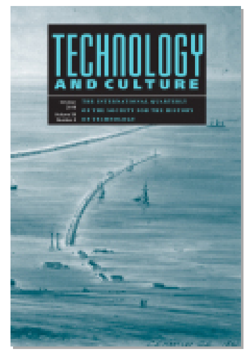
Financial and Administrative Infrastructure for the Early Internet: Network Maintenance at the Defense Information Systems Agency



Bradley Fidler, Andrew L. Russell

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Financial and Administrative Infrastructure for the Early Internet

Network Maintenance at the Defense Information Systems Agency

BRADLEY FIDLER and ANDREW L. RUSSELL

ABSTRACT: Popular and scholarly histories of computer networking often focus on technical innovation and the social impact of those innovations. These histories are marked by a contradiction, namely, failing to explain the existence of the infrastructure that they must ultimately use as evidence for the success of innovation, and the conduit of its social impact. The story of the U.S. Defense Advanced Research Agency's (DARPA's) Arpanet, and the role of both in the invention of the modern Internet, is a central archetype of this genre. Taking our lead from recent work in infrastructure and maintenance studies, we propose a methodological and ontological inversion of Internet historiography—centering our explanation around the infrastructure that is assumed but not explained in innovation-centric accounts. We do so by focusing on the U.S. Defense Communications Agency (DCA; now the Defense Information Systems Agency), which is traditionally cast, *contra* DARPA, as a conservative enemy of innovation. We explore its maintenance of the financial and administrative infrastructure necessary for the Arpanet to function as a contribution to broader histories of network infrastructure.

Introduction

Scholars of technology and computing history are by now familiar with historical accounts of the Arpanet and the Internet. Their familiarity is built

Bradley Fidler is assistant professor at the Stevens Institute of Technology, where he studies and consults on the politics of internet naming, addressing, routing, and security. His first book, with the MIT Press, will be out in 2019. Andrew L. Russell is professor of history and dean of the College of Arts & Sciences at SUNY Polytechnic Institute in Utica and Albany, New York. He is the author of *Open Standards and the Digital Age: History, Ideology, and Networks* (Cambridge University Press, 2014) and co-editor with Robin Hammerman of *Ada's Legacy: Cultures of Computing from the Victorian to the Digital Age* (Morgan & Claypool, 2015). The authors wish to thank Suzanne Moon, Alexander McKenzie, and three anonymous *Technology & Culture* reviewers for their helpful insights. Any remaining errors are the authors' responsibility.

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upon a foundation of research published in the mid- to late-1990s.[1] These works—to which we refer here as the first generation of Internet histories—introduced readers to an acronym-heavy sequence of historical and technological relationships. The Advanced Research Projects Agency (ARPA; referred to throughout as DARPA), together with Bolt Beranek and Newman (BBN), built the Advanced Research Projects Agency Network (Arpanet) in 1969, atop which the foundational Internet protocols that would become known as Transmission Control Protocol / Internet Protocol (TCP /IP) were tested famously in 1977. The Internet proper was born in 1983, a network of networks whose traffic flowed via the TCP/IP protocols; the National Science Foundation created a new backbone in 1986, the National Science Foundation Network (NSFNET), which it privatized in the early 1990s. With this infrastructure in place, further impacts ensued: applications appeared that used the Internet as a platform, most notably the World Wide Web, which emerged out of the European Organization for Nuclear Research (CERN) in 1991. In the more popular version of this story, one can drop the acronyms: a small number of (military-sponsored) pioneers built the Internet; Internet users, in turn, developed techniques and devices to exchange text, audio, and video that enabled new forms of human and machine interaction. The story, told in these ways, is rendered into a familiar tale of invention and societal impact, where the clever tricks of a small band of unlikely pioneers triggered waves of innovation that, in turn, are only beginning to ripple through, disrupt, and fundamentally transform societies.

As is common with the first generation of histories of any phenomenon, the first generation of Arpanet and Internet histories explained much, but at the same time left questions unanswered and paths unexplored.[2] By the 2000s, a second generation of scholarship explored international Internet histories, failures in packet-switching technologies, the uneven diffusion of computer networks, and many other complexities in social, cultural, political, and economic formations that took shape in and around the Internet.[3] This article takes its inspiration from the revisionist ethos of the second generation of Internet histories, especially their turn away from the hagiographic tone present in many of the journalistic accounts of the

1. Janet Abbate, *Inventing the Internet*; Ronda Hauben and Michael Hauben, *Netizens*; Matthew Lyon and Katie Hafner, *Where Wizards Stay Up Late*; Arthur Norberg, Judy O'Neill, and Kerry Freedman, *Transforming Computer Technology*; Neil Randall, *The Soul of the Internet*; Peter Salus, *Casting the Net*; Stephen Segaller, *Nerds 2.0.1.*

2. Roy Rosenzweig, "Wizards, Bureaucrats, Warriors, and Hackers"; Martin Campbell-Kelly and Daniel Garcia-Swartz, "The History of the Internet"; Thomas Haigh, Andrew Russell, and William Dutton, "Histories of the Internet"; Andrew Russell, "Hagiography, Revisionism & Blasphemy"; Russell, *Open Standards and the Digital Age.*

3. Lisa Nakamura and Peter Chow-White, *Race After the Internet*; Eden Medina, *Cybernetic Revolutionaries*; Slava Gerovitch, "InterNyet"; Manuel Castells, *The Rise of the Network Society*; Lawrence Lessig, *Code*; Finn Brunton, *Spam*.

first generation. However, where much of the second generation turned away from the Arpanet and the defense-funded ecosystem to focus on the many other networks that were once on the margins of the Internet narrative, our attention in this article is the consensus narrative that links DARPA to the Arpanet, and to the Internet.

We propose a methodological and ontological reversal in the history of networking. We aim to prioritize infrastructure and its maintenance as the ontological primitive to be explained—and to leave innovation aside as a taken-for-granted process for which explanation is unnecessary. As such, we will trace out the first steps at a history of the maintenance of network infrastructure, using the archetypical case of the Arpanet and its place in the early Internet as our case study. In many ways, the thing we seek to explain—the historical existence and significance of the Arpanet, for example—is the same ostensible explanatory goal of innovation-focused accounts. However, these innovation-focused accounts rely on infrastructure as evidence of successful innovation, and as the conduit linking innovation with its social impact. For example, innovation does not explain how the Arpanet continued to exist as an infrastructure after DARPA researchers accomplished its original purpose of demonstrating packet switching and resource sharing. Nor does the ingenuity of an innovation or cluster of innovations explain the failure of other feasible technologies to propagate. As such, they make the implicit (if unconscious) argument for the study of infrastructure as a crucial methodological and ontological position—one that we pursue explicitly here.

