ARPANET - THE PRECURSOR TO THE INTERNET: A PROJECT MANAGEMENT WRITTEN ANALYSIS

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ABSTRACT

Today, more than three billion people use the Internet to such a degree that a world without it seems unimaginable. The seedlings of this world-wide technology were sowed in the research facilities of ARPA (now DARPA), a government research and development agency, and brought into existence through a succession of visionary leaders who attracted the best and brightest to work unencumbered by micromanagement or budgetary limitations. These teams developed the computer-based communications array known as ARPANET, a system at first used by academics and the military and later utilized as the foundation for the World Wide Web. The development of ARPANET demonstrates Warren Bennis and Patricia Ward Biederman's concept of a Great Group, in which a group of experts, united in purpose and creative energy, create revolutionary products. ARPANET is also a project management case study in positive scope creep, in that an expanding project vision and costs ultimately resulted in positive dividends – the transformation of how humanity communicates.

INTRODUCTION

In October 1967, in a sleepy Tennessee town that rests in the shadow of the Great Smoky Mountains National Park, computer scientist Lawrence Roberts presented a paper at the Computing Machinery Operating Systems Symposium that would lay the foundation for the Internet. [1] After the symposium, Roberts would use his findings to conceive ARPANET, one of the most successful projects ever undertaken by ARPA (now DARPA), a government research and development agency.[2] ARPANET was a successful case study in project management both in terms of organizational efficiency and project outcome. The story of ARPANET is an example of a Great Group that had the organizational and funding freedom to not only deliver on their project's objectives, but to push a positive scope creep that would ultimately transform how humanity communicates.

A VISIONARY FINDS A HOME: THE CREATION OF ARPA AND THE GENIUS OF JCR LICKLIDER

On October 4, 1957, a signal transmitted from a manmade satellite ushered in a new chapter of the Cold War. Fearing the launch of Sputnik I, the Soviet Union's conquering of low-earth orbit, the United States national security establishment enlisted the best and brightest for a project equivalent in scope and dire purpose as the Manhattan Project.[3] President Dwight D. Eisenhower's science advisor, James Killian, and Secretary of Defense Neil McElroy proposed an agency that would finance and incubate technological advancements for the military to counter the Soviet threat.[4] Passed by Congress in 1958, the Advanced Research Projects Agency (ARPA) was housed in the Department of Defense (DoD) and charged with funding cutting edge research and development for ballistic missile defense and nuclear detection.[5] Typical of many government agencies, its mission statement was vague and rife for interpretation: "to be responsible for the direction or performance of such advanced projects in the field of research as the Secretary of Defense shall, from time to time, designate by individual projects or by that category."[6]

In 1961, ARPA's sole purpose was to develop command and control systems for the U.S. military. Command and control is a set of communication and coordination activities executed during extreme military scenarios, such as the event of a nuclear strike.[7] Because command and control activities required the rapid dissemination of data about situations, options, and decisions in capricious circumstances, the military sought to utilize computer technology.[8] To this end, ARPA hired JCR Licklider to lead the project. Licklider became the first head of the Information Processing Techniques Office (IPTO), an office in ARPA from where his team's work planted the seed for the development of modern-day computers and information systems.[9]

By conventional expectations, Licklider was an incongruous choice for the head of a computer-based research and development agency. A Harvard-educated psychologist, Licklider was a faculty member of both the Psychology and Electrical Engineering

1 O'Neill, J. E. (1995). "The Role of ARPA in the Development of the ARPANET, 1961-1972." *IEEE annals of the history of computing.* 17(4): 78

2 Bolt Beranek and Newman Inc. (1981). "A History of the Arpanet: The First Decade." Report No. 4799. Arlington, VA: Defense Advanced Research Projects Agency. I-2

