The History of ARPA Leading up to the ARPANET
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Part I

A climate of pure research surrounded the entire history of the ARPANET. The Advanced Research Projects Agency was formed with an emphasis towards research, and thus was not oriented only to a military product. The formation of this agency was part of the U.S. reaction to the then Soviet Union's launch of Sputnik in 1957. (ARPA draft, III-6). ARPA was assigned to research how to utilize their investment in computers via Command and Control Research (CCR). Dr. J.C.R. Licklider was chosen to head this effort. Licklider came to ARPA from Bolt, Beranek and Newman, (BBN) in Cambridge, MA in October 1962. (ARPA draft, III-6)

From Licklider's arrival, the department's contracts were shifted from independent corporations towards "the best academic computer centers" (ARPA draft, III-7). The then current computing mode was via batch processing (you know, input via stacks of punched cards, output: results, or lack of them, made known one or more days later.). Licklider saw improvements could be made in CCR only via work on advancing the current state of computing technology. He particularly wanted to move forward into the age of interactive computing, and the current contractors were not moving in that direction. In an Interview, Licklider told the interviewee that SDC "was based on batch processing, and while I was interested in a new way of doing things, they [SDC] were studying how to make improvements in the ways things were done already." (An Interview with J.C.R. Licklider conducted by William Aspray and Arthur Norberg on October 28, 1988 Cambridge, Mass. CBI Univ of Minn., Madison) The office "developed into a far-reaching basic research program in advanced technology." (ARPA draft III-7) Licklider's Office was renamed Information Processing Techniques (IPT or IPTO) to reflect that change.

The Completion report states that "Prophetically, Licklider nicknamed the group of computer specialists he gathered the 'Intergalactic Network'." ARPA draft, III-7) Before work on the ARPANET began, the very idea of the network was planted by the creation of the Information Processing Techniques Office of ARPA. Robert Taylor, Licklider's successor at the IPTO, remembers Lick's interest in interconnecting communities:

"Lick was among the first to perceive the spirit of community created among the users of the first time-sharing systems... In pointing out the community phenomena created, in part, by the sharing of resources in one timesharing system, Lick made it easy to think about interconnecting the communities, the interconnection of interactive, on-line communities of people, ..." (ARPA draft, III-21)

The "spirit of community" was related to Lick's interest in having computers help people communicate with other people (Licklider, Licklider, and Robert Taylor, "The Computer as a Communication Device") Licklider's vision of an "intergalactic network" connecting people represented an important conceptional shift in computer science. This vision was also an important beginning to the ARPANET. After the ARPANET was up and running, the computer scientists using it realized that assisting human communication was the most fundamental advance that the ARPANET made possible. (Cite Larry Roberts)

As early as 1963, a common question asked of the IPTO directors by the ARPA directors about IPTO projects was "Why don't we rely on the computer industry to do that?", or

ocassionally more strongly, "We should not support that effort because ABC (read, "computer industry") will do it - if it's worth doing!" (ARPA draft, III-23) This question leads to an important point - this ARPA research was different from what the computer industry had in mind to do - or was likely to undertake. Since Licklider's creation of the IPTO, the work supported by ARPA/IPTO continued his explicit emphasis on communications. The Completion Report explains,

"The ARPA theme is that the promise offered by the computer as a communication medium between people, dwarfs into relative insignificance the historical beginnings of the computer as an arithmetic engine." (ARPA draft, III-24)

The Completion Report goes on to differentiate ARPA from the computer industry:

"The computer industry, in the main, still thinks of the computer as an arithmetic engine. Their heritage is reflected even in current designs of their communication systems.' They have an economic and psychological commitment to the arithmetic engine model, and it can die only slowly..." (ARPA draft, III-24)

The Completion Report further analyzes this problem by tracing it back to the nation's institutions:

"...furthermore, it is a view that is still reinforced by most of the nation's computer science programs. Even universities, or at least parts of them, are held in the grasp of the arithmetic engine concept...." (ARPA draft, III-24)

Since Licklider's creation of the IPTO, the work supported by ARPA/IPTO continued the explicit communications emphasis. Thus history has witnessed the research and development which had led to the concrete existence of first the ARPANET, and later the Internet. Without the commitment that existed via this support, such a development might never have happened. One of ARPA's criterion for supporting research was such that it had to be of such a level to offer an order of magnitude of development. As most research and development is not immediately profitable, there has to be some kind of organization which helps to set higher goals than just in developing what will be immediately profitable. What is really strange is that computer networking is an immensely profitable field right now - only it is 25 years later.

