential book *City of Bits* (1995) published in the midst of the Internet 'take-off' was one of the first to analyse the significance of emerging Internet infrastructures for the built environment. Mitchell's (1995, 107) thesis claimed that "[c]omputer networks [will] become as fundamental to urban life as street systems. Memory and screen space become valuable, sought-after sorts of real estate." The highpoint of such urban-centred metaphors came in the late 1990s with popularity of 'virtual cities', some of which were 'grounded' with real-world equivalents while others were purely imaginary (Aurigi 2005). This has now been large usurped by the rise of placeless social networking focused around individual ego rather than communal life, as seen in the popularity of services such as Facebook and Myspace.

The widespread application of such architectural and city metaphors clearly has utility in making foreign media-based environments feel familiar, yet they are not innocent (mere convenient linguistic devices). The over-reliance on such metaphors, Graham (1998, 167) argues, "actually serves to obfuscate the complex relations between new communications and information technologies and space, place and society". How far is a digital library really like a 'real' library, for example, in relation to issues of access, usability and privacy? More subtly, these metaphors bring with them the oppressive potential of manmade environments, with their established power geometries of ownership and rules of access and exclusion. As Adams (1997, 167) notes: "We might worry that the primary function of virtual architecture would be a kind of containment, in which there was no longer an 'outside' and populations were everywhere contained and subjugated."

Beside place-based 'nouns' to describe the forms of the Internet, the action of using the network is frequently described in terms of spatial 'verbs' of physical movement and embodied travel. The lexicon of such metaphors includes: surfing, navigating, exploring, homesteading. (They are quite different from ways of describing other media use, e.g., book reading and television viewing.) These metaphors of movement also encompass spatial notions of following paths, getting lost, hitting dead-ends and the discovery of new places. Online activity draws from "every imaginable environmental situation, suggesting not simply a virtual place but an entire virtual geography" (Adams 1997, 155).

Closely allied with the spatial metaphors of movement used to explain participation in computer networks, are the transportation-oriented metaphors of pipes, routes, rails and especially roads used to analogise data flows. Transportation metaphors conceptualise the wider effects of the Internet infrastructure not as a virtual territory but as a means to *traverse* real territory, typically at great speed. (The nature of maps of transportation and travel contribute to this, with their highlighting of network above topography, see discussion in chapter six in relation to marketing maps.) The implication of this metaphorical approach to infrastructure, is that Internet's role is primarily about improving efficiency in shipping data, which is treated as a bulk commodity to be rapidly moved from point-to-point. The most common of these traversal metaphors is, of course, the 'information superhighway', which coupled the nascent Internet directly with ingrained American notions of automobility[8]. At the end of 1993 the highway metaphor was invoked directly as a political ideal of

[8] Of course mapping played a part in the rise of car culture, representing the landscape in ways amenable to drivers as the analysis by Akerman (1993, 2002) has shown; see chapter six for discussion.

what the Internet should become, as then U.S. Vice President Al Gore asserted: "Today, commerce rolls not just on asphalt highways but along information highways" (Gore 1993, 3).

Coming from a strongly techno-utopianist perspective, Gore championed a vision of universal public access to the Internet, explaining that a helpful way to think about such an infrastructure was as "a network of highways -- much like the Interstates begun in the '50s. Highways carrying information rather than people or goods" (Gore 1993, 5). Although these new 'information highways' would be built by private capital, the clear analogy with road infrastructures of the past implied that the government had a positive social remit to oversee development of the Internet, to ensure equality of provision and that all places are connected. Furthermore, the government had a duty to set the framework of the market (equivalent to the highway code) to ensure "there will be a 'public right of way' on the information highway" (Gore 1993, 10), rather than a private network, such as cable television.

The 'information superhighway' metaphor proved to be a potent choice and it quickly grew to be one of the dominant metaphors applied to 'explain' the nature of Internet infrastructure in the mid 1990s, endlessly promulgated in media coverage and in government reports[9]. While the socially progressive goals of Gore's vision were clearly articulated, the choice of the highway metaphor itself imposed distinctly instrumental notions on the future shape of network infrastructure: it would essentially be a flat hierarchy, accessible only at certain junctions, with people as passive drivers only able to go in certain directions[10]. Highways are, after all, built for efficiency and this has been paralleled in the Internet's subsequent development. As such the 'superhighway' had a "strong aura of linearity" (Sawhney 1996, 304) and can be read as an extension of the individualistic economic model over the communitarian one that dominated much of the Internet's nascent development in the late 1980s (emphasised, for

[9] The British Library catalogue lists 71 books which contain the phrase 'information superhighway' in their titles. Thirty-four of these books were published in 1995.

[10] Interestingly, this passivity was itself subverted metaphorically when commentators argued users should be allowed the freedom to 'go off road'.

example, in Rheingold's deployment of the 'virtual community' metaphor). Sawhney (1996, 307) argues that at its heart, the highway metaphor is reductionist: "[t]he ritual or the communal aspect of human communication is almost totally neglected" in favour of maximising the transfer of information.

The subsequent demise of the 'highway' as a meaningful explanation of the Internet shows how metaphors are contingent, partial and contestable[11]. By the end of the 1990s the 'superhighway' metaphor had become a thoroughly clichéd moniker and was being used most often in a derisory sense. It was also deployed counter-factually as commentators pointed up the reality of network 'dirt tracks' outside the developed core in discussion of global Internet diffusion and digital divides (The dichotomy of diffusion versus divides is considered in depth in chapter five in relation to the role played by global scale mapping of statistics on Internet globalisation.) As Sawhney (1996, 300) notes: "The initial metaphors basically function as provisional hypotheses which can be held only as long as the facts permit". As more people experienced the Internet first hand, and used it productively for everyday tasks, the appeal of the 'highway' metaphor waned, to be replaced by more organic metaphors of Web environments and social networks.

4.3.2 Visual metaphors for Internet infrastructure

Metaphors are not just verbal constructs, they can equally be fabricated through visual imagery. Given that much of modern experience is constructed 'second-hand' through visual media and marketing imagery in print and on screen, in many respects visual metaphors enjoy even greater political significance in defining 'what the Internet is like' than their verbal counterparts. This is well recognised by designers of advertising who strive to invent new metaphors and them taken up into circuits of cultural communication (see De Cock *et al.* 2001; Goldman *et al.* 2003).

[11] Of the 71 books with 'information superhighway' in their title catalogued by the British Library, only four have been published since 2000.

As noted in the introduction, the Internet lacks a single, obvious, physical representation that people experience for themselves, which could be moulded into its defining visual metaphor[12]. Uncertainty on the 'natural' visual shorthand for the Internet for a general audience is apparent; for example, in newspaper coverage in the 1990s that juxtaposed quite different image types. A significant proportion of these visual metaphors called upon explicitly spatial constructs to make the Internet appear as a tangible entity or to place it within familiar geographical contexts. Here, I audit and interpret the significant types of visual spatial metaphor that imagined the Internet infrastructure in four categories: (i) as a network of wires, (ii) as flows around the globe, (iii) as machines for moving objects and, lastly, (iv) as abstract clouds and organisms.

4.3.2.1 Wiring visions

The commonest visual analogy to explain the Internet as a spatially extensive infrastructure is a physical network of wires. Very often this imagery uses arc-node route lines plotted on top of a geographical base map such as the illustration of undersea cables shown above (Figure 4.1). As such they are part of a lineage of sketching the pathways of human movement stretching back throughout cartographic history to the earliest maps scratched in the sand. Route maps have been applied to telecommunication systems since they emerged in the mid nineteenth century, as shown in chapter six. As a visual analogy they demonstrate the material reality of the infrastructure in relation to a familiar and trusted geographical backdrop and are most widely deployed in commercial promotions as the analysis in chapter six demonstrates.

