The Spread of TCP/IP and the Political Origins of the Internet

(a/k/a why the Internet is *the* internet)

This study describes the spread of TCP/IP and therefore the diffusion of the Internet, beginning in the 1960s until the early 1990s. Understanding how TCP/IP emerged and spread provides insight into the changes and challenges brought by the Internet into world politics. Against arguments that the Internet reflects primarily economic or military concerns, I argue that notions of "academic" freedom are embedded in the fundamental technology of the Internet, TCP/IP, and that this embedded norm is essential to the Internet's consequences for modern political life.

In its first twenty years, the Internet grew from a novel experiment among a few scholars to a global phenomenon, connecting millions of people and changing the way people look at the world. This was achieved on a largely ad hoc, informal basis, with minimal guidance from government leaders. The source of this spread was the work of computer scientists associated with the Advanced Research Projects Agency of the U.S. Department of Defense, and the diffusion process followed closely the alliance patterns of the Western bloc in the Cold War. Within the international relations literature, the best descriptive analogy for the process comes from Finnemore and Sikkink's 'life cycle' of norms—emergence, cascade, and internalization. From this perspective, this study argues that academics served as 'norm entrepreneurs' working in an 'organizational platform' established by ARPA.

I document this process through extensive use of primary sources, as well as published and online sources, to examine the motives and incentives behind the spread of the Internet. I argue that neither military necessity nor economic reward drove the process, but rather an academic desire to solve problems for scientific prestige. I show that the process unfolded at an interpersonal scale across the group of industrialized countries anchored by the United States, without being driven by U.S. government policy. In this process, TCP/IP competed - and beat - alternative technologies proposed by international standards bodies and private corporations to become the backbone of the modern Internet.

Understanding this process and its product is crucial to proper adjudication of contemporary debates regarding the ownership, neutrality, accessibility, anonymity, and security of the Internet. Many of the alternative configurations proposed to remedy 'problems' of the Internet in fact duplicate previous alternatives which TCP/IP proved superior to. Moreover, I argue, any change in the underlying technology which diminish the embedded normative commitments risk diminishing the Internet's transformative power in the world.

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I. Why TCP/IP?

The Internet is an important variable in analyses of contemporary international phenomena; studies of globalization especially point to the Internet as both contributing to and accelerating the integrative tendencies of the modern world (Friedman, 1999; Held et al, 1999; Rosenau, 2003). Some recent exemplar studies focus on the construction of cybersecurity (Deibert and Rohozinski 2010; Cavelty 2008), the application of theoretical lenses to describe the Internet in international relations (Manjikian 2010), and the symbolic politics of the Internet with respect to human rights (McCarthy 2011).

Yet many of these studies never ask why the Internet should facilitate these trends, nor how it came to be so ubiquitous. This is par, as Herrera explains: “existing theories of international relations... view [technology] deterministically and exogenous to politics” (Herrera 2006, p. 193). Moreover, political scientists often assume that “information technologies are essentially neutral” - without “tilt in the direction of any particular values” (Rosenau 2002, p. 275). But far from being useful, the assumptions of exogeneity and neutrality are severe handicaps to a meaningful understanding of the Internet and its particular challenges to international politics.

On the other hand, studies of the Internet's history and consequences often elide the international aspect of that process. Janet Abbate, in what many consider the classic work on the emergence of the Internet,[1] describes in five pages the spread of the network outside the U.S. (Abbate 1999, pp. 208-212); her work is primarily history - and excellent history - but not focused on the political dynamics of the diffusion process. Other scholars mistakenly attribute the political origins of the Internet to the interests of the U.S. military; one author writers, “the U.S. Defense Department, in order to render its communication system impervious to nuclear attack, made the network independent of command and control centers” (Mazlish 2004, p. 22). This is demonstrably false; as discussed below, the Defense interests had little influence in the design of the network, which was never intended to serve operational purposes.

Understanding how technology can be political requires an appreciation of the ideational aspects of the former. One definition considers technology a form of knowledge: namely, "knowledge 'how,' that is, instructional or *prescriptive* knowledge" (Mokyr 2002, p. 4). When knowledge becomes prescriptive, it also becomes inherently normative and potentially political, and this is especially true for the knowledge 'how' embedded in the Internet, which "reflects both a political decision about disabling control and a technological decision about the optimal network design" (Lessig, 1999, p. 33). That is, the Internet embodies prescriptive decisions about how networking technology ought to work, and what privileges and responsibilities parties to the technology ought to have, and these decisions have important political consequences. The simple fact of a global computer network is not interesting; rather, why does the network function the way it does? Who made the decision to “disable control”, and how did that become entrenched in the technology?

The core technology which gives the Internet its particular characteristics is called Transmission Control Protocol/Internet Protocol, or TCP/IP; I argue that the development and spread of TCP/IP was deeply influenced by the specific political context from which it emerged. Simply put, cyberspace

1 To some extent my research replicates Ms. Abbate's; in acknowledgement of her priority, I have cited her work in some cases where I also have primary research to the same effect.

reflects political space. In the following, I review the literature on the spread of technology and the Internet, then offer an alternative explanation, coupled with original research, which shows that TCP/IP spread by a process analogous to norm diffusion among sub-state actors. Understanding this process is critical to appreciating the Internet as a phenomenon not only *in* International Relations, but also *of* international politics.

II. Explaining the Internet

Unfortunately, the literature on the international spread of the Internet pays little attention to the period before 1990, which I will argue is crucial. For example, Milner argues (correctly), "that the pattern of Internet adoption among countries has been driven neither by technological forces nor by economic ones alone. Rather, political factors... exert a powerful influence" (2006, 178). However, Milner's portrait of the Internet begins in 1991, towards the end of the important phase in TCP/IP diffusion. This is due in part to her data, drawn from Internet Software Consortium (ISC) surveys and World Bank data, and her exclusion of other networks from consideration. Data collection in both organizations began after the Internet was an interesting phenomenon, and simply miss the formative activity that shaped it into that phenomenon. So although Milner is correct that "Political institutions in particular matter" (2006, p. 178), her concern with democracy and autocracy is too macroscopic, and elides important details about the particular institutions that mattered in the development and spread of the Internet.