3 Lukasik, Stephen J. (2011)"Why the ARPANET was built." IEEE Annals of the History of Computing 33, no. 3: 6

4 Brendon, Laura K. (2001). "ARPANET: An Efficient Machine as Social Discipline." Science as Culture. 10 (1): 76

5 Hughes, Thomas Parke (1998). "Networking: ARPANET." Rescuing Prometheus. New York: Pantheon Books, 258

6 Lukasik, Stephen J. (2011)"Why the ARPANET was built." IEEE Annals of the History of Computing 33, no. 3: 6

7 Ibid. 4

8 Brendon, Laura K. (2001). "ARPANET: An Efficient Machine as Social Discipline." *Science as Culture.* 10 (1): 77

9 Hughes, Thomas Parke (1998). "Networking: ARPANET." Rescuing Prometheus. New York: Pantheon Books, 258

Departments at the Massachusetts Institute of Technology. In 1957, Licklider became a vice president at Bolt Beranek and Newman (BBN), a company that focused in acoustics and information systems.[10] However, his main research interest was human-computer interaction, which he articulated in his seminal article, "Man-Computer Symbiosis."[11] Licklider envisioned computers to be so much more than single-function, single-user devices. Computers, he believed, could augment human-thinking in a symbiotic partnership that would "think as no human brain has ever thought and process data in a way not approached by the information-handling machines as we know today."[12] When he joined ARPA as director of IPTO, Licklider saw his task of improving command and control as complimenting his vision for broadening human-computer interaction.[13] He selected and funded projects "nominally categorized as military command and control-related but more precisely characterized as interactive computing, or man-machine symbiosis – his deepest commitment."[14]

At the time, transferring data among computers—even those housed at the same academic institution—was inefficient.[15] Due to incompatible computing technology, the universities and corporations that contracted with ARPA could not 'talk to each other' with their machines.[16] Licklider envisioned a "Great Intergalactic Network" that would facilitate a far-reaching community through shared computer and data-processing functions. This network would rely on a concept called time-sharing, in which computer users share information simultaneously while computers processed data at speeds faster than humans could think. [17] IPTO funded Project MAC, which was a proto-time-sharing system that networked among two hundred users from various universities.[18] However, Licklider and his team soon discovered Project MAC's limitations: connecting incompatible systems through phone lines over long-distances proved to be a financially and logistically untenable.[19] Licklider stepped down from his position at IPTO in July 1964, his vision alive but left unrealized.[20]

ARPANET COMES ONLINE

As the new head of IPTO, Robert Taylor effectively laid the foundation for what would become ARPANET. Compelled by the desire to interconnect his Pentagon office's three time-sharing computers through a network, Taylor assigned Lawrence Roberts of MIT's Lincoln Laboratory to head a network project.[21] Taylor, Roberts, and their colleagues turned to Paul Baran of the RAND Corporation for a crucial component to their network design. Baran's team had been assigned by the Pentagon to create a communications network to assure the continuation of the United States' command and control retaliatory

10 O'Neill, J. E. (1995). "The Role of ARPA in the Development of the ARPANET, 1961-1972." *IEEE annals of the history of computing.* 17(4): 76
11 Ibid.
12 Brendon, Laura K. (2001). "ARPANET: An Efficient Machine as Social Discipline." *Science as Culture.* 10 (1): 77
13 O'Neill, J. E. (1995). "The Role of ARPA in the Development of the ARPANET, 1961-1972." *IEEE annals of the history of computing.* 17(4): 76
14 Hughes, Thomas Parke (1998). "Networking: ARPANET." Rescuing Prometheus. New York: Pantheon Books, 264
15 Ibid. 265
16 Brendon, Laura K. (2001). "ARPANET: An Efficient Machine as Social Discipline." *Science as Culture.* 10 (1): 78
17 Hughes, Thomas Parke (1998). "Networking: ARPANET." Rescuing Prometheus. New York: Pantheon Books, 266
18 Ibid.
19 O'Neill, J. E. (1995). "The Role of ARPA in the Development of the ARPANET, 1961-1972." *IEEE annals of the history of computing.* 17(4): 77
20 Ibid.
21 Hughes, Thomas Parke (1998). "Networking: ARPANET." Rescuing Prometheus. New York: Pantheon Books, 268

capabilities after a hypothetical Soviet nuclear strike.[22] In 1964, Baran presented a paper which presented an answer to this challenge: A distributed network of nodes redundantly linked to each other like an interconnected web.[23] The network could continue functioning in the event of a nuclear strike because no single node was essential; if one node went offline, the network would reroute to the surviving nodes. This concept, also known as packet switching, was the missing piece in what was needed to create a network. In 1968, Roberts conceived ARPANET as a realization of the distributed network as described in Baran's paper.[24] Now the team at IPTO had to find a group to make ARPANET a reality.