The 'wires-on-the-world' visual analogy also underlies a great deal of 'maps of cyberspace' produced (see examples in chapter three). They can be produced at different scales, from local maps in the form of wiring schematics for a neighbourhood or an individual corporation, up to global scale maps of transcontinental cable systems (Figure 4.1 above). National and global scale

[12] Here, I am distinguishing the Internet as an infrastructure, from the consumption of particular Internet services. The Internet as a service is typically represented visually by screenshots of particular media interfaces, such as websites 'in action' (e.g., e-commerce was often 'explained' metaphorically by a visual image of Amazon.com's homepage).

maps of infrastructure are frequently produced as part of network marketing (see chapter six). The level of realism in plotting the routes of lines can be varied and in many network maps the routes are logical links between end nodes and bear no relation to the physical pathway of the cable on the ground. Increasing the degree of topological generalisation of route lines morphs the Internet from conventional geographical network mapping into variable scale-distortion subway maps and non-geographical circuit diagrams (Figure 4.3).

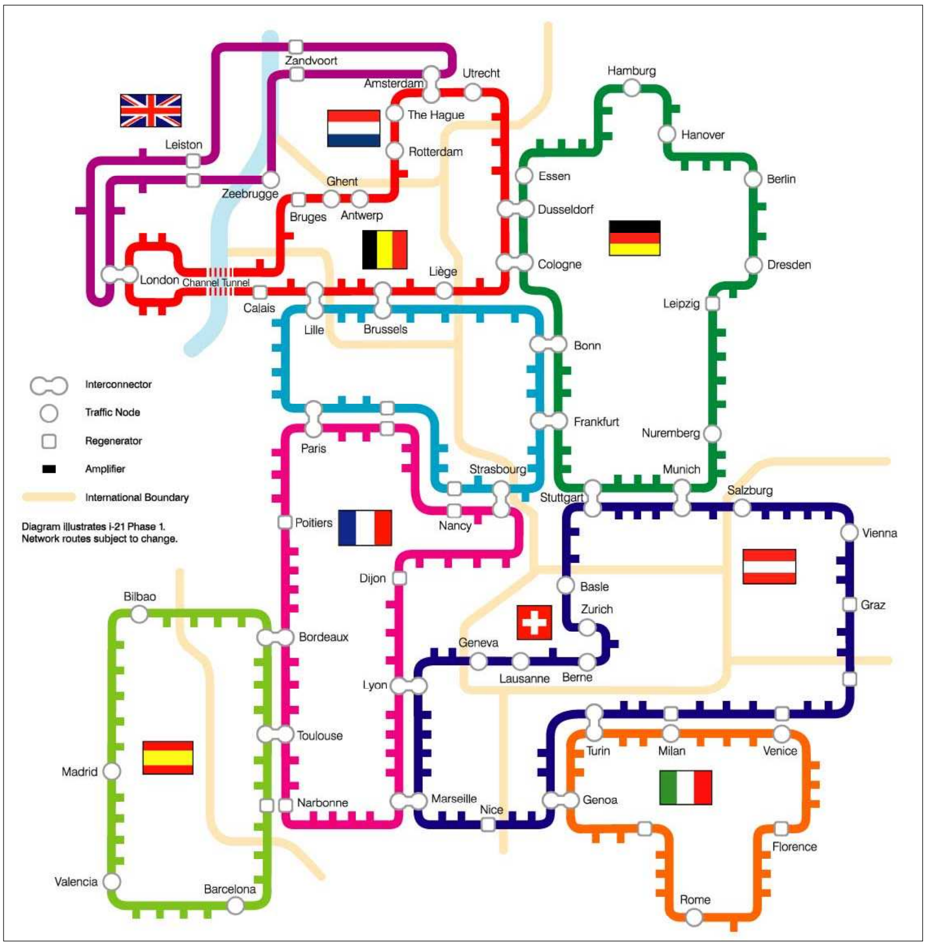


Figure 4.3: Internet infrastructure explained using the subway maps metaphor. This example was produced by Interoute in 2000 to promote its European network. (Source: www.interoute.com.)

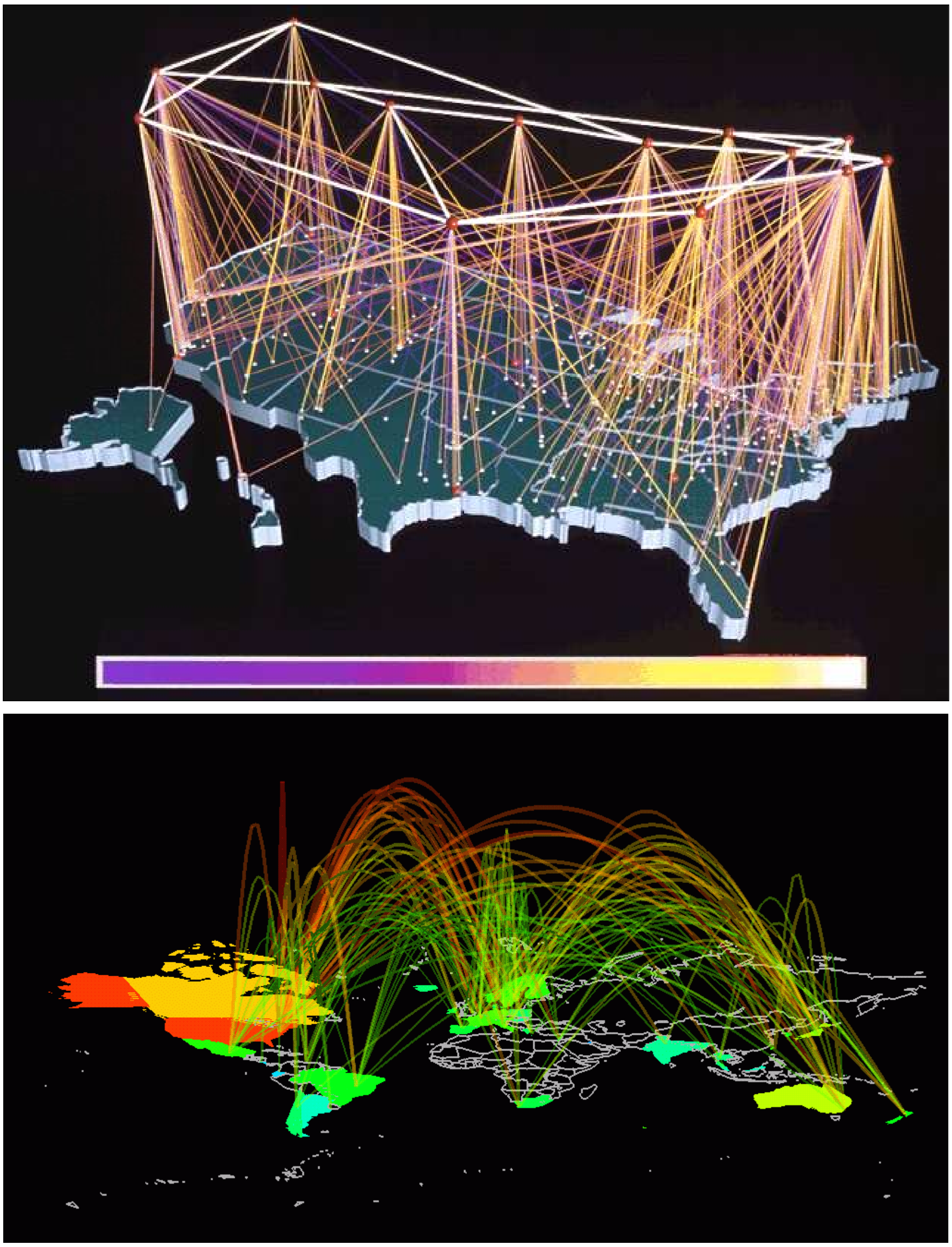


Figure 4.4: Top: A dazzling network of wires provides the central metaphor for a visualisation of NSFNET infrastructure produced by Donna Cox and Robert Patterson, National Center for Supercomputing Applications, University of Illinois Urbana-Champaign in 1994. The figure itself is a single frame from a short movie of the growth in traffic on the NSFNET backbone (source: NCSA 1994). Bottom: The metaphor of 'arcs across the world' creates a visually arresting image of Internet traffic flows between fifty countries as measured by the NSFNET backbone for a two hour period in February 1993 (source: Cox et al. 1996).

Attempts have also been made to increase the visual impact of Internet infrastructure maps by stringing the wires in three dimensions. One of the best known examples is the NCSA (1994) visualisation of the NSFNET network backbone (Figure 4.4 top). The network is imagined glowing white hot with pulses of data-light in the inky dark sky, a powerful presence radiating connectivity down to the nation. This striking image has been widely circulated and reproduced.