Milner is most prominent in her account of the spread of the Internet, but alternative explanations can be inferred from IR scholarship on related questions. For example, an obvious argument - and indeed, my working hypothesis when I began this research - is that the spread of TCP/IP was in the United States' interests as a form of hegemonic control. Drawing from Stephen Krasner's work, in this explanation TCP/IP became the Internet because a powerful state, the U.S., desired that outcome; Krasner uses power to explain the presence of international regimes for satellite broadcasts and telecommunications against their absence of regimes in radio broadcasting and remote sensing (Krasner, 1991, p. 343). However, Krasner's argument rests on the material realities of the technology; the Internet's material structures – fiber-optic cables and computer systems – are much more like that of telecommunications than like that of remote sensing and radio.[2] The problem is that this approach assumes the material and ideational structures of the Internet were fixed prior to any consideration of international regulation; this was not the case, as discussion of the X.25/OSI effort will show.

The X.25/OSI debates also point to another approach to the spread of the Internet, namely from the standards literature. In this view, standards are a particular kind of institution, used to resolve coordination problems. In Abbot and Snidal's typology, the Internet is a problem of "technological interconnectivity", which creates "network externalities" (2001, p. 350); in these situations firms and governments prefer private standards (p. 355) and "private governance is likely to be most effective" (p. 364).[3] However, the involvement of the CCITT and International Standards Organization (ISO), as described below, suggests that firms and governments *did not* prefer private standards-setting, and their intervention appears to be an effort to stem what Spruyt calls the "clear advantages" accrued to a "first

2 In fact, Krasner would likely class the Internet as a form of "transborder data flow" (Krasner, 1991, p. 353)

3 At present, standards setting on the Internet is in fact done by private governance - the Internet Engineering Task Force, a body made up primarily of users (Bradner, 1996).

mover" (Spruyt 2001, p. 375), namely those computer scientists who were already developing and using TCP/IP. But as first-movers, those users were able to impose their vision of decentralized networking on telecoms and computer manufacturers. Thus the relevant coordination game was not between states, but between interests – especially users versus telecoms.

A more complex, but more compelling, macroscopic argument is that the United States created during the Cold War a political space which incidentally allowed for the spread of the technology by sub-state actors. That is, the United States government permitted such activity but did not drive it, instead allowing network users to develop the software according to their needs. Such processes – open source, user-driven- -- "tend to be powerful magnets that attract standards to form around them," writes Weber (2004, p. 238) --- in contrast to the CCITT and ISO, where the network standards were determined by officials who might not be extensive users of the technology. In this context, the important institutions are not ISO and CCITT but NATO and the OECD, understood as a political landscape created by the United States and its allies. Only where political interaction had created a degree of openness across international boundaries among the U.S. and its allies --- did the early technology of the Internet spread. In Europe this spread reflected NATO membership, while the early connections in the Asia-Pacific region reflected hub and spoke alliance structure of U.S. engagement in that region. In this political space, the ARPANET and other precursors to the Internet were allowed to develop and thrive with minimal government interference.

To appreciate this explanation, it is important to understand the process by which TCP/IP spread --- namely, the parties to that process, and the context and relationships in which the process unfolded. In what follows, I couple my explanation to original research on the spread of the Internet, primarily consisting of interviews and correspondence with persons who played important roles that process, as well as histories of the process, both in print and online. Many of these interview subjects were identified from histories of the Internet's development; some were identified by the recommendation of other subjects. Some refused to participate. The interview process was neither as systematic nor as comprehensive as I would have preferred, but nonetheless traces the unmistakeable contours of the process by which TCP/IP became the Internet. Thus, against the above explanations, I argue that because the particular function of the Internet depends on the prescriptive norms embodied in TCP/IP, the spread of the Internet is best understood as a process of normative diffusion. To that end, I use Finnemore and Sikkink's model of norm diffusion as a template to identify both the entrepreneurs and organizational platform responsible for TCP/IP. I show that TCP/IP reached a tipping point in the early 1990s, and that accounts of the spread of the Internet which begin after this point only explain the internalization stage of its diffusion. I argue that it was the combination of 'academic freedom' and a relatively open political space in the Western bloc which gave TCP/IP its characteristics and allowed it to define the Internet.

III. The Emergence of TCP/IP

Finnemore and Sikkink define "norm" as "a standard of appropriate behavior for actors with a given identity" (1998, p. 251) --- that is, 'knowledge how' to behave. In their account of the “life cycle of norms”, Finnemore and Sikkink break the s-curve model of diffusion into three parts: emergence, cascade, and internalization, with the first two stages “divided by a threshold or 'tipping point' at which a critical mass of relevant state actors adopt the norm” (1998, p. 255). For TCP/IP, the 'relevant actors' are not so much states but the professional and academic computer users in each country. Thus TCP/IP was internalized not because states bureaucracies made official decisions to that effect, but because the technology became entrenched among the relevant users. Moreover, I argue that the 'tipping point' came in the early to mid-1990s, and the 'cascade' thereafter.

The focus of this account is 'emergence', which Finnemore and Sikkink break into two components: "norm entrepreneurs" and an "organizational platform" (Finnemore & Sikkink, 1998, pp. 255-256). Norm entrepreneurs are necessary because "norms do not appear out of thin air; they are actively built by agents having strong notions about appropriate or desirable behavior in their community" (256). Nor do norm entrepreneurs exist in thin air; instead, they "need some sort of organizational platform from and through which they promote their norms" (259). The norm entrepreneurs behind TCP/IP were a group of computer scientists working in the US and Europe in this period; their organizational platform was the U.S. Department of Defense's Advanced Research Projects Agency (ARPA). Though some of the scientists worked directly for ARPA, some did not --- yet nonetheless contributed to the development of TCP/IP and the Internet. The normative content of TCP/IP reflects their interests as computer scientists foremost; however, they were only able to realize those interests because of their situation within the Western bloc, which allowed them relatively unfettered interaction and collaboration; the scientists not only worked within that context, but exploited and shaped it to their advantage. The result is TCP/IP, the Internet, and everything that entails.

III.i. Entrepreneurs

The idea of an internet --- a network of networks --- emerged as the answer to a problem faced by researchers in the 1960s: universities and research institutions had computer networks, but these networks often could not communicate with one another. One solution would have been extensive overhaul and standardization of each institution's network to match every other institution's, with obvious expense and effort. Another solution was to develop technology that would allow each network to communicate with minimal reconstruction; the idea behind this technology, packet-switching, arrived in three places independently and nearly simultaneously.