Others have understood the communications promise of computers. For example, in RFC 1336, David Clark is quoted,

"It is not proper to think of networks as connecting computers. Rather, they connect people using computers to mediate. The great success of the internet is not technical, but in human impact. Electronic mail may not be a wonderful advance in Computer Science, but it is a whole new way for people to communicate. The continued growth of the Internet is a technical challenge to all of us, but we must never loose sight of where we came from, the great change we have worked on the larger computer community, and the great potential we have for future change."

Various research outside of ARPA had been done by Paul Baron, Thomas Marill and others. [This history is covered well in the article "From ARPANET to USENET" by Ronda Hauben..ref] This led Lawrence Roberts and other IPTO staff to formally introduce the topic of networking computers of differing types (incompatible hardware and software) together in order to share resources to the early 1967 meeting of ARPA's Primary Investigators (PI).

In the spring of 1967 at the University of Michigan, ARPA held its yearly meeting of the "principle investigators" from each of its university and other contractors. (ARPA draft, III-25) Results from the previous year's research was summarized and future research was discussed, either introduced by ARPA or the various researchers present at the meetings. Networking was one of the topics brought up at this meeting. (ARPA draft, III-25)

The Completion Report continues the story:

"At the meeting it was agreed that work could begin on the conventions to be used for exchanging messages between any pair of computers in the proposed network, and also on consideration of the kinds of communications lines and data sets to be used. In particular, it was decided that the inter-host communication 'protocol' would include conventions for character and block transmission, error checking and retransmission, and computer and user identification. Frank Westervelt, then of the University of Michigan, was picked to write a position paper on these areas of communication, an ad hoc 'Communication Group' was selected from among the institutions represented, and a meeting of the group scheduled." (ARPA draft, III-26)

In order to develop this network of varied computers, two main problems had to be solved:

" 1. To construct a 'subnetwork' consisting of telephone circuits and switching nodes whose reliability, delay characteristics, capacity, and cost would facilitate resource sharing among computers on the network.

2. To understand , design, and implement the protocols and procedures within the operating systems of each connected computer, in order to allow the use of the new subnetwork by the computers in sharing resources." (ARPA not draft, II-8)

After one draft and additional work on this communications position paper report, a two-day meeting was scheduled in early October 1967 by ARPA to "discuss the protocol paper and specifications for the Interface Message Processor (IMP)." The IMP was the decided upon method of connecting the participants computers (hosts) to each other via phone lines. This standardized the network which the hosts connected to. Now, only the connection of the hosts to the network would depend on vendor type, etc. ARPA had picked 19 possible participants in what was now known as the "ARPA Network", rather than the previously vague descriptions.

After the time of the 1967 PI Meeting, various computer scientists who were ARPA contractors were busy thinking about various aspects which would be relevant to the planning

and development of the ARPANET. Part of that work was a document outlining a beginning design for the IMP network. This specification would lead to the ability to a put out a competitive procurement for the design of the IMP subnetwork.

"At the end of 1967 ARPA initiated a small contract with the Stanford Research Institute for the development of specifications for the necessary communications system. Elmer Shapiro was to be the key person on this study. Published in the final version in December of 1968 was a 71-page SRI report entitled "A Study of COmputer Network Design Parameters", an early version in early 1968 served as the first draft of the IMP specification...In February or March a memo written by Shapiro and revised by Kleinrock entitled "Functional Description of the IMP" was circulated. After the first draft by Shapiro, it is believed that Glenn Culler wrote a second draft, and Robert and Wessler of ARPA wrote the final version of the IMP specification. In any case, by the first of March, 1968, IPT was able to report to the Director of ARPA that specifications for the IMP were essentially complete, and that they would be discussed at the upcoming PI meeting with the goal of issuing a Request for Quotation shortly thereafter. The network was discussed at the PI meeting and by June 1968, the ARPANET procurement officially started." (ARPA draft, III-32)

ARPA's Program Plan for the ARPANET was titled "Resource Sharing Computer Networks". It was submitted June 3, 1968, and approved by the Director June 21, 1968.