The key institutional site of our story is the U.S. Defense Communications Agency (DCA). The Department of Defense (DoD) created the DCA in 1960 as an outcome of the Defense Reorganization Act of 1958, in part to centralize military communications and to create communication systems that were global, common-user, and interoperable.[4] In 1975 the DCA took over management of the Arpanet (1969–89) from DARPA, a research agency which was ill-suited to maintaining an operational infrastructure. The DCA managed the Arpanet through a period of expansion, from the 55 nodes it inherited in July 1975 to 95 nodes in December 1983.[5] During that period, the number of Arpanet "hosts" (mainframe, time-shared computers) rose from 94 in June 1975 to 561 on 19 January 1983.[6] In Arpanet and Internet history, 1983 is a watershed in that a Department of Defense policy saw the adoption by all Arpanet hosts of the TCP/IP protocol suite—thus formalizing the Arpanet's emergent role as the Internet backbone. It also marked the DoD's creation of the Defense Data Network (DDN), a

4. David Pearson, *The World Wide Military Command and Control System*. DCA was reorganized and renamed as the Defense Information Services Agency (DISA) in 1991, after the conclusion of Operation Desert Storm.

5. Stephen Lukasik, "Why the Arpanet Was Built."

6. SRI NIC, "DoD Internet Hosts Table," 19 January 1983.

military Internet run by the DCA, for which the civilian component, centered around the Arpanet, functioned as a testbed.[7] As part of this transition, the military Arpanet nodes were reconnected on their own MILNET, which carried unclassified traffic for the DDN. By February 1986, just prior to the National Science Foundation Network's (NSFNET's) hosts joining the Internet as part of a second backbone, a total of 2,169 hosts were publicly listed as connected through the Internet, with the Arpanet at its center.[8] (The civilian Internet was commonly referred to as the "ARPA Internet" until the involvement of the NSF and NSFNET, a term we will deploy here to refer to the Internet from its emergence in the late 1970s until 1986.)

We call attention to three ways in which the Arpanet and ARPA Internet can be understood as historically significant. First, the development of the range of technologies required for the Internet to function at scale requires the capacity to test them extensively, at scale. Thus the Arpanet served as testbed for everything from host protocols to routing algorithms to electronic mail, both for its own technologies and for those of the ARPA Internet. Put in innovation-centric terms, the infrastructure of the Arpanet and ARPA Internet created the technical environment in which innovation could take place—and it was managed by the DCA. Second, the Arpanet and ARPA Internet provided the technical scaffolding around which a generation of engineers formed an "Internet community" that fought for DARPA's Internet technologies and against its international competitors, expanding dramatically "Internet governance" from its origins in DARPA's Information Processing Techniques Office (IPTO) to the Internet Configuration Control Board (ICCB) of 1979, the Internet Activities Board (IAB) of 1984, and the Internet Engineering Task Force (IETF) of 1986.[9] Third, this combined sociotechnical momentum made the National Science Foundation's adoption of TCP/IP for its NSFNET a virtual inevitability, thereby facilitating the next phase of the Internet's rapid growth—which ultimately led to the defeat or absorption within the Internet of competing internetworking and computer communication histories, and the convergence of the "Internet" with terms like "cyberspace" that typically denote the totality of the online world. As we will argue, infrastructure and infrastructure maintenance was required for the Arpanet and ARPA Internet based around it to serve these historical functions.

Infrastructure and Maintenance in Histories of Technology

Before we move on to the DCA and its roles in Internet history and historiography, some elaboration on our central themes of infrastructure and

7. Lee Maybaum and Howard Duffield, "Defense Data Network"; Lee Maybaum Oral History, April 2015, in COHR.

8. SRI NIC, "DoD Internet Hosts Table," 5 February 1986.

9. Russell, *Open Standards and the Digital Age*.

maintenance is in order. The infrastructure concept has attracted substantial scholarly attention in recent years, evident in publications and meetings on the concept by anthropologists, historians, literary scholars, and a variety of other humanists and social scientists.[10] We follow these and many other scholars who have framed their focus on infrastructure in stark contrast to conventional attention—common both in academic and popular writing—on invention and technological innovation. The processes of infrastructure growth and maintenance have profound societal significance, not only for computer networks by also for vital technological systems. Unfortunately, breakdowns in railroads, water, and energy pipeline infrastructures are common occurrences. Furthermore, the emergence of complex governance structures for these systems—structures that encompass multiple stakeholders from a variety of nations and groups in the public and private sectors—calls for historical explanations that take mundane developments as vital inputs.

While our project is a critical intervention into Internet historiography, it is also an effort to illustrate concepts of broader and more general interest to historians of technology. One of our conceptual starting points is present in the work of David Edgerton, who urged historians of technology to move beyond their traditional preoccupation with invention and innovation. We follow Edgerton's call to pay closer attention to technologies-in-use, to shift scholarly attention from the spectacular to the mundane, and to reconsider the significance of technologies that we might otherwise disparage as "old."[11] Edgerton's treatment of the subject of maintenance provides a stark example of his departure from the invention and system-building approach pioneered by Thomas Hughes. In *The Shock of the Old*, Edgerton features an entire chapter on maintenance; by contrast, the term "maintenance" is barely an afterthought in Hughes's landmark book *Networks of Power*, appearing only five times in 465 pages of text.