In the U.S., Paul Baran's seminal paper, “Survivable Command and Control”, conceived of packet-switching as a way of building communications systems that could survive a nuclear conflict; in case one or several nodes of a packet-switching network were destroyed in a conflict, packets could be re-routed to maintain the communications link. His work was published in 1964 under the auspices of RAND, the Air Force connected think-tank, but the Air Force abandoned its interest in packet-switching when it learned the Defense Communications Agency would have to build it (Lukasik 2011, p. 9). The same year, Leonard Kleinrock published his PhD thesis as book, "*Communication Nets; Stochastic Message Flow and Delay*" (Kleinrock 1964); Kleinrock, unlike Baran, was not focused on the military problems of command and control, but rather on the academic problem of computer networking. Meanwhile, Donald Davies was looking at packet-switching in the United Kingdom. Davies, the head of the National Physical Laboratory (NPL), sought a way to maximize computer resources through time-sharing (Abbate, 1999, p. 8, 27). None of these efforts resulted in an operational packet-switched network, but all three would contribute to the development of ARPANET.

ARPANET was a project of the Information Processing Techniques Office (IPTO) in ARPA. The first director of IPTO, J.C.R. Licklider, was interested in networking problems and pointed the agency in the direction of a large-scale computer network --- which Licklider called the Great Intergalactic Network --- an effort continued by his successor, Ivan Sutherland (Lukasik 2011, p. 6). In 1965, Robert Taylor took over as director of IPTO (Barbour 1975, IX-57). Taylor soon began work on connecting the various research communities that IPTO sponsored; his goal, similar to Davies', was to make efficient use of the computers in the IPTO system, which he believed could be done through a network (Abbate, 1999, p. 44). The resultant program was called ARPANET and begun in 1968 under the management of Lawrence Roberts, "The concept's chief promoter, and by general agreement the individual with the most valid claim to be the 'father' of ARPANET technology" (Barbour IX-57); Roberts, meanwhile, attributes his interest in the problem to Licklider's work (Lukasik 2011, p. 11). The first nodes on ARPANET were established in 1969, at the Stanford Research Institute, UCLA, UC-Santa Barbara, and the University of Utah (Lukasik 2011, p. 13). All were sites of defense-related computing research, although none were involved in military operations.

Roberts succeeded Taylor as director of IPTO in 1969, and began looking for ways to spread ARPANET out of the US. In 1971, Roberts decided to mount a demonstration of the ARPANET at the 1972 International Conference on Computers, and asked Robert Kahn of Bolt, Beranek, and Newman to organize the demonstration. Among those in attendance was a graduate student named Vinton Cerf, who with colleagues was already working on the ARPANET at one of the first nodes at UCLA. Cerf recalls that the demonstration drew representatives from France, the UK, Sweden, Italy, including Donald Davies, Peter Kirstein of the University College - London, and Louis Pouzin, who ran the Cyclades packet-switching network through the Institute Recherche d'Informatique et d'Automatique (Cerf 1993). The demonstration was a success, and lead to the formation of the "International Network Working Group", with Cerf as chair (Moschovitis 1999, p. 76). Meanwhile, the obvious first choice for international connection was the U.K., where Donald Davies had established NPLNet under his leadership of the National Physical Laboratory. Unfortunately, a dedicated ARPANET line to the U.K. was prohibitively expensive, especially in light of the pressure on the Defense Department budget; moreover, Davies was also obligated by the British government to focus his efforts on the European Informatics Network (Kirstein 1998, p. 4). However, ARPA also had a branch called the Nuclear Monitoring Research Office (NMRO), which ran a project, "Vela", "to provide data U.S. policy makers could use in negotiations for a treaty banning all nuclear weapon tests" (Lukasik 2011, p. 17); to that end, NMRO maintained a seismic array in Norway, called NORSAR, to study the seismological differences between earthquakes and nuclear weapons explosions. While Roberts was looking for a way to extend the ARPANET to the U.K., Lukasik - deputy director of ARPA but also de facto head of NMRO - was looking for ways to transmit NORSAR data electronically to the U.S.; Lukasik asked Roberts to connect NORSAR to ARPANET, but Roberts used this as a means to introduce a connection to the U.K. as well. Lukasik, as it happened, "was delighted, because not only did I get my Norway link for seismic monitoring and network demonstration purposes (with my arms control hat on) but I also got a richer R&D program of the UK (with my networking hat on.)" (email to the author, 28 December 2010). Norway thus became the first international connection to the ARPANET. Peter Kirstein was then able to establish a U.K. node for the ARPANET at the University College of London. Kirstein first tried to develop support for the connection in the British computing community, but these attempts were unsuccessful; the Science Research Council and Department of Industry both denied Kirstein funding. Ultimately, the British Post Office and the NPL (specifically, Donald Davies using his NPL discretionary funds) provided the funding necessary to complete the link, which became operational on July 25, 1973 (Kirstein 1998, pp. 1, 5). British users had wide access to the ARPANET; the UCL-CS contract specifically stated that many users were necessary to test the network with real traffic, so almost any British academic user could log on to the network. By 1977, at least 30 distinct institutions within the United Kingdom were using ARPANET for a variety of projects and research. (Kirstein 1978, Table 8.1). Kirstein also "interconnected with many other European countries", but "this was mostly underground, so as to not make the US DOD upset" (Roberts, email to the author, 28 Jan 2000).

In 1973, Vinton Cerf, by then an Assistant Professor at Stanford, and Robert Kahn, then at DARPA[4], began collaborating on a paper titled "A Protocol for Packet Network Interconnection"; this paper became the basis for TCP (Waldrop 2001, pp. 378-380). TCP/IP was a project of ARPA, but not part of the ARPANET proper. Kahn had been recruited to DARPA specifically on promises that he would not be working on ARPANET in particular, but other forms of packet-switching network (Waldrop 2001, p. 376); Cerf likewise was deliberately working towards a protocol that would allow the entire world to be connected (Moschovitis 1999, p.82). In this Cerf had advice from Louis Pouzin, founder of the French packet-switching network CYCLADES.[5] It was Louis Pouzin's belief, implemented in TCP/IP, that the network hosts (that is, the users' computers) should "take on the primary responsibility for maintaining reliable connections", instead of assigning that function to network nodes (Abbate 1999, p. 125). Pouzin's motives may have been purely technical, but one of the consequences in delegating so much of the network function to hosts is that the network is far more resistant to centralized control; this is what Lessig means by 'disabling control'. TCP was functional in 1977, and in the following year, Xerox engineers suggested an addition --- namely, the Internet Protocol, “a separate program that handles the routing of individual messages” (Moschivitis 1999, p. 91). The main purpose of TCP/IP was to integrate disparate networks --- specifically, ARPANET and a satellite-linked packet-switching network called SATNET. The latter began with a connection to the UK in 1975, and continued with connections to Norway in 1977; this replaced the original cable link established in 1973. Connections to Italy and (West) Germany were added later (R. Kahn, email to author, 28 June 2000). In this sense, the connection between ARPANET and SATNET represented the first instance of 'an internet' --- later to become 'the Internet'.