The NCSA visualisation is also interesting as it blends together the iconography of the engineer's wiring diagram with the thematic display of statistical mapping. The connecting lines from ground to network in the sky are colour coded to indicate the volume of traffic flowing from individual sites onto the network. "Icons such as this rely on the associations the audience makes between familiar forms- the maps of the United States with connecting lines – and the unfamiliar and formless realm of electronic networks" (Kallick-Wakker 1994, 313). Showing flows, rather than just the wire routes of a network, opens up many possibilities for metaphorical invention. Although, this approach is unusual and most network marketing maps are much more convention (see discussion in chapter six).

Another visualisation from the mid 1990s illustrates well the potency of visual imaginary to capture the essence of the Internet by displaying real flow data in three-dimensions (Figure 4.4 bottom). The Arc-Trans map of global traffic flows imagines the Internet as a set of fountain-like arcs of light traversing the world. The colour, link style and height of the arcs encode statistical information. It is important to realise that the arcs are not denoting network links per se but symbols plotted between capital cities to represent aggregate statistics on inter-country traffic flows. The map was produced by the researcher Stephen Eick and colleagues at Bell Labs-Lucent Technologies in 1996 as part of a project to create compelling 2D and 3D visualisations to understand network data flows. It is a screenshot of an interactive visualisation tool they developed called SeeNet3D (Cox *et al.* 1996). Of all the maps and diagrams catalogued in the *Atlas of Cyberspaces*, the 'arcs-across-the-world' metaphor at the heart of this image is far and away the most requested one for reproduction. In this manner, a few of most the visually impressive and compelling maps begin to define how the actual infrastructure of the Internet is perceived. Yet, it is not an innocent image. As Harpold (1999, 5) points out, the underlying metaphor draws its energy from “visual discourses of identity and negated identity that echo those of the European maps of colonized and colonizable space of nearly a century ago.”

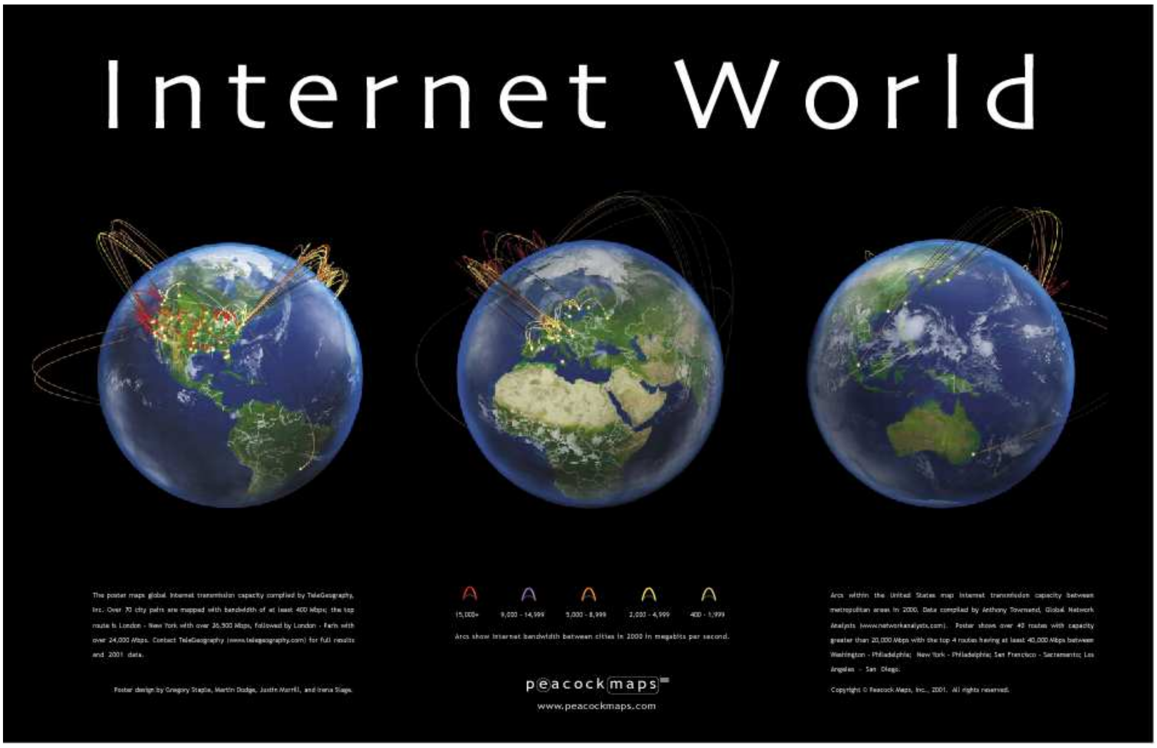


Figure 4.5: An effective example of the globe metaphor used to visualise Internet bandwidth statistics. It was conceived by Gregory Staple and Martin Dodge for a commercial poster in 2001. (Source: Peacock Maps, <www.peacockmaps.com>.)

4.3.2.2 Global visions

The earth globe is a dominant visual metaphor in Western contexts. The capability to command global vision is intimately associated with modernist culture. The globe has symbolic power because “we all assume for ourselves the position that most peoples have historically reserved for God. No longer confined by the local worlds of our direct experience, the conception of the globe allows us to make geography, for us to predict and then to discover new spaces, new worlds, new peoples” (Cosgrove 1989, 13). The globe has become integral in the imagery of many elements of corporate capitalism (e.g., aviation, telecommunications), as well as the key icon for the environmental movement (the ‘Whole Earth’ idea) (Cosgrove 1994). Universally displayed, often to the point of cliché, it is *the* iconic symbol of a business or institution with world-wide operations or aspirations, and potent for representing internationalism in political campaigning (cf. Edsall 2007) The global perspective, derived directly from the arms-race technical capacities in satellite monitoring, is also bound up with the militaristic gaze of command and control.

The globe as a visual metaphor is immediately recognisable[13]. It has become a staple visual metaphor for the Internet, with network arcs or data flows being wrapped around the world (good examples visualising aspects of the Internet infrastructure on the globe include: Cox *et al.* 1996; Lamm *et al.* 1996; Munzner 2000). Globes were used as the central motif on a poster called *Internet World*, produced by Peacock Maps in 2001 (Figure 4.5). Three views on the Earth show curving lines between capital cities to represent the available international Internet bandwidth. The height of the arcs above the surface of the globe is a function of distance. This is an imaginary view of the Internet, as if seen from a God-like position, with a dense mesh of arcs criss-crossing the USA from coast to coast, along with higher, longer transcontinental tunnels curving around the globe. The points on the globe *without* arcs are evident as well.

[13] It is also highly functional in graphic design terms because it can be rendered in myriad forms from a naturalistic ‘blue planet’ to a very stylised image conjured forth by a sparse grid of curving lines.