The main project was to design "gateways" that would serve as the nodes in the distributed network. IPTO contracted with BBN, Licklider's old employer, in 1969 to build this physical network of gateway computers, which were called "interface message processors," or IMPs.[25] The IMPs formed a subnet that connected time-shared host computers and the public telecommunications network.[26] BBN completed testing and installed the first node at UCLA in 1969. The nascent network would include additional nodes at SRI, University of California Santa Barbara, and the University of Utah.[27]

In 1972, ARPANET went live. Roberts (who had succeeded Taylor as the head of IPTO) gave a three-day public demonstration of APRANET at the Conference of Computer Communications (ICCC). There, visitors used programs that ran on time-sharing systems to share graphics, play games of chess, and send electronic messages across the country.[28] The ARPANET demonstration proved that packet-switching worked. Robert Kahn, who would later head IPTO, commented: "It was almost like the train industry disbelieving that airplanes could really fly until they actually saw one in flight."[29]

By the end of 1972, ARPANET was fully functioning for the universities and corporations that had access to the restricted network. ARPANET was transferred to the Defense Communications Agency in 1975.[30] The network would continue to expand and eventually splinter into a separate research and military network before being officially shuttered in 1989.[31]

EVALUATING ARPANET'S OUTCOMES

The success of many projects can be determined by an immediate outcome, such as the construction of the Sydney Opera House or the detonation of the first atomic bomb outside Los Alamos. In a report about the first ten years of ARPANET, BBN wrote, "In other cases, like the ARPANET, an equally important objective may be reached with equal success, but the event must be observed in a more complicated way over a longer period of

22 Ibid. 273
23 Brendon, Laura K. (2001). "ARPANET: An Efficient Machine as Social Discipline." *Science as Culture*. 10 (1): 80
24 O'Neill, J. E. (1995). "The Role of ARPA in the Development of the ARPANET, 1961-1972." *IEEE Annals of the History of Computing*. 17(4): 79
25 Ibid.
26 Lukasik, Stephen J. (2011)"Why the ARPANET was built." *IEEE Annals of the History of Computing* 33, no. 3: 11
27 O'Neill, J. E. (1995). "The Role of ARPA in the Development of the ARPANET, 1961-1972." *IEEE Annals of the History of Computing*. 17(4): 79
28 Ibid. 80
29 Hughes, Thomas Parke (1998). "Networking: ARPANET." Rescuing Prometheus. New York: Pantheon Books, 293
30 Bolt Beranek and Newman Inc. (1981). "A History of the Arpanet: The First Decade." Report No. 4799. Arlington, VA: Defense Advanced Research Projects Agency. I-2
31 Lukasik, Stephen J. (2011)"Why the ARPANET was built." *IEEE Annals of the History of Computing* 33, no. 3: 17

time."[32] This nuanced evaluation is incumbent upon ARPANET'S scope design. Consider ARPA's three objectives, as detailed in the BBN report:

1.) To develop techniques and obtain experience on interconnecting computers in such a way that a very broad class of interactions are possible.

2.) To improve and increase computer research productivity through resource sharing.