The entrepreneurs behind TCP/IP were researchers and scientists working to connect their computers to one another; their ideas about how the network should work now pervade the Internet. It is striking how difficult it is to locate their activity in economic or bureaucratic explanations. Their work did not, for the most part, lead to riches or high promotion; instead, they seem motivated by a belief (Steven) Weber attributes to computer programmers in general, "that 'scientific' success will outstrip and outlive financial success" (Weber 2004, p. 140). This ethos not only encouraged the spread of TCP/IP through open source means, but also led users to attempt to access it even when not officially allowed: "at almost EVERY research site where there were students, the students figured out some way to hack the internet because it was the best game in town technically and it was free." (E. Feinler, email to the author, 28 Jan 2000).

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4 In 1973 ARPA's named was changed to the Defense Advanced Research Projects Agency (DARPA).

5 Louis Pouzin has written a brief narrative of his experience with networking in France, "Cyclades, ou comment perdre un marche" ("Cyclades, or how to lose a market"), published in *La Recherche* No. 328, fev 2000 (32-33), but it is not accessible to the author at present.

III.ii. Organizational Platform

The organizational platform for all this effort was the Advanced Research Projects Agency, or ARPA, in the U.S. Department of Defense, which was created under the Eisenhower administration as part of its response to the Soviet's launch of Sputnik. By the early 1960s, ARPA management was characterized by a "free-wheeling" style that contrasted sharply with its bureaucratic siblings in the U.S. government (Waldrop 2001, p. 199). This managerial style gave ARPA staff and contractors --- especially academic researchers in the computer sciences --- the flexibility to pursue ambitious projects within the scope of defense relevance. ARPA's position within the defense establishment also gave it access to resources and connections in Allied countries that were unavailable to other organizations. It is no coincidence that almost all nations directly connected before 1989 were either NATO members or Pacific allies of the United States[6] (see Table 1). At the most basic level, diffusion of the ARPANET and thus TCP/IP operated within the boundaries of political alliances in the Cold War.

Yet the inference that this diffusion is indebted to military necessity --- as mentioned in the introduction --- is false. The closest approximation of this conclusion available comes from Stephen Lukasik, deputy director and then director of ARPA during the ARPANET era:

> Why did ARPA build the network? [...] There were actually two reasons. One was that the network would be good for computer science. [...] This is by far the dominant reason among the researchers. But there was also another side of the story, which was that ARPA was a Defense Department agency. (Waldrop 2001, p. 279)

At the time, "defense relevance" had become the watchword in ARPA, meaning projects were required to have some conceptual relationship with military operations, at least on paper. This was in keeping with the precedent established by Lukasik's predecessor as director, Eberhard Rechtin, to maintain an institutional "low profile" to help ensure ARPA's survival as an agency, especially against critics within the Department of Defense (Barbour 1975 , VIII:3-9, IX-5). Says Lukasik:

> So in that environment, I would have been hard pressed to plow a lot of money into the network just to improve the productivity of the researchers. The rationale just wouldn't have been strong enough. What *was* strong enough was this idea that packet-switching would be more survivable, more robust under damage to the network. [...] So I can assure you, to the extent that I was signing the checks, which I was from nineteen sixty-seven on, I was signing them because *that* was the need I was convinced of. (Waldrop 2001, p. 279-280)

But whatever Lukasik's priorities, he nonetheless maintained the ARPA management style, giving his staff and contractors in IPTO significant latitude to pursue their interests, and "protected and encouraged what that office was trying to do" (Waldrop 2001, p. 330). The product of that office was thus an ARPANET that reflected academic interests more so than military necessity.

This is especially true of TCP/IP. Contrary to Abbate's assertion that "military concerns and goals were built into the Internet technology", (1999, 5) the peculiar design of TCP/IP was not due to military

6 The only exceptions were Finland and Sweden, whose connections were incidental to their neighbors', and Mexico. The NATO members missing from the table were likely able to connect via EUNet through the Netherlands' connection in 1988

Table 1. Connections to the ARPANET and NSFNET by Year and Affiliation

Country	Yr. connected	NATO at time?	OECD at time?
United States	1973	Yes	Yes
United Kingdom	1973	Yes	Yes
Norway	1973 (1988)	Yes	Yes
Germany	1985	Yes	Yes
Italy	1985	Yes	Yes
France	1985?	Yes	Yes
Canada	1987	Yes	Yes
Australia	1988		Yes
Denmark	1988	Yes	Yes
Finland	1988		Yes
Iceland	1988	Yes	Yes
Mexico	1988		
Netherlands	1988	Yes	Yes
Sweden	1988		Yes
Japan	1989		Yes
New Zealand	1989		Yes
Korea, Republic of	1989		
Argentina	1990		
Israel	1990		
Singapore	1991		
Tunisia	1991		
Austria	<1995		Yes
Belgium	<1995	Yes	Yes
Brazil	<1995		
Chile	<1995		Yes
Greece	<1995	Yes	Yes
India	<1995		
Ireland	<1995	Yes	Yes
Spain	<1995	Yes	Yes
Switzerland	<1995		Yes

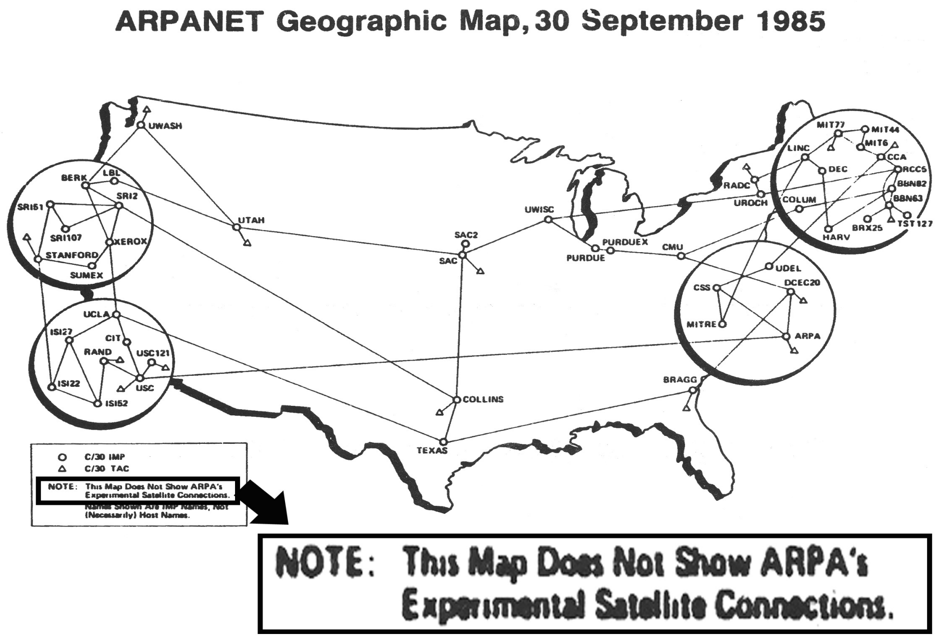
"Yr. connected" is based on the author's research; those connected '<1995' were probably connected by 1991, but the exact date is uncertain. Several European countries were connected simultaneously when the link to EUNet in the Netherlands was completed in 1988. Norway was connected to ARPANET for defense purposes in 1973, but use was restricted; Norway obtained a connection to NSFNET in 1988.