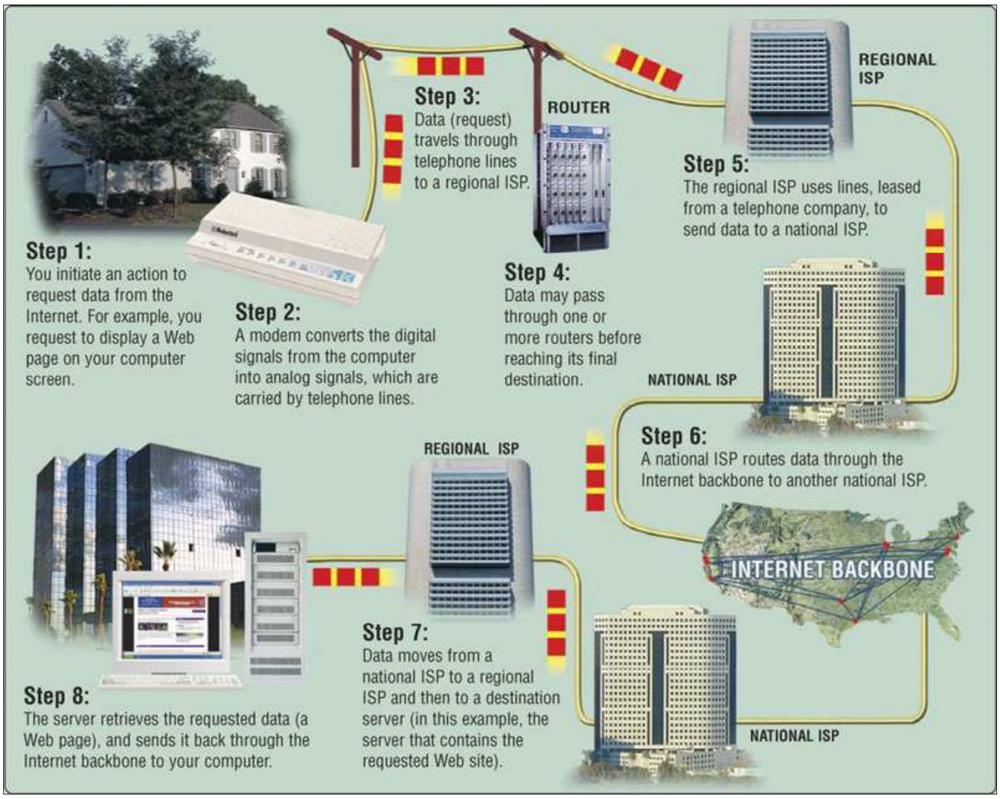


Figure 4.6: A step-by-step machine metaphor using photographs of hardware linked buildings to 'explain' basic Internet networking concepts (source: author archive).

4.3.2.3 Machine-like visions

In a very different mode to maps and globes, the Internet has also been spatially envisioned as a machine with working parts which handle and transport items of data. Representing the Internet through such mechanical metaphors can be particularly helpful in an educational context (e.g., Gralla 2003). The simplest of these approaches use photographs of actual network hardware or iconic images of equipment. These visual elements are sometimes presented as a systems model showing conceptually how a message is transported - what can be thought of as a 'tin cans and string' diagram (Figure 4.6).

More elaborate machinic metaphors imagine the Internet as a 'world-in-miniature' inside the infrastructure. For example, *Warriors of the Net*, a short animated film, shows in a jovial, non-technical way, how the Internet works internally by following the journey of data packets through different parts of the infrastructure (Elam 1999). Its underlying metaphor shows an industrial environment of grimy metal and of noisy machines – an example of ‘steampunk’[14] imaginary, rather than the slick, clean cyber-infrastructure of digital electronics and fibre-optics (Figure 4.7).

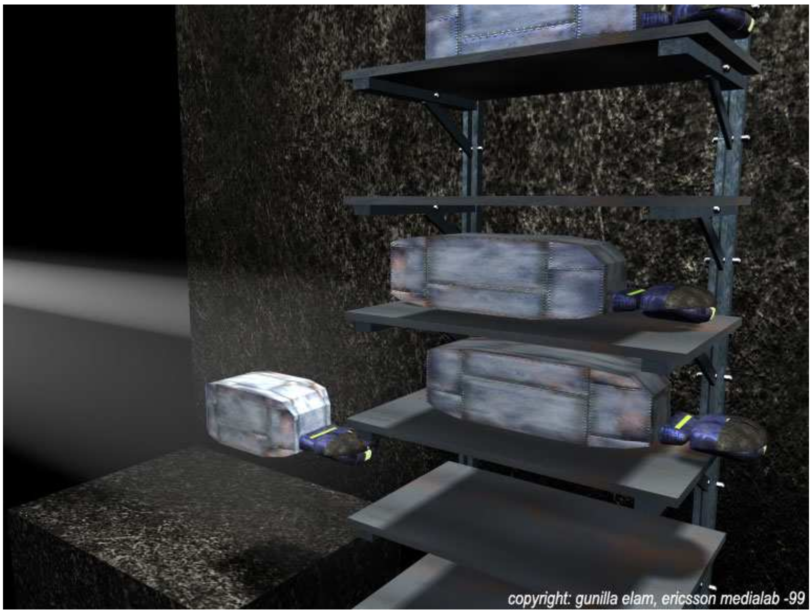


Figure 4.7: Stills from *Warriors of the Net* film, using a mechanical metaphor to explain the inner-workings of the Internet. Empty IP data packets, represented materially as large steel trucks, are filled with loads of data in the form of letters (top). They are then carried aloft in a freight elevator for entry onto the LAN (bottom). (Source: Elam 1999.)

[14] The visual aesthetic of ‘steampunk’ (named after the cyberpunk genre of science fiction) imagines advanced societies based on machinery (usually steam powered) rather than micro-electronics (cf. Gibson and Sterling 1992).

Rather than just imagine infrastructure spaces in mechanical terms, others have actually created physical machines to model the Internet's concept. For example, Japanese media artist Kouichirou Eto created 'a hands-on model of the Internet' that simulates physically the outward appearance of digital bits and data routing. As he succinctly notes: "[b]alls roll, and the workings of the Internet are revealed."[15]. Infrastructure is thus made tangible as an analogue model, a real spatial metaphor of the Internet that people can see, hear and touch (Figure 4.8).

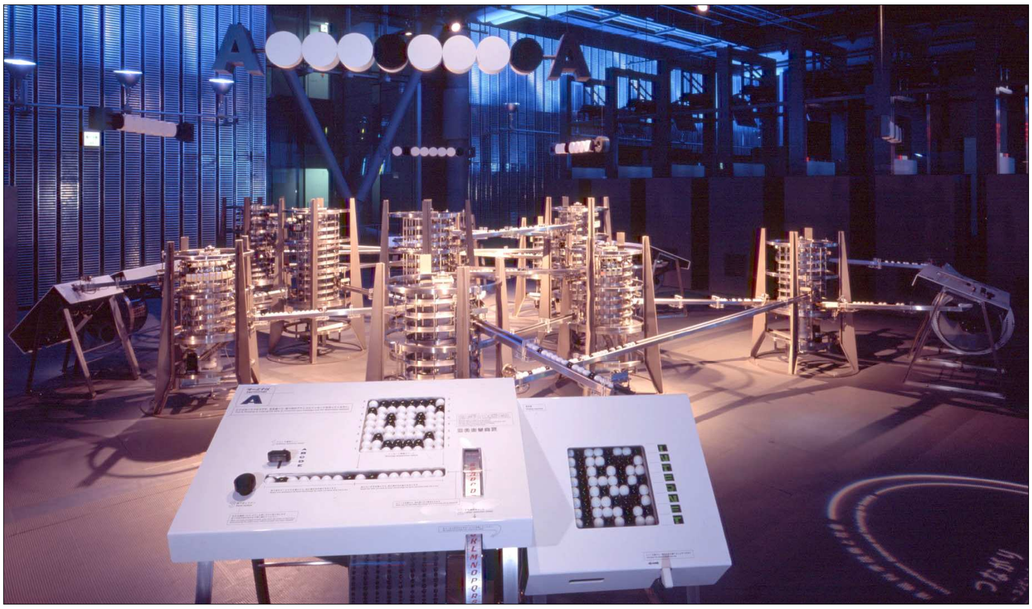


Figure 4.8: Kouichirou Eto's physical model of the Internet exhibited in National Museum of Emerging Science and Innovation, Tokyo. The control panel in the foreground is used to compose short messages by hand using black and white balls to encode letters in binary. Users then watch their message move through the machine, accompanied by suitably mechanical sounds of clanking metal and clinking of ceramic balls. (Source: <http://eto.com/2001/PhysicalInternet>.)

The metaphorical use of the movement of real objects to suggest the invisible workings of the Internet is also common. The power and speed of flows of data through network has often been visually connoted through images of blurring vehicle lights on highways or a soaring flight over a city at night. The feeling of physical movement experienced by the viewer captures the idea of flow through networks. For example, Goldman *et al.* (2003, no pagination) highlight a MCI

[15] Source: <http://eto.com/2001/PhysicalInternet/>.

WorldCom advert using this kind imagery, noting: "Here is the cyber-scape of the moment, not simply a symbol of a future that is upon us, but a functional conduit, the veins of a network that like a river flows through us, connecting us." Intertwined with the evocative imagery of movement and the power of incredible speed is the utopian message of transcendence over the tyranny of place and time, commonly used in promotional rhetoric of the 'New Economy' (De Cock *et al.* 2001).

