Choreographies of Information

The Architectural Internet of the Eighteenth Century's Optical Telegraphy

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Today, with the dominance of digital information and communications technologies (ICTs), information is mostly perceived as digital bits of electric pulses, while the Internet is seen as a gigantic network of cables, routers, and data centers that interconnects cities and continents. But few know that for a brief period in history, before electricity was utilized and information theory formalized, a mechanical version of what we call "Internet" connected cities across rural areas and landscapes in Europe, the United States, and Australia, communicating information by transforming a rather peculiar medium: geometric architectural form.

The Origins of Territorial Intelligence

Telecommunication was not a novelty in the eighteenth century. Early data networks communicated intelligence across land and sea through such media as fire, sound, light, pigeons, mirrors, and flags. In the twelfth century BCE, for example, Agamemnon used a bonfire relay line across six hundred kilometers of ocean and terrain to communicate the news of Troy's fall to Mycenae. In 150 BCE, Greek historian Polybius described a system of sending pre-encoded messages with torches combinations.[01] And in 1453, Nicolo Barbaro mentioned in his diary how Constantinople's bell-tower network alerted citizens in real time to the tragic progress of the siege by the Ottomans.[02] It wasn't until the mid-eighteenth century, however, that telecommunications developed into vast territorial networks that used visual languages and control protocols to disassemble any message into discrete signs, route them wirelessly through relay stations, reassemble them at the destination, and reformulate the message by mapping them into words and phrases through lookup tables. And all of this was done in unprecedented speeds. Two inventions made it possible: the telescope and the optical telegraph.

The telescope's invention in 1608 improved telecommunications as nothing else before. With a thirtyfold magnifying power, telescopes expanded communication links more than an order of magnitude, while dropping dramatically their infrastructure and operational costs.[03] Optical telegraphs were mechanically transformable structures—partly buildings, partly machines—that could reconfigure their silhouettes to visually manifest signs. Together with telescopes, they created a powerful mechanical internet that could automatically transmit any arbitrary message, independent of its length, through a choreography of mechanical transformations. Through its brief history, the mechanical internet of optical telegraphy introduced fundamental concepts of communication and computing like error detection, data compaction, flow control, encryption, handshaking, clock synchronization, signal restoration, routing, regulation and even fraud that are all present today on the Internet.

The contribution of this essay is twofold: on the one hand, it sheds light to the techno-sociopolitical context of the history of optical telegraphy, a topic that is largely disregarded in architectural and urban history; on the other hand, it makes three thesis statements on the relation of optical telegraphy to the contemporary critical discourse on architecture, media, and urban intelligence.

The Architectural Internet

In March 1791, Claude Chappe, a French cleric and inventor, placed with his brother two synchronized pendulums with ten signs each on their clock faces several hundred meters apart. His goal was to send a message as a combination of signs across the two devices.

To send a sign, the transmitting clock emitted a sound precisely at the moment when the indicators of both clocks passed from the specific sign. By combining signs, predetermined messages could be found in a dictionary.[04] The solution, however, was cumbersome, mechanically complex, and operationally complicated. Two years later, Chappe came up with a new idea, conceptually, mechanically, and operationally simpler: one mechanically transformable structure configured its silhouette to visually represent a sign; then, it waited for the remote structure to replicate the silhouette, thus confirming the sign. By placing the devices on high enough towers, the sky could be used as a bright background to visually enhance the silhouettes. Relay cascades could transmit messages by copying each other's silhouette through a domino effect. Chappe named his invention "telegraphy" from the Greek words *tele* (distant) and *graph* (writing). An architectural form of communication had just been invented.