imperative, but to the very particular interests of academics like Vinton Cerf, Robert Kahn, Louis Pouzin, and others. Three facts point to this conclusion: first, Larry Roberts' plan for the ARPANET did not envision the ARPANET as an operational military communication system; Roberts states, "There never was a military restriction on the Internet" during his tenure at IPTO (Roberts, email to the author, 28 Jan 2000). Nor was ARPA networking technology classified, but instead openly published, meaning Soviet researchers --- though not connected to ARPANET --- could and did use TCP/IP technology in their own work (Lukasik, email to the author, 13 February 2011). Second, ARPANET already had an operating set of protocols in place before TCP/IP was developed, NCP (Abbate 1999, p. 67-68); the TCP/IP suite connected ARPANET to other networks, and vice versa, and would have been unnecessary for a military command-and-control network. Third, the relationship between ARPA networking and the Vietnam-era U.S. military was a source of tension for many of the American researchers; but instead of dismissing ARPA as a branch of the military, they saw it as "an extension of the research community itself" (Walrop 2001, 281). Kahn says of his work for DARPA, " if you look at the people in the trenches who were building the technology and doing it, they thought they were solving a technical problem. This was not a military problem that had some urgency...." (Cerf 2006, p. 41). And given tensions among American researchers, it is also difficult to see how foreign academics would be willing to participate in a defense-specific project. Instead, TCP/IP owed much more to the academy than the military. Abbate describes as "military values" features of the Internet such "survivability, flexibility, and high performance" (1999, p. 5), but the latter two are at least as much academic values. Abbate might also include universality, decentralization, and accessibility as manifest goals of the Internet's technology, yet these are decidedly not military concerns; moreover, TCP/IP was notably lacking in the cardinal military value, namely security. Lukasik says that, in retrospect, he "should have pushed harder for security hooks in the project", that the academics working on ARPANET were "too naive and honest to conceive of real bad guys" (email to the author, 15 December 2010). Abbate's dichotomy between military and commerce rings false; it ignores the academy, and the set of values academics brought to the design of the Internet.

In 1972 the Defense Communications Agency began a separate packet-switching network, called WIN, which did serve operational command and control purposes; soon thereafter, ARPA officials began exploring the possibility of transferring control of ARPANET to a private organization (Abbate 1999, p. 134). In fact, ARPANET had begun with the goal of transfer to private control in short order, but this proved "legally difficult" given the "heavily regulated communications field" in the U.S. (Barbour IX-59). Meanwhile, ARPANET's expansion into an "email service to its contractors[7] as well as supporting a networking research community" put the project afoul government regulations, which led to its transfer to DCA control in 1975 (Lukasik 2011, 16). Despite transfer to DCA, ARPANET remained an important research project, and it is curious that documents from this period barely acknowledge the existence and extent of foreign connections. Maps bear the legend, "This map does not show ARPA's experimental satellite connections" --- thus hiding all international activity (see Figure 1). One explanation is that the DCA did not control those satellite connections, which were part of SATNET and still an ARPA project (Salus, 1995, p. 80). Whatever the reasons for omitting SATNET's existence, probably dozens, perhaps hundreds of foreign academic, non-military users were already using TCP/IP by the late 1970s.

7 "Contractors" here includes universities and research organizations working on ARPA projects.

Figure 1. ARPANET Geographic Map, 30 September 1985 (Dennet et al 1985, p. 3)



In London, for example, Peter Kirstein was not officially permitted to extend his connection to other nations --- his Governing Committee specifically forbade it --- but sometime between 1982 and 1985, networks such as BITNet, UUNet, EUNet, and EARN began connecting to UK networks and the University College of London (see Table 2). This allowed users on those networks access to the ARPANET, to an extent not fully appreciated until Dr. Kirstein was requested to block “unauthorized traffic”; to comply, he sent a message to all recorded users over the previous six months --- from which he received angry responses from all over Europe (P. Kirstein, email to the author, 2000). In this way the entrepreneurs used ARPANET to pursue their interests, even at the expense of the U.S. governments interests in security and secrecy.

ARPANET was not the only means by which TCP/IP spread. DARPA officials in the 1980s allowed the incorporation of TCP/IP into a freely distributed Unix operating system called 4.2BSD (also called BSD Unix); the software was developed by computer scientists at UC-Berkeley's Computer Systems Research Group, which also received funding from DARPA (Weber 2004, p. 34). This, more so than official connections to ARPANET, lead to the spread of TCP/IP: "BSD UNIX was what Sun workstations ran, and Suns (along with VAXes running VMS with DECnet *and* TCP/IP) were the darlings of the research community and a *major* export item. It was a brilliant move on DARPA's part. Europe (and Japan) sucked up Suns and got infected with TCP/IP for free (as it were)." (S. Wolff, email to the author, 15 Dec 2010) Weber suggests that, "In a real sense, 4.2BSD lies at the foundation of the Internet as we know it today." (2004, p. 35). The spread of TCP/IP allowed researchers in other countries to develop local networks running the protocols, even where they could not access

ARPANET directly. In 1985, the five Nordic countries started NORDUNet to connect their national networks. As realized in the 1988, NORDUNet was a star-shaped network connecting Finland, Norway, Denmark, and Iceland to a hub in Stockholm, Sweden (R. Nordhagen; email to author, 2000). When NORDUNET began, "the most desired service was the entire TCP/IP protocol suite, with a connection to the U.S. widely wanted." (Quarterman 485), and the Stockholm hub was in fact linked to the NSFNet (S. Tafvelin; email to author, 2000). In 1989, EUNet established RIPE --- the "Reseau IP Europeen" --- to connect European users via TCP/IP, including FNET, NORDUNET, and also links to NSFNet (Quarterman 428).