The Completion Report explains that the Program Plan was, "an interesting document. The stated objectives of the program were to develop experience in interconnection computers and to improve and increase computer research productivity through resource sharing. Technical needs in scientific and military environments were cited as justification for the program objectives. Relevant prior work was described. It was noted that the computer research centers supported or partially supported by IPT provided a unique testbed for computer networking experiments, as well as providing immediate benefits to the centers and valuable research results to the military. The network planning that had gone on was described, the need for a network information center was noted, and the network design was sketched. A five year schedule for network procurement, construction, operation, and transfer out of ARPA was presented. (It was noteworthy that IPT had initially had in mind eventual transfer of the operational network to a common carrier.) Finally a several-million-dollar, several-year budget was stated." (ARPA draft, III-35)

"The Defense Supply Service - Washington (DSS-W) agreed to be a procurement agent for ARPA. At the end of July the Request for Quotation for network IMPs was mailed to 140 potential bidders who had expressed interest in receiving it. Approximately 100 people from 51 companies attended a subsequent bidders' conference. Twelve proposals were actually received by DSS_W comprising 6.6 edge-feet of paper and presenting an awesome evaluation task for IPT, which more normally awards contracts on a sole source basis. Attempting to evaluate the proposals "strictly by the book", an ARPA-appointed evaluation committee retired to Monterey, California, to carry out their task. ARPA was pleasantly surprised that several of the respondents believed that they could construct a network which performed as much as a factor of five better than the delay constraint given in the RFQ..." (ARPA draft, III-35)

ARPA developed a program plan, which developed into a set of specifications. These specifications were connected to a competitive Request for Quotation to find an organization which would design and build the subnetwork between the IMPs.

BBN won the contract to develop the IMP-to-IMP subnetwork. However the second technical problem still remained to be solved. The protocol to allow the hosts to communicate with each other over the subnetwork had to be developed. This work was left "for host sites to work out among themselves." (ARPA draft, III-67) This meant that both the hardware and software necessary to connect the hosts to the IMP subnetwork had to be developed. ARPA assigned this duty to the initial designated ARPANET sites. As each site had a different type of computer to connect, they individually were the best informed designers for their personal setups. In addition the sites needed to develop the hardware and software necessary to utilize the other hosts on the network. (ARPA draft, III-39) ARPA's assigning of responsibilities makes the academic computer science community become an active part of the ARPANET development team. (Interview with Alex McKenize, Nov, 1 1993)

Steve Crocker associates the placement of the initial ARPANET sites at research institutions to the fact that the ARPANET was ground-breaking research. He wrote in a message responding to my questions on the COM-PRIV mailing list:

"During the initial development of the Arpanet, there was simply a limit as to how far ahead anyone could see and manage. The IMPs were placed in cooperative ARPA R&D sites with the hope that these research sites would figure out how to exploit this new communication medium." (Crocker, 1993A)

The first sites of the ARPANET were picked to provide either network support services or unique resources. They were also picked as deemed technically able of developing the protocols necessary to make communications between the varied computers connected possible. The key services the first four sites provided were

"UCLA - Network Measurement Center SRI - Network Information Center UCSB - Culler-Fried interactive mathematics UTAH - graphics (hidden line removal)" (Cerf, Vinton 1993)

Steve Crocker also recounts that the reason for selecting these particular four sites was because they were "existing ARPA computer science research contractors." This was important because "the research community could be counted on to take some initiative." (RFC 1000, pg 1)

The very first site to receive an IMP was UCLA. Professor Leonard Kleinrock of UCLA was involved with much of the early development of the ARPANET. His work consisted of understanding queueing theory and as such was one of the first computer scientists working on the ARPANET who was dealing with how to measure what was happening as the network would function. This made it natural to make sure that UCLA received the first node as it would be important to initiate the network from the site which would measure the networks activity. In order for the statistics to be correct and for analysis purposes - the first site had to

be the measurement site. Sure enough UCLA was assigned to be the Network Measurement Center (NMC).