3.) To permit the linking of specialized computers to the many general purpose computer centers.[33]

ARPA's initial victories were disseminating new networking information throughout academic circles and, eventually, the adoption of ARPANET by military and research institutions.[34] But the wide-ranging implications of ARPA's objectives (i.e. "to improve and increase computer research productivity") reveal the project's broad scope. ARPA wanted not only to upgrade the DoD's command and control capabilities, but also assist "society at large" by addressing the barrier imposed by thousands of private and public sector computers functioning autonomously, according to the BBN report.[35] The project objective wasn't just to 'build a better mousetrap' for the Department of Defense– it was to reformat the universal understanding of the mousetrap and expand its capabilities for users throughout the United States. Indeed, ARPA embraced Licklider's belief that interconnected computing was "what the military needs is what the businessman needs is what the scientist needs."[36] This ambitious scope also illustrates the amenities afforded by governmental funding. Licklider and his successors secured continuous government allocations by requesting funds for projects that were already underway and had shown results.[37] One may find it hard to fathom that ARPANET could have developed exclusively in the private sector—where funding for research and development is subject to the whims of the market—considering the fact it took two years for ARPANET's full potential to become apparent. [38]

Such broad scope inevitably invites scope creep, which Gray and Larson define as the tendency for a project to expand over time.[39] Indeed, though ARPANET's cost in the first two years of its existence was close to the project plan's estimates, the network's expanding scale lead to an unplanned increase in expenditures.[40] The DoD also cited ARPA for violating policy by developing an electronic mail system that should have been approved by the Department initially.[41] However, the development of ARPANET's personal messaging component proved unexpectedly to be the most popular feature of the network.[42] By early 1973, e-mail made up three-fourths of ARPANET traffic.[43] This unintended consequence

32 Bolt Beranek and Newman Inc. (1981). "A History of the Arpanet: The First Decade." Report No. 4799. Arlington, VA: Defense Advanced Research Projects Agency. II-21

33 Ibid. II-2, II-21

34 Ibid. II-8

35 Ibid. II-3

36 Hughes, Thomas Parke (1998). "Networking: ARPANET." Rescuing Prometheus. New York: Pantheon Books, 265

37 Ibid., 269

38 Bolt Beranek and Newman Inc. (1981). "A History of the Arpanet: The First Decade." Report No. 4799. Arlington, VA: Defense Advanced Research Projects Agency. II-22

39 Gray, C. F., & Larson, E. W. (2011). Chapter 4: Defining the Project*Project Management: The Managerial Process* (5th ed). Boston: McGraw-Hill/Irwin. 105

40 Bolt Beranek and Newman Inc. (1981). "A History of the Arpanet: The First Decade." Report No. 4799. Arlington, VA: Defense Advanced Research Projects Agency. II-22

41 Lukasik, Stephen J. (2011)"Why the ARPANET was built." *IEEE Annals of the History of Computing* 33, no. 3: 14

42 Hughes, Thomas Parke (1998). "Networking: ARPANET." Rescuing Prometheus. New York: Pantheon Books, 293

43 Ibid.

was facilitated by using the network's structure, communications system, and time-related protocols, and encouraged new users to join the network,[44] many of whom were students who would grow nascent computer science departments at numerous universities.[45] Though costs rose to subsidize the development of this unplanned function, the rise of electronic messaging is an example of positive scope creep, in which an outcome – in this case, the emergence of e-mail – far outweighs the negatives imposed by the expanding cost. In 2014, over 100 billion emails were sent each day.[46]

E-mail was not the only positive externality of ARPANET. The DNA of ARPANET is found within the 21st Century Internet, which is a distributed network that still uses packet-switching to transmit data.[47] Today, over 40% of the world's population (three billion people) uses the Internet.[48] Even in 1981, only a decade into ARPANETS existence, BBN had the foresight to know that just "as the telephone, the telegraph, and the printing press had far-reaching effects on human intercommunication…the ARPANET project represents a similarly far-reaching change in the use of computers by mankind."[49] It is inarguable that ARPA's objectives in the 1970s were not only met, but the long-term outcomes exceeded the wildest ambitions of the ARPANET's creators.