4.3.2.4 Abstract visions

The last category of spatial metaphors deployed to envision Internet infrastructures connote in a very much more abstract way. These metaphors draw on naturalistic iconography of organic structures (the fractal branching of trees and leaves, structured lattices of coral and webs of spiders, the fine filigrees patterning of brains or veins) and emergent aesthetics redolent of meteorology and astronomy (cloud patterns, glowing gas nebulas and star clusters).

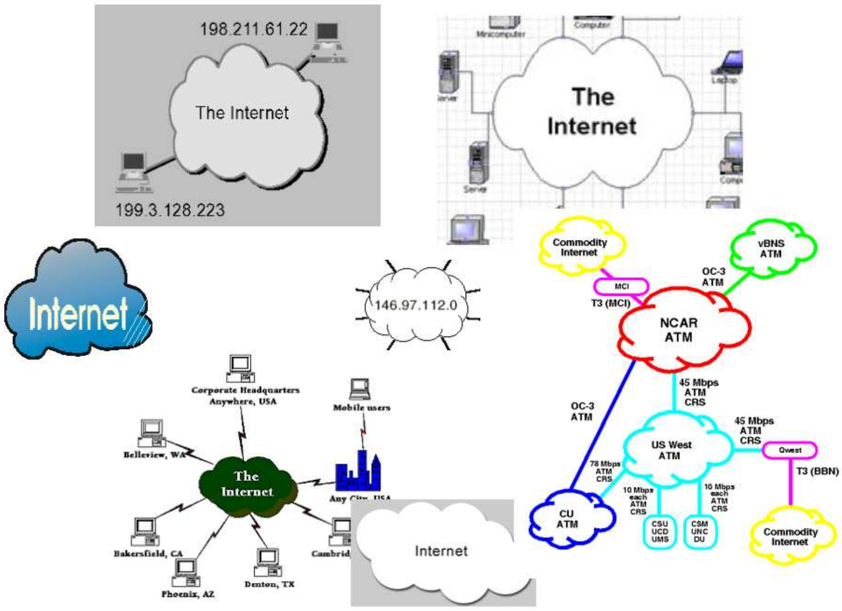


Figure 4.9: A montage of typical representations of the Internet as a cloud. (Source: various, images gathered from the Web through Google image search.)

The simplest and most common genre of abstract visual metaphors is the cloud (Figure 4.9). Curiously, cloud diagrams are ubiquitous in the Internet literature as a visual shorthand for infrastructure, particularly favoured in technical 'explanations', as they allow the author to signify the Internet as a definite object without needing to spell out the detail. As such they are a useful envisioning metaphor precisely because they obscure the infrastructure's heterogeneity and topological complexity: "the cloud's main usefulness lies in its vagueness" (Gibson, quoted in Scanlon and Wieners 1999, no pagination). Clouds can be quickly sketched and are instantly recognised, and "[a]sk the founders of the Net about the cloud, and it quickly becomes apparent that the Net cloud is as old as the Net itself" (Scanlon and Wieners 1999, no pagination).

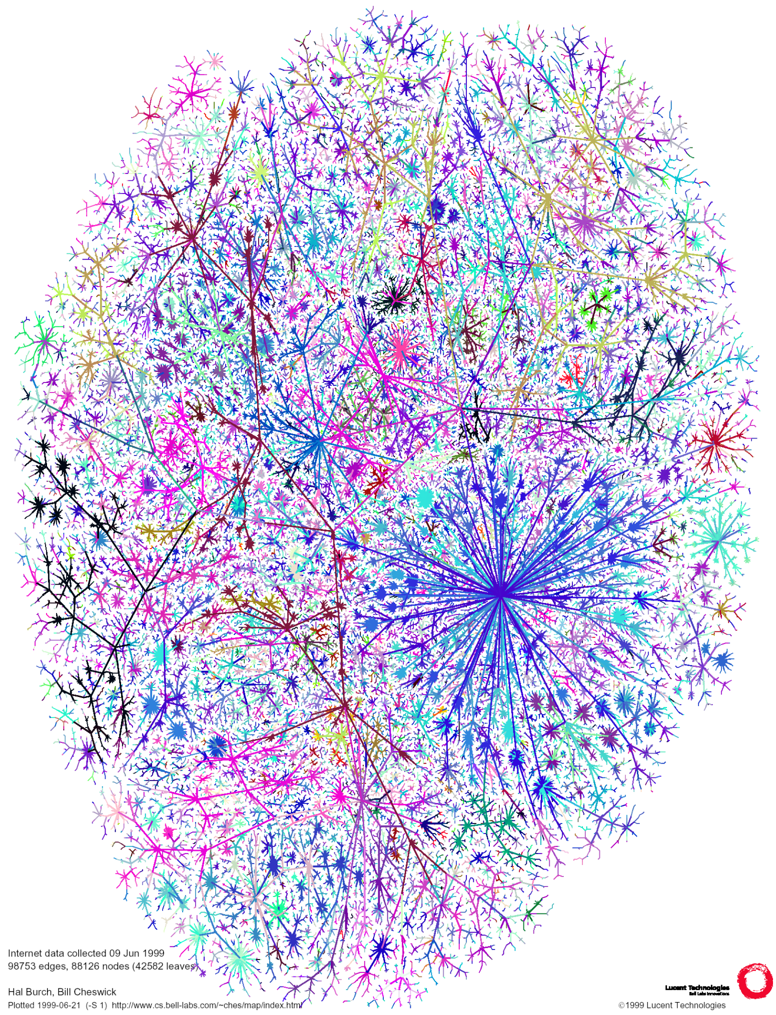


Figure 4.10: Connectivity graph to visualise the core of the Internet 'cloud' in topological terms. The colour coding of nodes is according to the IP address and seeks to highlight zones that share common network addresses and, likely, corporate ownership. The striking dark blue cluster represents a key hub owned by Cable and Wireless (formerly MCI); Cheswick describes this as "the magnetic north of the Internet". (Source: Bill Cheswick.)

Computer scientists and network researchers have produced many other abstract visual representations of the Internet that try to show the full complexity of the infrastructure rather than hide it inside cartoon clouds. These images, created by and for technoscience elites, tend to be amongst the most elaborate and visually dramatic representations of the Internet (e.g., chapter three, Figure 3.4). They use graph-like network representations to show the topology of connections and are distinct from the wiring metaphors using geographical ‘arc-node’ links examined above. Even though their construction is avowedly technical, some have resonated with wider public constituencies as ‘artistic’ renderings of the Internet.

The outstanding example of this genre emerged from the research of Bill Cheswick and Hal Burch[16] (Figure 4.10). Their technoscience visualisation is noteworthy in normative aesthetic terms, but also politically, in terms of the impact it has had on how the infrastructure has subsequently been imagined. Automatic surveying of the topology of thousands of interconnected Internet networks provides raw data that is visualised as huge, complex, multi-coloured graphs. The layout algorithm uses simple rules, with forces of attraction and repulsion jostling the nodes into a stable configuration that looks distinctly organic. It is projected within abstract space because as Cheswick notes: “We don't try to lay out the Internet according to geography ..... The Internet is its own space, independent of geography”[17].

Indeed, the power of the metaphor underlying the Cheswick-Burch graphs derives directly from this evolved, organic look - this is what people in some senses *expect* the Internet to look like now. Their results have been variously described as a peacock’s wing or a coral reef. These graphs have been widely circulated, including being sold as large wall posters proclaiming to show the ‘Whole Internet’, used on book covers and featured in art galleries and as

[16] Begun in 1998 as a research project at Bell Labs - Lucent Technologies and subsequently continued as a part of commercial venture Lumeta, <www.lumeta.com>.

[17] Source: <www.lumeta.com/research/mapping.asp>.

exhibits in science museums[18]. Typically, these types of abstract graphs are employed as purely 'artistic' images and there are no instructions as to how they maybe interpreted, or even that careful interpretation is necessary. The image's main function is as a connotation for the sublime complexity of the Internet and as a demonstration of the technical prowess of its creator.