Part II: The Network Working Group

Once the initial sites were picked, representatives from each site gathered together to start talking about solving the technical problem of getting the hosts to communicate via protocols. The ARPA Completion report tells us about this beginning:

"To provide the hosts with a little impetus to work on the host-to-host problems. ARPA assigned Elmer Shapiro of SRI "to make something happen", a typically vague ARPA assignment. Shapiro called a meeting in the summer of 1968 which was attended by programmers from several of the first hosts to be connected to the network. Individuals who were present have said that it was clear from the meeting at that time, no one had even any clear notions of what the fundamental host-to-host issues might be." (AC Draft III-67 1.4.1.7)

Again, we see that this group, which came to be know as the Network Working Group (NWG), was exploring new territory. The first meeting took place several months before the first IMP was put together and they had to think from a blank slate. Throughout the existing recollections of the important developments the NWG produced, (especially RFC 1000) the reader is reminded that the thinking involved was totally original and thus thought-provoking.

Steve Crocker remembers in the RFC Reference Guide (RFC 1000) that the first meeting was chaired by Elmer Shapiro, who initiated the conversation with a list of questions. (Crocker, 1993b) Also present were Steve Carr from University of Utah, Stephen Crocker from UCLA, Jeff Rulifson from SRI, and Ron Stoughton from UCSB. These attendees are the programmers referred to in the ARPANET Completion Report.

In the words of Steve Crocker, this was a seminal meeting. The attendees could only be but theoretical, as none of the lowest levels of communication had been developed yet. They needed a transport layer or low-level communications platform to be able to build upon. BBN did not deliver the first IMP until August 30, 1969. It was important to meet beforehand, as the NWG "imagined all sorts of possibilities." (Rfc1000) Only once their thought processes started could this working group actually develop anything. These fresh thoughts from fresh minds help to incubate new ideas. The ARPANET Completion Report properly acknowledges what this early group helped accomplished: " Their early thinking was at a very high level." (ARPA draft, III-67) A concrete decision of the first meeting was to continue holding meetings similar to the first one. This wound up setting the precedent of a holding exchange meetings at each of the sites.

Steve Crocker, describing the problems facing these networking pioneers, writes:

"With no specific service definition in place for what the IMPs were providing to the hosts, there wasn't any clear idea of what work the hosts had to do. Only later did we articulate the notion of building a layered set of protocols with general transport services on the bottom and multiple application- specific protocols on the top. More precisely, we understood quite early

that we wanted quite a bit of generality, but we didn't have a clear idea how to achieve it. We struggled between a grand design and getting something working quickly." (Crocker,1993c)

The initial protocol development lead to DEL (Decode- Encode-Language) and NIL (Network Interchange Language). These languages were ahead of their time. The basic purpose was to form an on-the-fly description that would tell the receiving end how to understand the information that would be sent. However, these first set of meetings were extremely abstract as neither ARPA nor the universities had deemed any official charter. The lack of a charter allowed the group to think broadly and openly however.

BBN did submit details as to the host-IMP interface specifications from the IMP side. This information provided the group some definite starting points to build from. Soon after BBN provided more information, on Valentine's Day, 1969, members of the NWG, members of BBN and members of the Network Analysis Corporation (NAC) met for the first time. [The NAC was contracted by ARPA to "specify the topological design of the ARPANET and to analyze its cost, performance, and reliability characteristics. (ARPA not draft, III-30)] As all the parties had different priorities on mind, the meeting was a difficult one. BBN was interested in the lowest level of making a reliable connection. The programmers from the host sites were interested in getting the hosts to communicate with each either via various higher level programs. And BBN also did not turn out to be the "experts from the East" that Steve Crocker wrote the members of the NWG expected. He continues by writing in RFC 1000 that they constantly thought that "a professional crew would show up eventually to take over the problems we were dealing with."