ORGANIZATIONAL STRUCTURE AND CULTURE: "THEY PRETTY MUCH LET ME DO WHAT I WANTED TO DO."[50]

A project as technical and complex as the development of ARPANET required a confluence of organizational structural, leadership, and cultural factors that would accommodate the long-term and evolving work ahead. It would seem reasonable that the organizational structure of ARPA and IPTO would emulate the rigid hierarchies of the DoD and military, however this was not the case. First, ARPA's organizational mission ("to be responsible for the direction or performance of…advanced projects") invited open-ended interpretation, which permitted broad discretion for project managers to expand ARPA's command and control systems objective to establish IPTO and conduct research on information processing technologies.[51] Second, IPTO maintained a "strong matrix" structure which, according to Gray and Larson, creates the "feel" of a project team by allowing project managers to control scope trade-offs and assignment of personnel within a functional environment.[52] ARPA attracted excellent managers with the promise of the freedom to grant contracts to teams whom they deemed the best, brightest, and most apt for the job.[53]

Bennis and Biederman could have highlighted the team at IPTO as an example of a "Great Group" in their book, Organizing Genius: The Secrets of Creative Collaboration. Great Groups are teams of original thinkers, fully engaged in the process of discovery and

44 Brendon, Laura K. (2001). "ARPANET: An Efficient Machine as Social Discipline." Science as Culture. 10 (1): 88
45 Hughes, Thomas Parke (1998). "Networking: ARPANET." Rescuing Prometheus. New York: Pantheon Books, 257
46 The Radicati Group, Inc. (2013). "Executive Summary." Email Statistics Report, 2013-2017. Executive Summary
47 Brendon, Laura K. (2001). "ARPANET: An Efficient Machine as Social Discipline." Science as Culture. 10 (1): 83
48 Internet Live Stats (2014). "Internet Users." Internet Users. Retrieved June 29, 2014 from http://www.internetlivestats.com/internet-users/
49 Bolt Beranek and Newman Inc. (1981). "A History of the Arpanet: The First Decade." Report No. 4799. Arlington, VA: Defense Advanced Research Projects Agency. I-2
50 Lukasik, Stephen J. (2011)"Why the ARPANET was built." *IEEE Annals of the History of Computing* 33, no. 3: 8
51 Brendon, Laura K. (2001). "ARPANET: An Efficient Machine as Social Discipline." Science as Culture. 10 (1): 78
52 Gray, C. F., & Larson, E. W. (2011). Chapter 4: Defining the Project*Project Management: The Managerial Process* (5th ed). Boston: McGraw-Hill/Irwin. 72
53 Hughes, Thomas Parke (1998). "Networking: ARPANET." Rescuing Prometheus. New York: Pantheon Books, 298

freed from micromanagement to achieve creative results.[54] Within ARPA, the IPTO team was essentially isolated from the military's oversight.[55] Its remote relationship with the military permitted a non-hierarchical culture, which the engineers and scientists embraced wholeheartedly. Team members became advocates of consensus and meritocracy over hierarchical management,[56] which allowed bright people to do their best work.

Another trait of a Great Group is a strong and visionary leader at the helm.[57] Great Group leaders, first and foremost, have a keen eye for attracting, recruiting, and inspiring top talent.[58] ARPANET was ushered into existence through the leadership of two irreplaceable men. Both Licklider and Taylor shared a knack for bringing out the best in their teams. Taylor deferred to his team's technical expertise because of his limited computing background and his pressing bureaucratic priorities,[59] and the team was better off for it. "The program managers at ARPA didn't really have the time to tell people how to do it," recalled an ARPA contractor. "They really much more aimed at funding people who were smart enough and self-motivated enough to recognize what the problems were and go solve them."[60]