While they have become firmly established, showing the entity with "no beginning, no centre, no end (or all beginning, all centre, all end)" (McClellan 1994, quoted in Kress and von Leeuwen 1996, 88), the wider implication of these graph metaphors is the number of people who assume that they denote the endogenous characteristics of the Internet infrastructure itself. In fact, all the visual properties of the graphs (geometry of the lines, their spatial arrangement, colours, etc) are exogenous to the phenomena being mapped; they are in that sense purely technical artefacts. Changing the parameters of the graph layout algorithm even slightly can produce a radically different looking Internet. While it is possible to make the Internet look like something from nature, there is nothing natural about the graph's appearance.

4.4 Overcoming Internet invisibility via scientific inscription

> Instead of being a figment of one's imagination ..., it will become a 'real objective thing', the existence of which is beyond doubt. (Latour and Woolgar 1979, 241)

Using ideas from science and technologies studies (STS) concerning the construction of objective authority within technoscience working practices, particularly Steven Shapin's (1984) theory of virtual witnessing, I will now consider how infrastructure invisibility is overcome by computer scientists and network engineers who are studying the structures and dynamics of the Internet.

[18] See <www.peacockmaps.com>. I worked for Peacock Maps in 2001 and contributed to the publication of the 2001 *Whole Internet* poster. Book covers include: Castells' *Internet Galaxy* (2001); Mitchell's *ME++: The Cyborg Self and the Networked City* (2003).

According to detailed ethnomethodological studies[19] by STS scholars, the natural and biological sciences do not discover 'laws of nature', but socially construct knowledge by stabilising particular experimental findings as widely agreed 'facts'. Because the phenomena to be experimented upon are usually undetectable directly by human senses, they require measurement techniques and graphical inscriptions to make them visually apparent. There is an almost obsessive preoccupation by scientists and engineers with such inscription (Lynch and Woolgar 1990), producing a bewildering array of "traces, spots, points, histograms, recorded numbers, spectra, peaks and so on" (Latour and Woolgar 1979, 88). Indeed, Latour (1990, 42) has characterised laboratory work as fundamentally a "cascade of inscriptions". As visual re-presentations of 'nature' such scientific inscriptions are constructed from direct empirical measurement, then cleaned, redrawn, smoothed, transformed, and finally displayed prominently in publications to the bolster the of the truth claims made in the text.

The potency of such inscription is due, in large part, to the ocularcentric nature of Western scientific practices. Since the Enlightenment, vision has been the dominant mode of understanding of the material world: 'seeing is believing'. Reflecting this primacy of vision, most geographical research, for example, was, until recently, a matter of 'looking' at the landscape as the best way of obtaining truthful knowledge (Sui 2000). It has been argued that the Enlightenment 'scientific revolution' itself depended significantly on Renaissance development of new ways of seeing, such as linear perspective, which allowed the creation of far more mimetic inscriptions of reality (Edgerton 1975). Many 'technical' approaches in engineering-drawing, which are now taken-for-granted modes of inscription, were invented at this time, such as the orthographic projection depicting three views of an object, the exploded view to show how complex mechanisms were assembled, and the cut-away view to show internal workings. Contemporary scientific endeavour - partly in response to modern media driven agendas – has also realised the power of inscription for public communication and promotion; as Heller (2003, 57) wryly notes: "[s]cientific disciplines with

[19] These seek to understand scientific epistemology by looking at what scientists and technicians actually do in their everyday working practices, rather than accept the formally published methodology of 'discoveries' as sufficient explanation for the production of knowledge.

good pictures are rich in resources that keep them ... moving forward." This equally applies to those scientists seeking research funding to study the dynamics of the Internet.

Inscriptions are usually produced by measuring devices, specialised machines or an assemblage of apparatus designed purposefully to "transform pieces of matter into written documents" (Latour and Woolgar 1979, 51). Inscription devices come in all different sizes and work in a myriad of different ways - from a simple weighing balance up to an sophisticated radio telescope - but their end result is always the same - inscriptive markings written out on paper. The markings are invaluable to scientific endeavour because "scientists themselves base their own writing on the written output of the [inscription devices]" (Latour and Woolgar 1979, 51).

Yet, the real importance of inscriptions, Latour and Woolgar (1979, 245) argue, is "not so much as a method of transferring information but as a material operation of creating order." Inscriptions work to 'create order' within the social practices in technoscientific settings in several ways. Firstly, they define objects of interest. They are seen as having a direct relationship to reality, providing the focus of discussion about the properties of the phenomena that are otherwise invisible. The pattern of peaks on the graph is itself analysed as a legitimate object of scientific study. Secondly, they are a means for organising collaborative effort between scientists and reaching common agreement on 'what is happening'. As such, Roth and McGinn (1998, 217) characterise inscriptions as 'conscription devices', noting how they are of such importance in many discussions that "scientists and engineers will stop a meeting to fetch a design drawing, produce a more or less faithful facsimile on the whiteboard, or render a diagram in a gesture." Inscriptions are also a most effective means of forging unity of effort across different communities of practices, which may well be distributed geographically and in time. In this way inscriptions work publicly in the production of 'matters of fact', that is discrete elements of knowledge that have been verified by the scientific community and enjoy widespread assent as being true explanations of reality.

However, a significant problem in the production of such ‘matters of fact’ is the limited access to experimental activities and the inner working of inscription devices for independent verification. Scientists strive to solve this verification problem through what Shapin (1984) describes as a process of ‘virtual witnessing’, a way that an experiment can be validly observed via a particular kind of publication of results rather than by being physically viewed in the laboratory. Assent that an inscription constitutes valid ‘matters of fact’ can, thus, be manufactured remotely and infinitely using ‘literary technology’. This is now easily recognisable and taken-for-granted as an ‘objective’ style of scientific writing, but it had to be invented[20]. It comprises a functional, dispassionate form of prose, with a puritan form of diagrammatic inscription. The results, Shapin and Schaffer (1985, 62) argue, “served to announce, as it were, that ‘this was really done’ and that ‘it was done in the way stipulated’; [it] allayed distrust and facilitated virtual witnessing.” Objectifying ‘matters of fact’ works by the denial of human subjectivity. ‘Facts’ have to appear to have been discovered from nature rather than being man-made artefacts.

For this kind of ‘literary technology’ to be successful in virtual witnessing it requires that scientists themselves be ‘modest witnesses’ - “the author as a disinterested observer and his accounts as unclouded and undistorted mirrors of nature” (Shapin 1984, 497). Modest witnesses describe facts objectively for the advancement of science, not for personal rewards; and they willingly admit weaknesses in their methods and present the results of failed experiments. “Such an author gave the signs of a man whose testimony was reliable” (Shapin 1984, 497). They produce descriptive and systematic work and do not indulge in overly theoretical and speculative writing.

Literary technology for virtual witnessing also mandates a very particular style of published inscriptions. The now conventional scientific ‘look’ of inscriptions is achieved through various semiotic strategies, many of which are also evident in the generation of objective authority in modernist cartography (see discussion in

[20] Shapin and Schaffer (1985) argue it came about in relation to the contested emergence of experimentalist natural philosophy in the mid seventeenth century. They highlight the significance of Robert Boyle’s empirical studies on the nature of vacuum using air-pumps.

chapter two). Objective authority is, in large part, constructed by how the image-marker chooses to position the viewer in relation to the data. Typically, technical pictures are authored as the 'view from nowhere' that situates the viewer as an outside observer. Kress and van Leeuwen (1996) identify several distinct viewpoints that convey an 'objective attitude' by eliminating the subjective distortions associated with linear perspectivism. These disinterested positions include the front-on view, the cross-sectional view and, most significant, the top-down angle that "contemplates the world from a god-like point of view, puts it at your feet, rather than within reach of your hands" (Kress and van Leeuwen 1996, 149).