TCP/IP service was also attractive to other US government agencies: the National Science Foundation (NSF) established the Computer Science Network (CSNET) to connect academic computer science researchers in the United States (Quarterman 295). CSNET was born of a proposal by Larry Landweber, at University of Wisconsin, which created a multi-protocol network that "included a provision to link the proposed CSNET with ARPANET. Vinton Cerf [at DARPA] not only proposed the link but urged that CSNET employ the TCP/IP protocol, thus making the link transparent"; Cerf explains that NSF only got involved with TCP/IP in 1980, "when it became obvious that being on the ARPANET was critical for universities" (Roessner et al 1997, Ch. IV). In fact, ARPANET began using *exclusively* TCP/IP in 1983, approximately the same time CSNET connected, which meant that CSNET had to support TCP/IP to connect to ARPANET (Roessner et al 1997, Ch. IV). NSF then signed a memorandum of understanding with ARPA in 1985 that allowed the NSF to connect up to forty academic institutions of their choice per year to the ARPANET, at a fee of $1 million per year - although this arrangement connected relatively few nodes (Steve Wolff; email to the author, 15 Dee 2010). Until 1985, ARPANET had been restricted to approved users; these restrictions denied a great many would-be users access to the network, though some people were able to use the ARPANET without official authorization, as seen in Peter Kirstein's experience. In 1986, NSF started NSFNET to be a general purpose academic TCP/IP network, built without ARPANET's restrictions along a different topology:

> By 1990, the NSFNET backbone had nodes at (I believe 13) universities where the emerging "regional" networks of the NSFNET attached to the backbone. And the regionals linked university campuses to the backbone. It was a 3-tier system - backbone, regionals, campuses - whose layout/topology had exactly *nothing* to do with ARPANET (that was in fact the whole point!). (S. Wolff, email to the author, 15 December 2010)

The establishment of NSFNET was a crucial step towards the modern Internet for two reasons. First, obviously, NSFNET helped connect many, many users via TCP/IP in a network that would become the Internet itself. Second, the academic nature of NSFNET's commitment reinforced and amplified the decisions regarding information and control embedded in TCP/IP. It suffered neither the restrictiveness of a military network nor the financial demands of a commercial network. In building NSFNET according to distributed topology, project managers[8] also worked against other government agencies that wanted more central control; even the ultimate decision to allow commercial traffic on the Internet was managed in a way to ensure it remained "the Internet", rather than degenerate into separate networks (Roessner et al 1997, Ch. IV).

8 Dennis Jennings was the first project manager for NSFNET, followed by Steve Wolff.

In 1990 ARPANET was decommissioned; by this point, CSNET/NSFNET had links to “Australia, Finland, France, Germany, Israel, Japan, Korea, New Zealand, Sweden, Switzerland, the United Kingdom, and the People's Republic of China” (Quarterman 295) - among others. By May 1995, NSFNET no longer ran the Internet, which "was 'owned' by no one"; control of the main research backbone was turned over the MCI, and myriad subnetworks were run by commercial, academic, and non-profit groups. (Roessner et al 1997, Ch. IV). The Internet was already an international phenomenon, with its decisions about political control firmly entrenched in TCP/IP technology.

IV. Competitors to TCP/IP

The emergence of TCP/IP as the dominant international networking technology was not foreordained. Even within ARPANET, TCP/IP was one of two possible technologies --- the other being Network Control Protocol, or NCP (Cerf 1993). In 1983, ARPA made TCP/IP the mandatory protocols for the entire ARPANET and connected networks; “by spring [of 1983] any system that has not converted is bumped off the network”, and his had world-wide ramifications. At the same time, the use of the term “Internet” to describe the TCP/IP landscape was made official, as the DCA split ARPANET into MILNET (for the military only) and the civilian Internet. (Moschivitis 1999, 110)

Outside of ARPA, still more alternatives to TCP/IP were in development. These included proprietary products developed by commercial interests: IBM developed Systems Network Architecture (SNA) in 1974, Xerox offered Xerox Network Services in 1975, Digital Equipment Corporation introduced DECNet that same year, and other companies introduced later products (Abbate, 1999, p. 153). The proliferation of commercial networking software only reproduced the problem TCP/IP was designed to solve --- an array of networking protocols that were not interoperable. Worse, these were not open source technologies --- unlike TCP/IP.

The proliferation of network technologies led to the development of two technical standards for internetworking. The first, X.25, came from the Consultative Committee on International Telegraphy and Telephony (CCITT), an organization of national telecommunications providers.[9] It was initially a response to IBM's SNA, which many telecoms feared would allow the computer maker to dominate the market (Abbate, 1999, p. 153). American representatives to the CCITT suggested TCP/IP as a possible standard, but that was "flatly rejected" (Abbate, 1999, p. 153); the national telecoms opposed the normative decisions about network architecture reflected in TCP/IP. The standard they promulgated instead reflected their interests; where TCP/IP gave the balance of control to the hosts (end users' machines), X.25 gave control to the network nodes. This model favored the telecoms, and was similar to the way telephone exchanges operated. Because the CCITT only approved standards in plenary sessions held every four years, the ad hoc committee working on X.25 had to work quickly to ensure that it would be ready for the 1976 plenary meeting. As a result, X.25 was not as well-developed as it could have been, nor was it as tested or reliable as TCP/IP. Nonetheless, it was deployed for a time, and became the basis for many important networks, but TCP/IP was faster; some networks were configured to allow TCP/IP to work over X.25 links (Quarterman 425).

Development of the second standard began in 1978, when some members in the International

9 Robert Kahn (email to the author, 28 June 2000) writes that SATNET was developed in part because "the complexities of connecting more lines was too great at that point due to CCITT rules."

Standards Organization began work on Open Systems Interconnection, or OSI (Abbate, 1999, p. 168). OSI was not itself a protocol or software package, but a model that described how networks should interact across seven layers of protocols. Given the influence of the ISO, "the OSI framework was quickly endorsed by standards bodies in all the countries that were involved in computer networking"; this included the United States, where even the Defense Department made an effort to incorporate OSI into the ARPANET (Abbate, 1999, p. 171). However, the OSI model did not prescribe specific standards for each layer of protocol, out of concern that such standards might "prematurely freeze innovation" (Abbate, 1999, p. 169). The model was to be filled by protocol standards as they were developed and proven.