A growing literature around maintenance in other disciplines likewise represents a conscious effort to bring to the fore people and groups often obscured amid popular emphasis on innovation. For example, social scientists such as Craig Henke, Stephen Jackson, Stephen Graham, and Nigel Thrift link the concepts of maintenance and repair, and emphasize their importance in the context of failure and breakdown across a wide variety of modern social and technological systems. And the philosopher Nancy Fraser applies insights from feminist ethics to the problem of social reproduction—that is, care for and maintenance of social bonds and shared understandings within households and across broader communities. One conclusion from this literature is that between inventors and users—two

10. Ashley Carse et al., "Keyword"; Stephen Collier, James Mizes, and Anita von Schnitzler, "Preface."

11. David Edgerton, *Shock Of The Old*; Edgerton, "Innovation, Technology, or History."

canonical categories for historians of technology—there are vast networks of maintainers, or people whose expertise and effort sustains social and technological infrastructures.[12]

Our second conceptual starting point comes from work in "infrastructure studies," a recent coinage for interdisciplinary work on the dynamics of technological systems that sustain modern societies—and that users often take for granted. Scholarship in this area regularly invokes the notion of an "infrastructural inversion," described with great clarity by Geoffrey Bowker and Susan Leigh Star as "learning to look closely at technologies and arrangements that, by design and by habit, tend to fade into the woodwork (sometimes literally!)."[13] In a series of books and articles, often developed through interdisciplinary collaboration, historian Paul Edwards has developed useful conceptual language as well as a wide range of case studies that show how technological and human components form infrastructures, such as computerized global climate models, scientific cyberinfrastructures, and platforms such as Facebook and Google. We follow Edwards's distinction between Hughesian "large technical systems," where there are system builders whose motives and actions can be identified with relative ease; and networks or webs that defy "the desire for smooth, system-like behavior" as they struggle to "combine capabilities no single system can provide."[14] We note, following Plantin et al., that the history of the Arpanet and Internet can be understood as the transition from large technical system to network to internetwork.[15] The power of the accounts that Edwards and others have provided lies in part with their ability to highlight the social and technological points of friction that frustrate efforts to create smooth systems and seamless webs. In the account that follows, we highlight several of these points of friction present as the Arpanet moved partially out of DARPA's jurisdiction, and DCA managers took steps to develop it as network infrastructure.

Our emphasis on infrastructure and maintenance can provide avenues for thinking in closer and clearer ways about the power relations and labor relations that constitute technological systems. Through infrastructures, we can think more about human agency—that is, where human action is deliberate, and where social and technological systems follow logics that

12. Andrew Russell and Lee Vinsel, "After Innovation"; Pierre-Claude Reynard, "Unreliable Mills"; Christopher Henke, "The Mechanics of Workplace Order"; Stephen Graham and Nigel Thrift, "Out of Order"; Ignaz Strebel, "The Living Building"; Steven Jackson, "Rethinking Repair"; Jérôme Denis and David Pontille, "Material Ordering and the Care of Things"; Jérôme Denis, Alessandro Mongili, and David Pontille, "Maintenance & Repair in Science and Technology Studies."

13. Thomas Hughes, *Networks of Power*; Paul Edwards, "Infrastructure and Modernity"; Geoffrey Bowker and Susan Star, *Sorting Things Out*; Geoffrey Bowker et al., "Toward Information Infrastructure Studies"; Steven Jackson et al., "Understanding Infrastructure."

14. Paul Edwards, *A Vast Machine*.

15. Jean-Christophe Plantin et al., "Infrastructure Studies Meet Platform Studies."

humans initiate. In a recent essay on "information labor," for example, Greg Downey remarks that "users tend not to see it . . . information laborers of all sorts are likely to be hidden, out of sight and out of mind, from those who encounter their products and processes on a daily basis."[16] The task for scholars of infrastructure, then, is not merely to dwell on the materiality of infrastructure—an important topic on its own right, to be sure—but to dig deeper and uncover the humans who keep things going.[17] Downey summarized his approach with a set of questions—"who does what kind of information work, when and where and why?" In this article, we seek to highlight the labor and institutional struggles hidden by prevailing narratives that fixate on invention and innovation narratives around the Internet.

The Defense Communications Agency in Histories of the Internet

Where the DCA does appear in the first generation of Arpanet and Internet histories, it usually appears as a villain and impediment to innovation and a foil to the disruptive innovations sponsored by DARPA. More specifically, historians characterize DCA as a technologically conservative Arpanet custodian. In these interpretations, we find that authors drew heavily on firsthand accounts of the participants in these histories. These firsthand accounts were not wrong, but nonetheless they were not contextualized or evaluated critically.

The DCA's biggest sin, in Internet histories, is its technological conservatism, which is offered as the reason that a packet-switched network like the Arpanet was not built sooner. A major source for this interpretation is Paul Baran, a pioneer of early analytical and architectural work on distributed and packetized communication networks. In a 1990 interview with Judy O'Neil, Baran explained why he would sooner not create a packet-switched network in the early 1960s, rather than let the DCA attempt it:

> this early DCA had near zero technical competence in digital technology. . . . Even in 1966, the DCA was extremely weak in technology. If you were to talk about digital operation they would probably think it had something to do with using your fingers to press buttons. . . . I felt that they could be almost guaranteed to botch the job since they had no understanding for digital technology, nor for leading edge high technology development. . . . We found ourselves agreeing that DCA should not be given the funds to proceed, as the chance of their success would be too low to justify the risk.[18]

16. Greg Downey, "Making Media Work," 148.
17. Nathan Ensmenger, "Computation, Materiality, and the Global Environment."
18. Paul Baran, "Oral History Interview with Paul Baran."

Baran was interviewed for Hafner and Lyon's popular *Where Wizards Stay Up Late*, and repeated his account. Interviewed again for Randell's 1997 book *The Soul of the Internet*, Baran elaborated on his view of the DCA as a "bureaucratic brick wall" for packet-switched defense networks: "Everything had to be built by the Defense Communications Agency, which was at the time a group of incompetent old communications people."[19] Larry Roberts, Chief Scientist at DARPA IPTO and responsible for the early planning and management of the Arpanet, provides a similar, if more visceral, account of the DCA's relationship with the early and unproven packet-switching technology:

> They [DCA representatives] even stood up in meetings when I made speeches and booed and hissed and made nasty comments, because they just could not get their mind into a new focus, that this was popular work. . . . I remember meetings where people just were caustic.[20]

These interpretations set the tone for the treatment of the DCA in first generation Arpanet and Internet histories.