Besides employing such objectifying viewpoints, the scientific inscription's most conspicuous semiotic strategy is the strategic use of blank space. Scientific diagrams are most recognisable by their lack of decoration or aesthetic embellishment. Graphical austerity connotes objective authority. The data are always denoted on an bare white canvas to focus attention and to connote that the data is sufficient and stand alone for inspection; the existence of issues of uncertainty and province in the data are connotatively covered over by the blanket of white space. Such emptiness, according to Lynch (1985, 59), "is infused with moral significance, inasmuch as it involves the tacit claim of scientific integrity, with motives assumed to be beyond reproach, and is offered with an unstated presumption that, if anything significant should have been said about the operational history of the graphic line, it will have been stated." This kind of semiotic interpretation is applicable to the connotative meanings of modernist cartography, with Wright (1942, 527) noting that "[t]he trim, precise, and clean-cut appearance that a well drawn map presents lends it an air of scientific authenticity that may or may not be deserved …. We tend to assume too readily that the depiction of the arrangement of things on the earth's surface on a map is equivalent to a photograph – which, of course, is by no means the case." We can also draw direct parallels to MacEachren (1995) two internal map connotations of veracity and integrity discussed in chapter two. He gives the exemplar of official topographic mapping claiming that "[t]he U.S. Geological Survey uses highly detailed, unadorned, visually unassuming maps to connote accuracy, impartiality, authority – thereby creating an impression that the U.S. Geological Survey maps have no point of view" (MacEachren 1995, 335).

A noteworthy manifestation of the active manufacture of cartography with 'view from nowhere' in the empty space, as Turchi (2004, 37) says: "a blank on a map became a symbol of rigorous standards; the presence of absences lent authority to all on the map that was unblank." The origin of this strategy for a 'scientific' mode of cartography is often traced to Jean Baptiste Bourguignon d'Anville's 1749 map of Africa with its famously blank interior replacing earlier imaginings of map-makers. Yet, this map is not only a laying claim to honesty, for as Hiatt (2002, 248) points out, "the blank testifies to a lack of possession, since it signifies land, rather than territory, earth rather than ownership. Consequently, the blank also can be seen to invite exploration, and in a colonial context this is the inevitable prelude to acts of demarcation."

Allied to the strategy of blank space is the normalising power inherent in scientific inscriptions. They work as 'sensible pictures' according to Lynch (1985), to literally refigure the natural world into geomatisied and mathematised form. Continuous phenomena are measured into detached units of data, these are classified and transformed, then plotted into idealised, abstract graphical space that is correctly determined by its labels, axis, scales and legends. (As discussed in chapter two this kind of charge is made again official maps by those advocating critical cartographic deconstruction. Also, see chapter five in relation to the normalising effects of statistical maps). In effect, all data points on a scatter graph become exactly similar (except for their position in the grid) and "all other circumstantial features of their observation 'drop out'" (Lynch 1985, 43).

4.4.1 Virtual witnessing of Internet infrastructures

Computer network infrastructures have been constructed as objects of 'scientific' study since the very beginning. The engineers and computer scientists involved in designing ARPANET in the 1970s, for example, produced detailed analysis of its topology and performance from direct measurement of the network (e.g., Frank *et al.* 1972). Their goal was to discern the underlying 'facts' of wide-area computer communication by experimental study of the real dynamics of a working packet-switching network.

Today, a sizeable interdisciplinary ‘Internet science’ community undertakes experimentally-driven studies using positivist scientific approaches. The self-stated aims of ‘Internet science’ research are primarily pragmatic, being to aid future engineering efforts to achieve more optimal design of data routing software and equipment through more accurate descriptions of the Internet. A key part of this work involves building complex inscription devices in the form of large-scale software systems for passively monitoring traffic flows or actively scanning instruments to measure the connectivity of the network from multiple sample points (see Murray and Claffy 2001; Spring *et al.* 2004 for reviews). To achieve this, most inscriptions devices use the network infrastructure to measure itself (Dodge 2000d).

Whilst sharing much of the ethos with other scientists and engineers, ‘Internet science’ research centres suffer because they have little or nothing in the way of scientific equipment in their labs, so the output of the software-based inscription devices becomes all the more critical to witnessing their work. Their inscriptions strive to render the Internet ‘factually’, as opposed to most of the more ‘impressionistic’ envisioning produced through visual metaphors for lay audiences, discussed early in this chapter. A range of different inscriptions are produced, including schematic diagrams, statistical charts and tables and, most especially, complex topological graphs. Another notable feature of their inscription practices is the desire to present ever greater data volumes as a kind signifier of machismo in modern scientific endeavour.

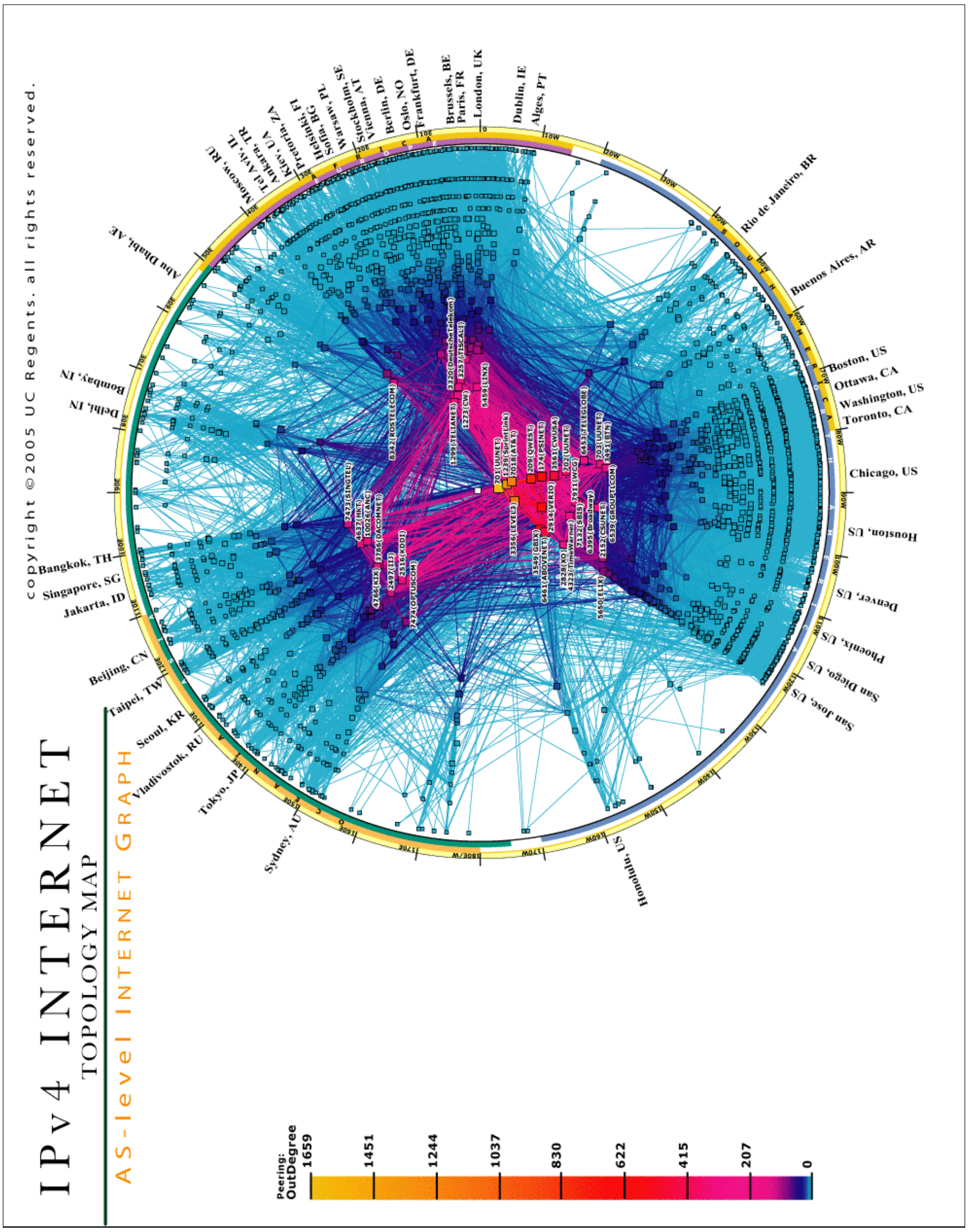


Figure 4.11: A scientific inscription of Internet connectivity measured in April 2005. It is used as a key part of the virtual witnessing of ‘Internet science’ researchers at CAIDA, producing a matter of fact of the otherwise unobservable infrastructure.

(Source: <www.caida.org/analysis/topology/as_core_network/>.)