Initially, the ISO rejected TCP/IP as an international standard out of fear of U.S. dominance (Abbate, 1999, p. 174), but in many cases the OSI model allowed users of pre-existing network protocols to adapt their protocols to the OSI model, including TCP/IP users; by the mid-1980s, a version of the protocols were approved as standards for their respective layers in the model (Abbate, 1999, p. 175). Had OSI succeeded to the exclusion of TCP/IP, “Europe would have been an island, connected to the Internet via gateways with limited functionality,” says Piet Beertema (email to the author, 2000). Although exclusion of TCP/IP did not happen, it was a very real threat, but ultimately the debate was settled by the users themselves. Those who recognized the value of the TCP/IP protocols got involved in the standards-development process and saw to it that OSI was reshaped to include TCP/IP. For some layers of the OSI model, however, no protocols were developed for many years, leaving users in the early 1980s with a fairly simple choice when it came to building networks: TCP/IP, which was well-developed and supported; or OSI, which was still incomplete (Abbate, 1999, p. 178). By 1990, Quarterman could still complain that OSI lacked “implementations of the necessary protocols” (433). By 1992, OSI was "clearly dead" (Salus, 1995, p. 226).

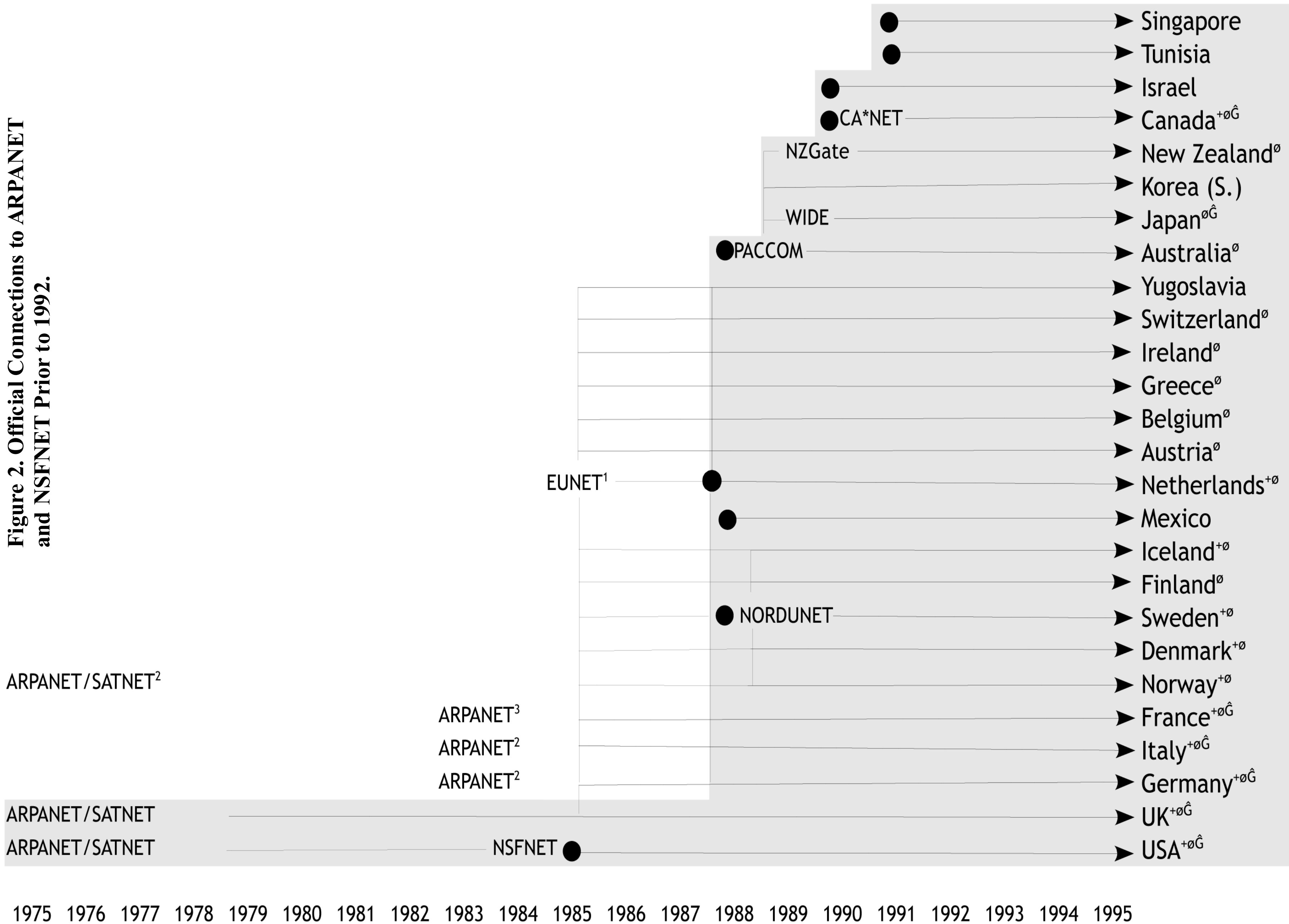
As TCP/IP was developing, other networks were spreading throughout the world. Most of these were based on dial-up software included in various computer systems. For example, BITNet was developed from a file-sharing protocol included in certain IBM computers. UUCP, included with AT&T’s Unix programs, was the basis for several networks including Japan’s JUNet and the European Academic Research Network (EARN) (see Table 2). These networks were called “store and forward”: they connected users' computers over regular telephone lines. A user would set his computer to dial a central computer at a given time to receive and send e-mail or files. Since BITNet and UUNet required only a computer, modem, and a telephone line—all easily attainable—these networks spread rapidly across the globe. The spread of these networks had important consequences for the Internet: store-and-forward networks created demand for the kinds of services provided by the Internet. The store-and-forward model's major drawback was that messages were not sent in real time: users usually set their computers to send and retrieve on a 24-hour cycle. They could also be expensive: making long-distance phone calls via modem to distant computers was not cheap. In most cases, store-and-forward networks were steps or stopgaps towards TCP/IP connectivity. For example, Japanese academics began JUNet in 1984, and connected it to USENET in 1985 and CSNET in 1987 (J. Kanetaka, email to author, 2000). In 1986, the same group of researchers began a TCP/IP network called Widely-Integrated Distributed Environment (WIDE); WIDE became part of the PACCOM project, and realized Japan’s connection to the Internet in 1989 (Murai, 1996). Along similar lines, as Internet connectivity exploded in the 1990s, many of the alternative networks were either discontinued or subsumed into the larger network.