There is no clearer example of Great Group principles in action than at BBN, the private firm that was contracted to construct the IMP subnet. Great Groups are comprised of "tinkerers" who, as professionals, bring a vivacious zeal to their work.[61] A recurring descriptor BBN personnel used in their recollections to describe their time working on ARPANET was "fun."[62] It was ideal that team members felt this way, given that designing the IMP subnet was an intimate process involving a team of only five to six people.[63] The team functioned on a level closely resembling a "Skunkworks," a small group structure which Clarence "Kelly" Johnson of Lockheed Martin used as a way to organize high-performing specialists to accomplish projects independent from the main organization.[64] BBN's freedom from micromanagement allowed it to perform agile project management, which "relies on incremental, iterative development cycles to complete projects."[65] For example, without a playbook to guide them, the BBN team invented the IMP subnet through an iterative process that continued when ARPANET was functional and necessitated a new nodal switching unit to allow more users to connect to the network.[66] Through visionary leadership and the organizational flexibility that allowed brilliance to flourish among personnel, IPTO fostered a Great Group environment that filtered down to the contracted firms that ultimately put ARPANET online.

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54 Bennis, W. G., & Biederman, P. W. (1997). The End of the Great Man. *Organizing Genius: The Secrets of Creative Collaboration* (). Reading, Mass.: Addison-Wesley. 7;9;19

55 Hughes, Thomas Parke (1998). "Networking: ARPANET." Rescuing Prometheus. New York: Pantheon Books, 279

56 Ibid.

57 Bennis, W. G., & Biederman, P. W. (1997). The End of the Great Man. *Organizing Genius: The Secrets of Creative Collaboration* (). Reading, Mass.: Addison-Wesley. 11

58 Ibid.

59 Hughes, Thomas Parke (1998). "Networking: ARPANET." Rescuing Prometheus. New York: Pantheon Books, 268

60 Ibid., 287

61 Bennis, W. G., & Biederman, P. W. (1997). The End of the Great Man. *Organizing Genius: The Secrets of Creative Collaboration* (). Reading, Mass.: Addison-Wesley. 16

62 Hughes, Thomas Parke (1998). "Networking: ARPANET." Rescuing Prometheus. New York: Pantheon Books, 278; 297.

63 Ibid., 272

64 McCurdy, H. E. (2001). Chapter 6: Organization. *Faster, Better, Cheaper Low-Cost Innovation in the U.S. Space Program* (). Baltimore: Johns Hopkins University Press. 90

65 Gray, C. F., & Larson, E. W. (2011). Chapter 4: Defining the Project*Project Management: The Managerial Process* (5th ed). Boston: McGraw-Hill/Irwin. 72

66 Bolt Beranek and Newman Inc. (1981). "A History of the Arpanet: The First Decade." Report No. 4799. Arlington, VA: Defense Advanced Research Projects Agency. II-19

CONCLUSION: A NEW COMMUNITY OF TINKERERS

Beyond the seismic contribution of having invented the precursor to the Internet, the people of ARPA and its subsidiaries ushered in a new era of collaboration among computer scientists around the world. ARPANET was the first open-source program to invite tech-savvy contributors outside of ARPA to partake in the development of a computer network.[67] ARPANET's success can be attributed to a number of factors that encouraged access, including its unclassified project status and that people could experiment with the nascent system - send emails or ferry codes, for example – for free.[68] ARPANET was quickly discovered to be a social network that connected geographically disparate research groups.[69]

The legacy of ARPANET lives on in the billions of people who use the Internet every day to communicate, engage, and stay connected with each other. The individuals who log on to the Internet today are indebted to the enduring success of the ARPA, IPTO, and BBN teams and their ARPANET project, which started as a network between two university computer sites in California in the 1970s.[70] The worldwide online community that has developed since, however, is a testament to Licklider's vision, now realized.

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67 Raymond, E. (2005, June 21). Open Minds, Open Source. . Retrieved June 22, 2014, from http://www.catb.org/esr/writings/analog.html, 4

68 Bolt Beranek and Newman Inc. (1981). "A History of the Arpanet: The First Decade." Report No. 4799. Arlington, VA: Defense Advanced Research Projects Agency. III-109

69 Ibid., III-108

70 Brendon, Laura K. (2001). "ARPANET: An Efficient Machine as Social Discipline." Science as Culture. 10 (1): 93

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11. Raymond, E. (2005, June 21). Open Minds, Open Source. . Retrieved June 22, 2014, from http://www.catb.org/esr/writings/analog.html