The second major theme of the DCA's role in Arpanet and Internet history casts the DCA as an agency with a minor, custodial role. When the time came to transfer operational responsibility for the Arpanet away from DARPA, which was not a suitable home for operating and maintaining a network, the first consideration was private sector organizations.[21] According to Hafner and Lyon, one candidate was the networking startup Telenet—a spinoff from BBN—but when Roberts became Telenet president, the conflict of interest was too evident to ignore.[22] Abbate's *Inventing the Internet* also describes plans to move Arpanet to a private company in the hopes that it would stimulate commercial activity and competition in the nascent computer networking industry.[23] The obvious choice for this role was AT&T, the giant of American telecommunications, but AT&T managers declined. In *A Brief History of the Future*, Naughton relays Baran's recollection of the early 1960s, when an AT&T executive reacted harshly to the notion of a packet-switched network.[24]

19. Randall, *The Soul of the Internet*, 11.

20. Lawrence Roberts, "Oral History Interview with Lawrence G. Roberts."

21. A study chaired by Paul Baran made recommendations on the transfer of the Arpanet to the private sector. Paul Baran et al., *ARPANET Management Study*.

22. In *Where Wizards Stay Up Late*, Hafner and Lyon suggest that the Arpanet might have gone straight to the private sector in 1972 were it not for Roberts's move to Telenet, which created a conflict of interest in the only viable home for the network.

23. Abbate, *Inventing the Internet*, 135.

24. John Naughton, *A Brief History of the Future*, 32. See also Lawrence Lessig, *The Future of Ideas*, 32. (Note Lessig's emphasis on the word "allow," which he and Naughton both interpret as a sign of AT&T's arrogance and, more boldly, to defend the notion that "monopolists don't innovate.")

With all private avenues seemingly exhausted by 1975, DARPA turned to DCA to provide operational oversight for the Arpanet. To refer again to Abbate's account: "ARPA would continue to provide funding and technical direction, and access would be open to DoD users and to government contractors approved by the DCA. The agreement left the fate of the network after three years unresolved, since DARPA still hoped to find a home for the Arpanet outside the government."[25] In some accounts of Arpanet history, the DCA itself does not appear as a significant actor in the 1975 handover. For example, Norberg and O'Neil's 1996 book *Transforming Computer Technology* only mentions the DCA as "the DOD [Department of Defense]." In Salus's *Casting the Net* of one year earlier, the DCA appears in much the same way—merely the Arpanet's new bureaucratic host.[26] For Thomas Parke Hughes, this transition marked a new phase of stability in Arpanet history—the "post-innovation" era that presumably signaled the end of the interesting part of the story.[27] While differing in emphasis, these works all link the discovery and innovation process with its subsequent social impact: for example, packet-switched networking with the Arpanet's transformation of computer networking, or TCP/IP with the social impacts of the Internet.

The major exception to the overall themes we have identified, where the DCA barely features in the first generation of Arpanet and Internet histories, is Janet Abbate's landmark book *Inventing the Internet*. Abbate has by far the most thorough discussion of the DCA's role, even though the dozen or so pages in which the DCA appears have not elicited much commentary or discussion among the nearly 2,000 publications that have cited *Inventing the Internet*. The key theme in Abbate's discussion of the DCA is that it operated under its own institutional logic, aiming to prevent waste and misuse, enforce access policies, and increase security. Each of these priorities stood in somewhat stark contrast to DARPA's more lax approach summarized above. Abbate also emphasized how the DCA's mission to maintain command and control networks—rather than the research community's desires or demands—drove some of the DCA's technological choices.[28] Similarly, Alexander McKenzie and David Walden provide account of the nature of the agreement between DARPA and the DCA in the transition, locating the transfer in long-standing plans to transfer the network once it was operational, and drawing attention to both the Arpanet Sponsors Group and Communications Industrial Fund, both of which we expand on below.[29]

25. Abbate, *Inventing the Internet*, 135.

26. Salus, *Casting the Net*.

27. Thomas Hughes, *Rescuing Prometheus*, 293.

28. Abbate, *Inventing the Internet*, 136–40.

29. Alexander McKenzie and David Walden, "The ARPANET, the Defense Data Network, and the Internet."

The Defense Communications Agency: Maintaining Arpanet Administrative Infrastructure

In this and subsequent sections we provide a new account of the DCA's key roles in Arpanet and Internet development and maintenance. We begin here by outlining the DCA's role in the Arpanet's administration: the historical and institutional context in which Arpanet stakeholders ran the network, as well as the DCA's relationship with individual network users.

The DCA that assumed managerial responsibilities for the Arpanet in 1975 was a different agency than the one upon which Paul Baran passed judgment in the early 1960s. While at RAND, Baran's research in packet switching was funded by and carried out for the U.S. Air Force, a military service that, like the others, was modernizing its communication technologies and infrastructure. The political context of the Air Force's research was one of centralizing forces within the Department of Defense, including efforts to centralize service and agency communication systems. The process was not an easy victory for the forces of centralization, however. As one scholar of military command and control systems noted:

> As the decade of the 1960s dawned, the dynamic tension between the forces of centralization and decentralization remained unresolved. Despite an ever-increasing technical capacity for rapid global communications the services—comfortable with their traditional missions, conservative and resistant to change—tended still toward ways of doing business that had proven efficacious in the past.[30]

These "ways of doing business," argues the sociologist and Army veteran David Pearson, were organized around communications systems designed for the specific needs of individual military services—systems that worked well, but were hardly interoperable. During the early 1960s, as Baran undertook his research into packet switching, his Air Force sponsor continued to push for the decentralization of military communication infrastructure, and against DCA mission of centralization.[31] The DCA was created as part of broader and highly contested efforts to change these ways of doing business, changes that would necessarily deprive the services of a certain amount of autonomy. Insofar as Air Force staff identified the DCA with the centralizing forces (often personified with McNamara's tenure as Secretary of Defense), and insofar as Baran came to understand the defense ecosystem on their terms, this would provide a further reason—perhaps the major reason—to distrust the DCA.[32]

Baran's suspicions notwithstanding, the DCA in fact had substantial

30. Pearson, *The World Wide Military Command and Control System*, 16.
31. Ibid., 46.
32. David Jardini, "Out of the Blue Yonder."