Table 2. Internet precursor, associated, and similar networks, 1969-1989

Network	Protocol	Funded by	Use	Yr. begun
NPLNET	packet switching	U.K.	research	before 1969
ARPANET	TCP/IP	U.S.	research, gov't	1969
CYCLADES	packet switching	France	research	early 1970s
SATNET	TCP/IP	U.S.	research	1975
USENET	UUCP	users	public	1979
EUNET	X.25, later TCP/IP	users (Europe)	academic	mid 1980s
ACSNET	UUCP	Australia	academic	1980s?
SPEARNET	X.25	Australia	academic	1980s?
CSNET	TCP/IP, X.25	NSF (U.S.)	academic	early 1980s
BITNET	IBM protocol	users	academic	1981
FIDONET	Fido protocols	users	public	1984
EARN	UUCP	users (Europe)	acad., research	1984
JUNET	UUCP	corporations (Japan)	academic	1984
NSFNET	TCP/IP	NSF (U.S.)	academic	1986
NORDUNET	X.25, also TCP/IP	Nordic countries	academic	1986
UUNET	UUCP	commercial	commercial	1987
WIDE	TCP/IP	Japan	acad., research	1988

Source: author's research. This list is by no means comprehensive. Note that OSI and X.25 were standards, akin to TCP/IP, and not themselves networks. NSF stands for National Science Foundation.

Figure 2. Official Connections to ARPANET and NSFNET Prior to 1992.



Key to superscripts: + = NATO ; ø = OECD ; Ĝ = G7 (all at time of connection; e.g. Mexico is presently a member of the OECD, but was not in 1988)

1 EUNET initially did not support TCP/IP, but a connection to NSFNET was created in 1988 through the Netherlands
2 Norway's connection to ARPANET was limited to military use.
3 Connections to ARPANET may have been limited to defense use; countries were also part of EUNET, and connected to NSFNET when the Netherlands connected.

V. The TCP/IP Tipping Point

Finnemore and Sikkink posit that widespread adoption --- the "norm cascade" --- occurs after a "tipping point", at which acceptance of the norm has reached "critical mass" (1998, p. 261). In determining the tipping point of diffusion processes, Finnemore and Sikkink identify two salient issues. The first is that the tipping point "rarely occurs before one-third of total states in the system adopt the norm". Second, "it matters which states adopt the norm" (1998, p. 261). By these criteria, the tipping point for TCP/IP and the Internet occurred sometime in the early mid-1990s: by 1995 nearly every major industrialized nation-state was connected through TCP/IP to the Internet (See figure 2).

The key period for Internet expansion occurs between NSFNET's establishment in 1986 and turnover in 1995. In 1990, Quarterman reported of the Internet, “Estimates of numbers of hosts range from 40,000 to 500,000, and of the number of users from 500,000 to more than a million” (Quarterman 1990). ISC surveys the same year returned some 313,000 hosts, meaning computers attached to the Internet. In 1992, the survey returned 727,000 hosts spread across 33 ccTLDs[10] --- approximately one-sixth of countries in the world at that time. A similar survey by RIPE in late 1990 found more than 31,000 active hosts in 19 countries across Europe, the Middle East, and part of Asia (RIPE 1990). It is clear that the TCP/IP-based Internet was already an international phenomenon by the early 1990s; no other protocol suite was anywhere near as widely used.

If this is true of the Internet alone, it is doubly so when related networks are counted. Landweber's (1991) data on international networking shows 50 countries with significant links to international networks (either the Internet, FIDONET, UUCP, or BITNET) and a total of 91 with at least some form of international network connection. These represented about one-quarter and almost half, respectively, of the countries in the world in 1991. Moreover, users on the Internet could communicate with users of BITNet, UUCP, and other networks --- and vice versa (Quarterman 281). By 1991, some form of international network connection utilizing TCP/IP was available in nearly every developed society - and a great many developing countries, too.

More important than simple quantity is the second aspect Finnemore and Sikkink identify: *which* states adopted TCP/IP. By 1991, the countries connected to the TCP/IP Internet including most of NATO, most of the OECD, and all of the G-7 (see Table 1 and Figure 2); that is, an overwhelming majority of what Finnemore and Sikkink call "critical states" were already connected to the Internet. Furthermore, most of the critical *users* --- especially academic computer scientists - in these countries were using TCP/IP. Even in Europe --- where official resistance to TCP/IP was particularly severe --- "researchers were either for or were forced to use the open system because of the nature of their contracts. They then grew to know and love the open system approach." (Feinler, email to the author, 28 January 2000) By 1991, the Internet had a significant presence in nearly every developed country, but it was still dominated by academic and research interests, and would not become an economic phenomenon until the late 1990s. Given the entrenchment of TCP/IP in the developed world and especially among computer scientists, it is difficult to imagine that any sort of internet could have replaced what was already *the* Internet by the early 1990s.

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10 That is, Country Code Top Level Domains – the two letter indicators indicating a specific country, e.g. “.fr” for France. While the US has a CCTLD (.us), most US-based websites use .com, .org, .net, or .edu .

V. Conclusion

The spread of TCP/IP is essentially the spread of the Internet, a process accomplished by academics operating in a political space of relative freedom and mobility across international boundaries, a space created by the structure of U.S. alliances during the Cold War. The spread of knowledge, especially technology, often occurs in such politicized contexts, and recognizing the normative content of technological knowledge allows the political scientist to grasp questions that might otherwise be beyond reach. If a given technology facilitates one kind of political or social arrangement while precluding others --- as does TCP/IP --- this is of definite concern to political scientists.

Without government interference, the entrepreneurs behind the network were allowed to impose their interests and values on the technology. The result is characterized by prescriptive norms which are very typical of academia --- and in fact, reflect the academic's desire for “freedom of inquiry and research” (AAUP 1915). This is not say the Internet is founded on a universal concern for human freedoms; academic freedoms have always been, “ an attempt to protect the interests of a particular occupational group”, even if “that group espouses and, at best, practices important values - intellectual honesty, scholastic rigour, self-examination, respect for divergent views, etc.” (Nixon 2001, 175). But in creating ARPANET, and then pushing its diffusion, these academics have allowed users around the world a degree of freedom perviously known only to the academics themselves. The extension of that freedom to a world of people and institutions who do not recognize it or accept it is both the power of the Internet, and its challenge to international politics.

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