One of the leading ‘Internet science’ centres, combining both academic and industrial researchers, is CAIDA[21] and they create a range of scientific inscriptions to aid the virtual witnessing of ‘matters of fact’ about the Internet infrastructure. It was founded in 1997 by KC Claffy[22] and Tracie Monk to “foster development of tools and analysis methodologies for promoting the engineering and maintenance of a robust, scalable global Internet infrastructure.”[23] It has succeeded in securing multi-million dollar grant funding and employs fifteen people. It also collaborates extensively with industrial partners and has ties to Internet network operators. CAIDA exhibits a fetishistic obsession for measurement, generating huge data volumes on different aspects of Internet infrastructure performance. This is perhaps unsurprising, given the depth of empiricism underlying most engineering practice associated with this approach to understanding networking. Here I focus on one example of an inscription that is illustrative of the type work that CAIDA produces to make Internet infrastructure visible and researchable. The ‘IPv4 Internet Topology Map: Autonomous System (AS)-Level Internet Graph’[24] (Figure 4.11 above) was created by a team of researchers to visualise the macroscopic structure of the Internet for a snapshot in time by showing relationships between networks

An important element in the inscription is the large-scale, automatic measurements of the Internet’s topology, using a distributed systems of scanning beacons, known as ‘skitter’. This generates large data volumes which are aggregated and filtered prior to visualisation. So the 220,000 odd individual nodes in the skitter dataset were aggregated by the ISP that they belonged to, based on the technical grouping by Autonomous System (AS) number. This yielded some 1516 AS nodes which represent the most highly connected ISPs

[21] The Co-operative Association for Internet Data Analysis is based at the San Diego Supercomputing Center, the University of California at San Diego, <www.caida.org>.

[22] Her 1994 PhD thesis topic, in some senses sets the tone of CAIDA’s research, entitled: “Internet traffic characterization: a methodology to support more accurate workload characterization in the face of increasing diversity in Internet traffic types and qualities.”

[23] Source : <www.caida.org/home/staff/kc/kclaffy.xml>.

[24] Source: <www.caida.org/analysis/topology/as_core_network/>. Research team: Brad Huffaker, Andre Broido, KC Claffy, Marina Fomenkov, Sean McCreary, David Moore and Oliver Jakubiec.

that form the core of the Internet and carry the bulk of the traffic. These are plotted as dots in a calibrated space as 'matters of fact' on the topology of the Internet.

Its form is a complex graph displayed using a polar projection, where each AS node encodes two data characteristics. First, the distance away from the centre shows the relative strength of peering relationships with other networks. Second, the angular position around the circumference of the circle shows the approximate geographical position of its corporate headquarters[25]. The peering links between ISPs are shown by the arcs which are colour-coded 'hot to cold' based on the relative strength of connection (as indicated in the legend). So yellow, central nodes are some of the most well connected ISP and the scientifically witnessed core of the Internet.

In terms of the geographical data encoded in the inscription, one can think of this as somewhat like a map of the Earth, with a projection centred on the North Pole. Around the circumference of the graph, longitudes are marked every 10 degrees and coloured strips denote different continents. Key cities are also labelled. The graph generally divides the nodes into three distinct segments based on the continents of North America, Europe and Asia/Oceania related unsurprisingly, to the major metropolitan nodes in the world economy.

In normative terms, the IPv4 Internet Topology Map has the ability to identify the most powerful ISPs and where on the globe are they are concentrated. It is clear that the densest concentration of AS nodes, towards the centre of the graph, lies along the longitude of about 70 degrees west, which relates to the eastern seaboard of the USA. The headquarters of some of the leading Internet backbone operators such as UUnet, PSInet, Qwest, CWUSA are found there. In many ways this inscription reinforces what is apparent from many of the other infrastructure maps of the global Internet – that the U.S. is the dominant player in terms of infrastructure provision. It has been described as the world's 'switching centre'

[25] Obviously there is considerable generalisation as many large ISPs will have their infrastructure spread across the globe. As such, one might like to think of this as more of a geopolitical location.

(Singel 2007) in terms of global traffic flows. In fact the top 15 most connected AS nodes are in North America (one is in Canada). The IPv4 Internet Topology Map also reveals that many of the ISPs based in Europe and Asia-Oceania have relatively much fewer connections between them, relying instead on peering with U.S. backbones to act as a hub.

Besides the normative reading, this graph clearly is a significant scientific inscription for CAIDA. It enjoys prominence in many of their presentations[26] and is displayed in pride of place on their Web homepage. Whilst there have been some attempts to use it metaphorically as an impressionistic visualisation (for example it is available for purchase on wall posters), it is too technical, and it lacks the immediate visual punch and instant recognition of a more familiar metaphor (for an example of a global image, see Figure 4.4; for world maps, see chapter six). It makes use of all three semiotic strategies to achieve the dispassionate 'scientific look' needed for a successful inscription to use in virtual witnessing processes. Firstly, it situates the viewer in a top-down position, inspecting the data from a God's-eye vantage point, apparently offering totalising vision 'over' the core of the Internet. Secondly, the graph itself is embedded in a antiseptic, blank canvass, unadorned except for title and technical scale bar. Lastly, the graph is an archetypal 'sensible picture' with the connectivity of the Internet thoroughly re-figured to fit into calibrated, circular space. The reality of the Internet is reduced to an orderly (albeit informationally over-crowded and in some area illegible) layout of dots in a graph.

More generally, the way that IPv4 Internet Topology Map is embedded in the web page text[27] also demonstrates how this inscription functions as part of CAIDA's virtual witnessing of the Internet's topology. Firstly, the witnessing makes claims to sources of empirical data that are comprehensive and accurate. The size of dataset is given precisely, along with exact dates when the experimental measurements were run. The description of the data uses various

[26]<www.caida.org/publications/presentations/>

[27] Source: www.caida.org/analysis/topology/as_core_network/>.

specialised terms that create an aura technocratic authenticity. The witnessing also uses other strategies to bolster its objective attitude, such as:

(1) making older versions of the graph available for consultation,
(2) making the raw data available for independent verification,
(3) setting out a detailed list of caveats demonstrating that the authors are ‘modest witnesses’ willing to admit their weaknesses,
(4) text sets out the ‘insights’ in terms of descriptive, experimentalist understanding of Internet topology only and makes no grand theoretical claims - again this is a necessary tactic of the ‘modest witness’.

4.5 Conclusions

Ultimately, the choice of how to visually represent the Internet, to overcome infrastructure invisibility, is a far from simple question. Over time many conceptions have dominated. Implicit in any approach are the underlying power geometries of the metaphors used (verbal, visual, numerical) regarding what the Internet is, and more importantly, what it could be. None of these conceptions can really be said to be ‘incorrect’. The various impressionistic visualisation and technical diagrams can be seen as imaginal explorations of what the Internet is ‘at its essence’. In some respects, this exploration phase has ended, various metaphors and diagrams having been tried and rejected, while a few dominant ones have been legitimated[28]. Certain kinds of cartographic representation remain one of the mainstays for overcoming Internet invisibility. Two of the most firmly established genres of mapping that are in common use, and are clearly deemed to be effective to some degree for this process, are route maps showing network structure and thematic maps showing aggregate national statistics. How these two genres of mapping work semiotically and politically to make the Internet visible and tangible, in particular ways, is the focus of analysis in the next two chapters.

[28] Indeed, as Internet as become commonplace, it has itself become a metaphor in its own right, for example, used to describe new forms of decentralised, corporate organisation or supposedly new modes of war fighting.

In conclusion, spatial metaphors and scientific inscriptions not only make visible the invisible infrastructures of the Internet, they work as narrative devices to dramatise the dull and banal nature of a network wholly lacking in striking physical motifs of soaring airliner or impressive architectural displays. Thus they explain visually what the Internet looks like, but they also delude in equal measure, as this is never a view of the Internet one could see naturally. This applies, for example, to the kinds route map discussed in chapter six which are created by commercial operators to market their network and use various design strategies to try to demonstrate they have the best available infrastructure. Although from empirical evidence, investigated in chapter six, they have varying degrees of success at connoting wholly positive impressions because they often represent their infrastructure too realistically rather than more metaphorically.