experience managing and maintaining communication and computer networks. By 1975 the DCA managed three network infrastructures useful to consider here: the AUTOmatic DIgital Network (AUTODIN), communication infrastructures belonging to the World Wide Military Command and Control System (WWMCCS), and the Prototype WWMCCS Intercomputer Network (PWIN), an experimental packet-switched network based in part on the Arpanet. In AUTODIN, the DCA developed and managed a computer network for record communication (that is, a network whose communications could serve as military orders) that linked bases of the military services with the U.S. government, intelligence community, and international allies.[33] AUTODIN was based on the Air Force's COMLOGNET, a store and forward message switching service that went online in 1962. Installations began in 1966, and by the late 1970s its name referred to not only the original network, but a broader integrated set of networks and communication centers, as well as pieces of its planned replacement, AUTODIN II.[34] Development of the Worldwide Military Command and Control System (WWMCCS), a replacement of Plan 55 switching centers, was underway in 1970 with hardware installation beginning in 1972. WWMCCS was a federation of multiple systems under a range of jurisdictions within the Department of Defense; one of its major functions was the command and control of the U.S. nuclear arsenal.[35] While the DCA possessed formal authority over the network, it exercised it amid a great deal of competition from preexisting communications authorities through the DoD. Finally, the Prototype WWMCCS Intercomputer Network (PWIN) was an experiment, initiated in the 1970s, to test the suitability of Arpanet technologies for the WWMCCS environment. For this, the DCA led some of the earliest tests of encryption hardware (KG-32 units) with Arpanet packet switches.[36]

Neither AUTODIN, WWMCCS, nor PWIN were examples of bleeding edge technological development. Both AUTODIN and WWMCCS were far larger and more complex, institutionally and technologically, than the Arpanet in 1975, and the Cold War stakes of their proper use were immeasurably higher—and they would have certainly provided the DCA with experience in operating large-scale communication infrastructures. Nonetheless, the DCA did not run the Arpanet as an AUTODIN or WWMCCS, as we will see below. PWIN, on the other hand, provided DCA staff with experience with Arpanet technologies. Given the significant problems encountered in PWIN testing beginning in 1975, which were likely linked

33. Robert Lyons, "A Total AUTODIN System Architecture"; "DoD Directive 4140. 29."

34. Lyons, "A Total AUTODIN System Architecture."

35. The Office of the Secretary of Defense, *The Worldwide Military Command and Control System*.

36. Quinn DuPont and Bradley Fidler, "Edge Cryptography."

at least in part to the complex environment in which Arpanet technologies were being implemented, PWIN may have provided a cautionary tale for the DCA in keeping the technical and bureaucratic environment simple.[37]

When the DCA took over management of the Arpanet in 1975, it possessed the experience of maintaining these networks, as well as managing the centrifugal forces within the Department of Defense. Since its establishment, the DCA was intended as an agency that, in part, would reconcile the desires for autonomy of the military services with the longstanding desire for inter-service communication and cooperation. (For example, until February 1975, the DCA was responsible for the AUTODIN network, but individual military services retained control over their multiplicity of AUTODIN terminals.[38]) Beginning in 1976, for example, the DCA engaged in multi-stakeholder efforts to develop consensus between military services and government agencies for the design of the Integrated Autodin Systems Architecture (IASA), a program for the next generation AUTODIN backbone switch mandated by the Office of the Secretary of Defense (OSD) and carried out by the DCA.[39] Just prior to this effort (on behalf of the OSD) to further centralize control over AUTODIN, the DCA embarked on a new program for managing the Arpanet.[40] This system, outlined below, lasted from 1975–83, during the first phase of the DCA's management of the Arpanet.

The Arpanet was transferred to the DCA on 1 July 1975. The transfer furthered DARPA's strategy of ensuring the widespread adoption of its packet-switching technologies. Having failed to interest the private sector in the early 1970s, DARPA found far greater success in the Defense Department.[41] According to the Memorandum of Agreement between DARPA and the DCA, during the following six months DARPA would continue to assist with management of the network. The plan called for DCA to continue to operate the Arpanet until 1978 or until other military networks (such as the planned AUTODIN II) could take its place.[42] Before the conclusion of this six-month period, on 21 October of that year, the Arpanet Sponsors Group met for the first time. Sponsors were government agencies or military services that paid for nodes on the Arpanet, such as DARPA, NASA, the Army, and the National Security Agency. While sponsors might fund their own node and thus share its name (e.g. DARPA or the NSA),

37. Pearson, *The World Wide Military Command and Control System*, 185.

38. *Integrated AUTODIN System Architecture Report: Part 2*, 2.

39. Oral History with John Lane, April 2015, in COHR; *Integrated AUTODIN System Architecture Report: Part 2.*

40. Alexander McKenzie identifies the Sponsors Group as an idea proposed by DARPA to help convince the DCA to assume responsibility for the ARPANET. McKenzie, "ARPA and DCA."

41. Ibid.

42. McKenzie and Walden, "The ARPANET, the Defense Data Network, and the Internet."

they were more often responsible for funding a number of nodes.[43] Also known just as the Arpanet Sponsors, the group met biannually as a "forum for the exchange of ideas and information on the operation of the Arpanet," both for the DCA to announce plans and for sponsors to "make recommendations to DCA on network operational activities and services."[44] In principle, every Arpanet user would have representation through a sponsor, and the group's existence was described by the DCA in one instance as established to "be flexible and responsive to the requirements of the user community."[45] By 1978, a year before the first Internet governance organization (the Internet Configuration Control Board [ICCB]) arose under DARPA IPTO, sponsors' responsibilities included managing the requests for new sponsors and member nodes, monitoring access control policies, present user needs and policy change recommendations at sponsors' group meetings, and communicate policy to users at their nodes.[46] The group was chaired by the DCA.

In 1983, the Arpanet's military nodes were moved to their own network, creating the MILitary NETwork (MILNET). Both networks became part of the Defense Data Network (DDN), a network of military networks operated by the DCA's Defense Data Network Program Management Office (DDN PMO). By 1985, the Arpanet Sponsors Group responsibilities were split between DARPA IPTO, which remained as the sole sponsor of remaining (civilian) Arpanet nodes, DARPA IPTO's Internet Advisory Board (IAB), and the DCA's DDN Program Management Office (PMO).[47] DARPA IPTO acted as sponsor for all Arpanet nodes, and worked with the IAB to develop Internet infrastructure and technology. The DCA, through the (expanded) Stanford Research Institute Network Information Center, continued to manage the day-to-day operations of the Arpanet.