A step of incredible importance and openness occurred as a result from a "particularly delightful" meeting that took place a month later in Utah. (RFC1000) The participants decided it was time to start recording their meetings in a consistent fashion. What resulted was a set of informal notes titled "Request for Comments." Steve Crocker writes about their formation:

"I remember having great fear that we would offend whomever the official protocol designers were, and I spent a sleepless night composing humble words for our notes. The basic ground rules were that anyone could say anything and that nothing was official. And to emphasize the point, I labeled the notes "Request for Comments." I never dreamed these notes would distributed through the very medium we were discussing in these notes. Talk about Sorcerer's Apprentice!" (Crocker, RFC 1000, pg 3, 1987)

Crocker replaced Shapiro as the Chairman of the NWG after the initial meeting. He describes how they wrestled with creation of the host-host protocols:

"Over the spring and summer of 1969 we grappled with the detailed problems of protocol design. Although we had a vision of the vast potential for intercomputer communication, designing usable protocols was another matter. A custom hardware interface and custom intrusion into the operating system was going to be required for anything we designed, and we anticipated serious difficulty at each of the sites. We looked for existing abstractions to use. It would have been convenient if we could have made the network simply look like a tape drive to each host, but we knew that wouldn't do." (Crocker, RFC 1000, pg. 3)

The first two IMPs were delivered to UCLA (number 1) and SRI (Number 2). Once two IMPs existed, the NWG had to implement a working protocol. This first set of host protocols included a remote login for interactive use (telnet), and a way to copy files between remote hosts (FTP). Crocker writes:

"In particular, only asymmetric, user-server relationships were supported. In December 1969, we met with Larry Roberts in Utah, [and he] made it abundantly clear that our first step was not big enough, and we went back to the drawing board. Over the next few months we designed a symmetric host-host protocol, and we defined an abstract implementation of the protocol known as the Network Control Program. ("NCP" later came to be used as the name for the protocol, but it originally meant the program within the operating system that managed connections. The protocol itself was known blandly only as the host-host protocol.) Along with the basic host-host protocol, we also envisioned a hierarchy of protocols, with Telnet, FTP and some splinter protocols as the first examples. If we had only consulted the ancient mystics, we would have seen immediately that seven layers were required." (RFC 1000, pg 4)

After Robert's guidance, the Network Working Group went forward in developing the protocols necessary to make the network viable. The group swelled in attendance as more and more sites connected to the ARPANET. The group became large enough (around 100 people) that one meeting was held in conjunction with the 1971 Spring Joint Computer Conference in Atlantic City. A major test of the NWG's work came in October 1971, when a meeting was held at MIT. Crocker continues the story,

"[A] major protocol "fly-off" - Representatives from each site were on hand, and everyone tried to log in to everyone else's site. With the exception of one site that was completely down, the matrix was almost completely filled in, and we had reached a major milestone in connectivity." (Crocker, RFC 1000, pg. 4)

The NCP was created as what was called the "host to host protocol." Explaining why this was important, the authors of the ARPA draft write:

"The problem is to design a host protocol which is sufficiently powerful for the kinds of communication that will occur and yet can be implemented in all of the various different host computer systems. The initial approach taken involved an entity called a "Network Control Program" which would typically reside in the executive of a host, such that processes within a host would communicate with the network through this Network Control Program. The primary function of the NCP is to establish connections, break connections, switch connections, and control flow. A layered approach was taken such that more complex procedures (such as File Transfer Procedures) were built on top of similar procedures in the host Network Control Program." (Arpa draft, II-24)

As the ARPANET grew, the number of Users bypassed the number of developers. This signaled the success of these networking pioneers. Steve Crocker appointed Alex McKenize

and Jon Postel to replace him as Chairmen of the Network Working Group. The Completion Report details how this role changed:

"McKenzie and Postel interpreted their task to be one of codification and coordination primarily, and after a few more spurts of activity the protocol definition process settled for the most part into a status of a maintenance effort." (ARPA draft,III-69)

ARPA (Advanced Research Projects Agency) was a management body which lent funding to academic computer scientists. ARPA's smart management sense paved the way for these scientists to create the ARPANET. BBN helped via developing the packet switching techniques most suitable to passing a wide variety of information. However, the most important development was that of the "Request for Comments" documentation.