The context of these changes within the histories of computer networks is significant. When DARPA supported each Arpanet node between 1969–75, universities without Arpanet access would not have been able to find other nationwide, general purpose U.S. networks to which they could connect. By 1983, amid the creation of the Defense Data Network and the sponsorship of all Arpanet nodes by DARPA IPTO, universities had other options for network connectivity. Projects such as CSNET, funded by the National Science Foundation, linked universities with dial-up and Telenet (a private computer network) accounts to the Arpanet. The Arpanet had

43. GIRDVAINIS@BBN-TENEX, "Arpanet Management Transition."

44. Defense Communications Agency, *ARPANET Information Brochure*, 1976, 11.

45. GIRDVAINIS@BBN-TENEX, "Arpanet Management Transition"; Defense Communications Agency, "ARPANET Information Brochure," 1976, 9.

46. Defense Communications Agency, *ARPANET Information Brochure*, 1978, 9.

47. Defense Communications Agency, *ARPANET Information Brochure*, 1985. The Internet Advisory Board (IAB) was created in 1984 to replace the Internet Configuration Control Board (ICCB), the first Internet governance organization created by DARPA IPTO (and mentioned above).

gateways to the USENET, an international UNIX-driven network created by users who felt neglected by the military-driven networking community, and to BITNET, another international network. Private users had access to Bulletin Board Systems (BBSs), as well as "walled garden" online services such as Compuserve and Prodigy.[48] Thus, in 1983 U.S. military users were served by non-Arpanet DoD networks, as were universities and private users. The Arpanet, however, continued to provide the functions noted above: serving as an infrastructure around which the Internet community could continue to develop technologies and fight (and win) the "protocol wars" between competing visions for global internetworking.

Among the DCA's many governmental responsibilities during this era, one prominent role was its regulation of user access, carried out through the Stanford Research Institute Network Information Center (SRI NIC), for which it was also responsible after 1975.[49] Users on the Arpanet are portrayed erroneously by the first generation of Internet and Arpanet historiography as existing without regulation, a template for a free cyberspace that was subsequently intruded upon by governments and corporations.[50] In this existing literature, as we have explained above, the DCA appears as a new, naive, and sometimes unremarkable presence that, at the very least, added a layer of meddling bureaucracy. In the context of its administrative and budgetary roles that we have sketched, however, the DCA's management of Arpanet users does not appear restrictive, especially given the evolving aims of the DCA and of DARPA IPTO (which we turn to after our discussion of users).

User access to the Arpanet was organized through the DCA-chaired group of Arpanet Sponsors.[51] Each user would gain access through an Arpanet node, and each node gained access to the network by way of one of the Arpanet sponsors. Sponsors, in turn, were responsible for user behavior at each of the nodes for which they were responsible. Sponsors were also responsible for each node's management of Arpanet resources, including security resources. The first mention of the network liaisons occurs in IPTO's 1968 Request For Quotations (RFQ) for the Arpanet (then the ARPA Computer Network), as an empty column in an appendix of network nodes (since the network was not yet operational, the network liaisons would not yet be known).[52] The roles of the liaisons were built out, in part, by Douglas Engelbart's Augmentation Research Center at the SRI NIC, prior to the development of network mail (email). Sometimes referred to as "technical liaisons", they were used as a point of contact

48. Campbell-Kelly and Garcia-Swartz, "The History of the Internet."

49. Defense Communications Agency, *ARPANET Information Brochure*, 1976.

50. Bradley Fidler, "Eternal October and the End of Cyberspace."

51. The following information is taken from *Arpanet Information Brochures*, cited above.

52. Defense Supply Service, "Request for Quotations, Request No. DAHC15 69 Q 0002," 41.

between IPTO and the network sites, in particular to use physical mail to distribute network documents (such as RFCs), and to "[match] requests from the network community to people or services at his site, and vice versa."[53] In 1972, a NIC report noted that liaisons were "to be familiar technically with his site and usually also to participate in network development and use."[54] By 1974, liaisons were comprised of graduate students, professors (many highly esteemed), and principal investigators.[55] In other words, liaisons were not a purely administrative or clerical role, were involved in the early milieu of user-developers, and either exercised or were close to people who exercised (academic) power at each node. They were crucial components in a vast social infrastructure that maintained the Arpanet.

The DCA did not mention network liaisons in its 1975 announcement to Arpanet users concerning the transfer of the Arpanet to its management. Nor were liaisons described in the 1976 Arpanet Information Brochure, the main publication about the Arpanet and its policies, produced by the SRI NIC on behalf of the DCA. In the 1978 Brochure, however, the liaisons re-emerged.[56] Technical liaisons were then assigned to each host and TIP of the Arpanet, rather than each node. The change was significant, because hosts and TIPS were the two points of entry to the Arpanet: hosts, as local computers which could be accessed by local users (or dial-up front-ends), and TIPs (Terminal IMPs) that provided dial-in access to the Arpanet to anyone with a modem and a phone line. The host and TIP liaisons were to "promptly provide information on host-terminal connection changes as they occur" to the SRI NIC and the BBN Network Control Center, a codification of a previous role. In addition, they were to change TIP dial-in modem numbers as per DCA policy, as part of an attempt by the DCA to thwart unauthorized access to the Arpanet. Thus, by 1978 liaisons were at least somewhat involved in network access control. In 1979 the technical liaison also reported on not just the resources available at (now) "his/her" host, but also "the people."[57] These people appeared in the "Arpanet Directory," a listing of all official Arpanet users.[58]

The Arpanet Directory represented the ability of the DCA to access, via the SRI NIC, a record of all official Arpanet users, a new feature that did not exist under DARPA IPTO's watch. On July 1st, 1980, the DCA requested of its liaisons a step toward further monitoring: "a detailed survey" of all Arpanet users that they would use to build an "Identification Data

53. Stephen Crocker, "Distribution of NWG/RFC's through the NIC"; Jeanne North, "ARPA Network Mailing Lists."

54. Douglas Engelbart, "Online Team Environment," 137. The male pronoun further demarcates the role from clerical positions.

55. Diana Skocypec, "Network Liaison List."

56. Defense Communications Agency, *ARPANET Information Brochure*, 1976, 12–13.

57. Defense Communications Agency, *ARPANET Information Brochure*, 1979, 24.

58. SRI Network Information Center, *ARPANET Directory*.

Base," an "all encompassing description of who, where, and why a user is on the Arpanet."[59] The request was accompanied by the announcement, directed to the liaisons:

> When the network was small, a decentralized management approach was established due to the nature of the network and the small community of users. . . . Now that the network has grown to over 66 nodes and an estimated four to five thousand users, flexibility must be tempered with management control to prevent waste and misuse. The decentralized management of network access and resources is still our objective. . . . We believe that the data base that we are establishing, can be used as a tool for improving your and our management control. We deal in gross quantities, you deal in the particulars.[60]

The Arpanet community reacted swiftly: a month later a second announcement clarified the DCA's position, essentially backing down from a centralized host login authentication system.[61] Consequently, while the DCA did, in 1983, eventually implement a login authentication system for dial-in users, individual nodes were left to authenticate their own users.[62] Furthermore, there is no evidence that nodes were vigilant in keeping users to strictly Arpanet business: to say nothing of individuals, in the June announcement to liaisons, the DCA requested that nodes not connect, via gateways, entire networks to the Arpanet. Ultimately, during 1975–83, the DCA did increase the amount of information about Arpanet users stored at SRI NIC, in preparation for a login authentication system implemented for dial-in users in 1983.[63] However it did not use the network liaisons to exert control over local sites. Instead, it was the network sponsor that ultimately was responsible for users. In this way, the management of users was also a part of the DCA's early Arpanet governance structure.

The Defense Communications Agency: Maintaining Arpanet Financial Infrastructure

Next, we turn to the related mechanisms through which DCA developed and sustained the Arpanet's financial infrastructure, and the significance of funding mechanisms for infrastructure. In our subsequent concluding section we draw out the significance for the histories of computer networks and technology historiography more generally.

59. Joseph Haughney, "ARPANET News from DCA."

60. Ibid.

61. Bradley Fidler and Morgan Currie, "Infrastructure, Representation, and Historiography in BBN's Arpanet Maps."

62. This debate mirrors discussions in the early 1970s as to the structure of network sockets. Bradley Fidler and Amelia Acker, "Metadata, Infrastructure, and Computer-Mediated Communication in Historical Perspective."

63. Fidler and Currie, "Infrastructure, Representation, and Historiography in BBN's Arpanet Maps."

Funding is significant because any large-scale infrastructure exists in a bounded financial and institutional environment. Beginning in 1975, the DCA operated the Arpanet through the DCA's Communication Services Industrial Fund (CSIF). Industrial funds were established with the Department of Defense itself in the National Security Act Amendment of 1949, replacing systems in which goods and services were funded by appropriations and provided for free to defense customers.[64] Industrial funds created quasi-market mechanisms within the (new) Department of Defense, forcing defense customers to better budget for requirements and producers to rely more on orders.[65] These funds brought with them a broader set of market-like tools for funding projects and allocating resources, such as the financial authority to hire, and the ability to provide and receive services based on contracts.[66] Centralized DoD funding mechanisms such as the industrial funds are important: the centralization of financial mechanisms (and infrastructures) appear to have been necessary in order to proceed with the centralization of communication infrastructure.

These processes began in 1957 with the U.S. Air Force's Semi-Automatic Ground Environment (SAGE) air defense system, when centralized funding mechanisms permitted the Air Defense Command to perform all (communication line) leasing functions. The Department of Defense subsequently expanded this authority to include *all* line leasing for the Air Force. In 1961 the Air Defense Command was further given this authority over the entire Department of Defense. In 1963 the Office of the Secretary of Defense moved this authority from the Air Force to the DCA as the Defense Commercial Communications Office (DECCO). (One can imagine how this major transfer of power from the USAF to the DCA, ordered from above, may have impacted assessments of the DCA in Air Force communication circles—where Paul Baran, for example, was active and influential.) This unified funding mechanism was the economic foundation on which centralized communication infrastructure was based, first with AUTOVON in 1963 and then AUTODIN in 1964. At around this time, in 1963, the DCA was asked by the DoD to find better ways to (centrally) fund centralized communication systems, and their answer was to use the industrial fund mechanism, but for communications. As such, the Communication Services Industrial Fund (CSIF) was approved by Defense Secretary Robert McNamara in 1964, and its charter was approved in 1965.[67] A decade later, the DCA used the CSIF to fund the Arpanet.

In 1976, industrial funds were defined in a Comptroller General report as "working capital funds that finance the operating costs of most industrial and commercial-type activities of the Department of Defense," which

64. Edwin Wicklander, "The Navy Industrial Fund," 15; Jan Hinton, *A Study of the Communications Services Industrial Fund*, 16.

65. *27 Years' Experience with Defense Industrial Funds*.

66. Hinton, *A Study of the Communications Services Industrial Fund*, 17–18.

67. Ibid., 20–25.

are meant to "provide incentives and controls for better management similar to those existing in private enterprise" (the report stated that they more or less fulfilled their goals).[68] These funds were provided with initial capital, and were expected to recover costs by billing (largely internal/defense) customers.[69] The Department of Defense Directive (7410.4) that authorized industrial funds ensured that the fund managers—in this case, the DCA—were responsible for the control of costs. Further, the directive stated that costs could be incurred by "local management" "under the direct supervision of the agency having direct command and management control." Non-defense customers (present on the 1975 Arpanet) would be charged the higher of either predetermined rates "to secure reimbursement for total costs" or the "fair market value" for the goods or services.[70] The CSIF would fund the operations and maintenance of the Arpanet backbone (e.g. the lines and packet switches), and included longer term issues, such as capital investments, and core network services, such as the SRI Network Information Center (SRI NIC) and the Network Control Centers (NCCs; later called Network Operation Centers [NOCs], or Monitoring Centers).[71] This meant that, initially, costs would be allocated based on the number of network nodes under the responsibility of a network sponsor. All of this is to say that the DCA carried a great deal of responsibility in managing the funding apparatus that supported the Arpanet from 1975.

The CSIF was also implicated in the relationship between the DCA, its management including not only the Arpanet but also all defense communication systems (referred to as the Defense Communications Systems, or DCS), and the higher echelons of authority up to the Office of the Secretary of Defense. While the process is remarkably complex, ongoing budget proposals and approvals meant that the DCA was continually engaged with the DoD and Office of the Secretary of Defense, suggesting technical and budget requirements, receiving actual budgets, and adjusting capabilities accordingly.[72] These activities were required for the operation of any such communications infrastructure in the DoD, and are a largely taken for granted component in the administrative and financial maintenance of infrastructure in extant histories of the Internet.

The DCA and its role in creating the infrastructural basis for the Arpanet is most evident when we compare the basic operating principles of the CSIF to the way in which the Arpanet was actually funded. Formally, a (normally military) customer requests a service of the industrial fund and its operating agency, in this case the DCA and its CSIF. Then, the agency

68. *27 Years' Experience with Defense Industrial Funds*, i.

69. *Government Accountability Office Report*.

70. Hinton, *A Study of the Communications Services Industrial Fund*, 19–22.

71. Defense Communications Agency, "Defense Industrial Fund Charter."

72. "Communications Services Industrial Fund (CSIF)," 1-1-1–2. Here we refer especially to the Planning, Programing, and Budget System (PBSS).

receiving the request will either provide the service outright (thus settling the arrangement), or hire a third party such as a defense contractor to provide the service. The third party provides the service directly to the requesting customer, and bills the DCA (via DECCO). As noted above, the goal of DoD industrial funds is to break even. In the case of the Arpanet, the DCA (with DECCO) administered an extremely complex industrial fund, to financially and organizationally sustain a complex technological infrastructure. Through the CSIF the DCA coordinated nodes at IPTO-funded civilian, non-IPTO DARPA funded, military, and non-DoD R&D organizations, as well as funding the work of BBN and the Network Analysis Corporation (NAC; for network topology optimization), and leasing lines from AT&T. In 1977 twenty-four nodes were sponsored by IPTO, three by elsewhere in DARPA, another twenty-four by elsewhere in the military, and ten by outside of the DoD.[73] (In 1983 operations and maintenance accounted for 73 percent of CSIF activity.[74]) These outlines begin to reveal economies of early network infrastructure—required for the continued existence of the Arpanet—and insight into why, in the Department of Defense, a centralization and rationalization of economic and organizational infrastructure preceded the centralization of communication infrastructure.

Conclusion

After inheriting the management of the Arpanet in 1975, the DCA provided administrative and financial infrastructure, sketched above, that allowed planners, engineers, and users to create and develop the Internet. When the DCA took over Arpanet management in 1975, IPTO's Internet Program was yet to be created out of experiments based in its packet radio program, and IPTO contractors had yet to complete any significant tests of the technology.[75] As early as 1979, an early testbed Internet infrastructure was emerging under IPTO guidance. To have broad civilian relevance, the Internet's new governance bodies—first formed with the ICCB in 1979 and expanded to the IAB in 1984—required a large-scale civilian TCP/IP infrastructure on which they could practice the frequently noted "rough consensus and running code," expand the Internet, and defeat international competitors. Beginning in January 1983, IPTO and the DCA mandated that Arpanet hosts run TCP/IP, making it the formal basis of the modern civilian Internet. The networks connecting to the Arpanet with the Internet Protocol in 1983 depended on the Exterior Gateway Protocol (EGP) that presumed the Arpanet's existence as the sole large, long-haul network with which smaller networks would connect.

Recall that in 1983, the global victory of the internetworking technolo-

73. Lukasik, "Why the Arpanet Was Built."
74. Hinton, *A Study of the Communications Services Industrial Fund*, 35.
75. Abbate, *Inventing the Internet*.

gies and governance infrastructures built into the ARPA Internet was anything but certain, and it remained a small experiment confined to the U.S. military and the defense contractors and universities it funded. It was on the Arpanet, however, that a civilian community of engineers and practitioners continued to develop Internet technologies, and on which they also developed their ideological self-awareness amid the struggles to displace both private and international standards as the model for the future Internet.[76] When, several years later, the National Science Foundation (NSF) sought an architecture for its planned network to link its supercomputer centers together with regional networks, it had this expanding civilian body of TCP/IP knowledge and experience on which to draw, and there was no reasonable technological alternative to TCP/IP.

None of this is to argue the extremist claim that there would be no computer networks or global internets without the Arpanet or the ARPA Internet. Instead, we argue that the histories of computer networks and global internets would be different without the Arpanet and Internet—and that, had other social and technical systems prevailed, we would for better or worse be living under a different kind of internetwork infrastructure, with different modes of governance and regulation. Accounting for the unique role of the Arpanet and ARPA Internet in the history of technology is not, after all, an argument about its significance solely as the lived experience of a userbase that was, in comparison with other online systems of the era, small. Rather, it is necessary to account for the history of the Arpanet and ARPA Internet in order to understand the historical origins of important social and technical systems that structure our world today.

Within the lineage of the Arpanet and ARPA Internet, we make the limited argument that it is necessary to understand infrastructure and its maintenance in order to begin to account for the success and impact of (innovated) technologies. Here we have offered an initial sketch of what such a history of the Arpanet might look like, focusing on the role of the DCA in the governmental and economic infrastructure of the Arpanet, and thus also the ARPA Internet. We also offer a more expansive claim, that infrastructure and maintenance should be methodologically and ontologically central in histories of computer networks. The bare process of innovation is a common feature of human society and, as its boosters argue, especially prevalent in the twentieth-century United States—needing scarcely more than a garage and commercial off the shelf technologies to flourish. The successful creation and maintenance of large-scale, well-functioning technical and social infrastructures of everyday life—or merely preventing their outright sabotage—is proving far more elusive.

The existence and historical repercussions of the Arpanet from 1975, we argue, is not only a consequence of DARPA-led technological innovation, but that it was also a consequence of *infrastructure maintenance*. The

76. Russell, *Open Standards and the Digital Age.*

maintenance we discuss in this early research is of the organizational and economic infrastructures that were necessary to run and expand network infrastructure. Accounts of the prime movers that generated the present-day Internet, we argue, require explanation of infrastructure maintenance, even to satisfy their own explanatory objectives.

Elsewhere, as noted above, scholars study other forms of infrastructure and maintenance. Historians of technology are only beginning to develop a conceptual vocabulary for the analysis of what we refer to as infrastructure maintenance—by groups that scholars are increasingly terming "the maintainers."[77] This term is not deployed to demarcate with precision the social position of certain groups, e.g. their relationship to an economic system or their place in an industry. Instead, it identifies a broader ontological shift toward maintenance as an explanatory strategy. Our contention is that the Arpanet sponsors, liaisons, and bureaucrats who labored to sustain and link the organizations and technologies known by their elaborate acronyms—these people were acting as maintainers. Understood within innovation-centric modes of historical explanation, there was little that was sensational or attention-grabbing in their work: no epoch-making demonstrations, no "eureka" moments in the lab, just steady, solid, and unspectacular work.

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77. Vinsel and Russell, "Innovation Is Overvalued."

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