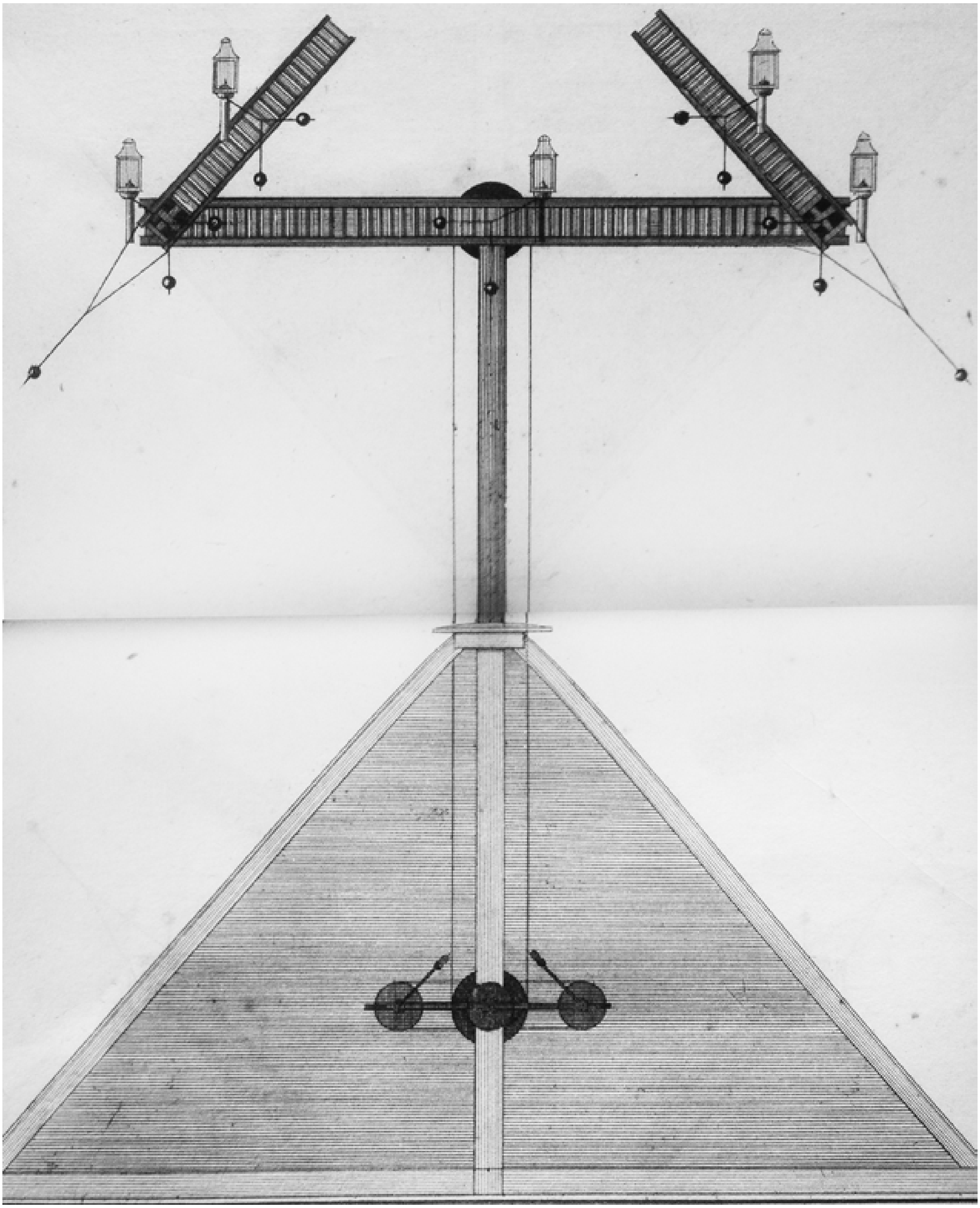
The Signaling Apparatus: Form Follows Information

The evolution of optical telegraphy was an interplay between communication protocols, engineering ingenuity, operational simplicity, and cost. The concept though remained the same: form follows information. Over the years two designs prevailed: the semaphore and the shutter telegraph.

The semaphore, invented in 1793 by Chappe, consisted of a thirty-foot-high mast with a pivoting arm on top called the regulator. At the two ends of the regulator, which measured fourteen feet long and thirteen inches wide, there were two smaller rotating arms called the indicators, which measured six feet long and one foot wide each. Chappe found through experiments that their thin silhouettes were easily distinguishable from large distances. Both the regulator and the indicators could rotate in forty-five-degree intervals: the regulator could take four positions (horizontal, vertical, and the two diagonals), while each indicator could take eight positions. The apparatus, which was painted black to contrast with the blue sky, could take a total of 256 (eight by eight by two) different positions, or eight bits of information storage. Not all positions were retained, however: Chappe eliminated the positions in which the two indicators were parallel to the regulator and pointed inward because they were hidden. Furthermore, from the four positions of the regulator, he only kept the vertical and horizontal ones. After eliminating a few other positions, the semaphore telegraph eventually encoded a total of ninety-two signs.[05]

The shutter telegraph, first invented in 1794 by the Swedish baron Abraham Niclas Edelcrantz and modified in 1796 by the British lord George Murray, utilized a matrix of flipping shutters, pivoted on horizontal axes, that could open and close individually. Edelcrantz's apparatus had ten shutters organized in a three-by-three matrix, with a tenth shutter mounted on top of the middle column. It could encode 1,024 signs, or ten bits. Murray's apparatus used only six shutters, organized in a two-by-three matrix, with a capacity of sixty-four different alphanumerical characters or six bits. Like Chappe, both Edelcrantz and Murray optimized the design of their devices through experimentations. Edelcrantz found that the gap between shutters needed to equal the width of one shutter, at the least, to prevent the human eye from mistakenly blending adjacent shutters when viewing the apparatus from a great distance. He also determined the size and angle of the matrix as a function of the distance the towers had between them, the magnitude of the telescope used, and the minimum visual angle of a human eye.[06] Likewise, Murray standardized the design of his matrix on two supporting posts twenty feet high and twelve feet apart; each shutter was roughly six feet by five feet in size.[07]

Opposite: Chappe semaphore.



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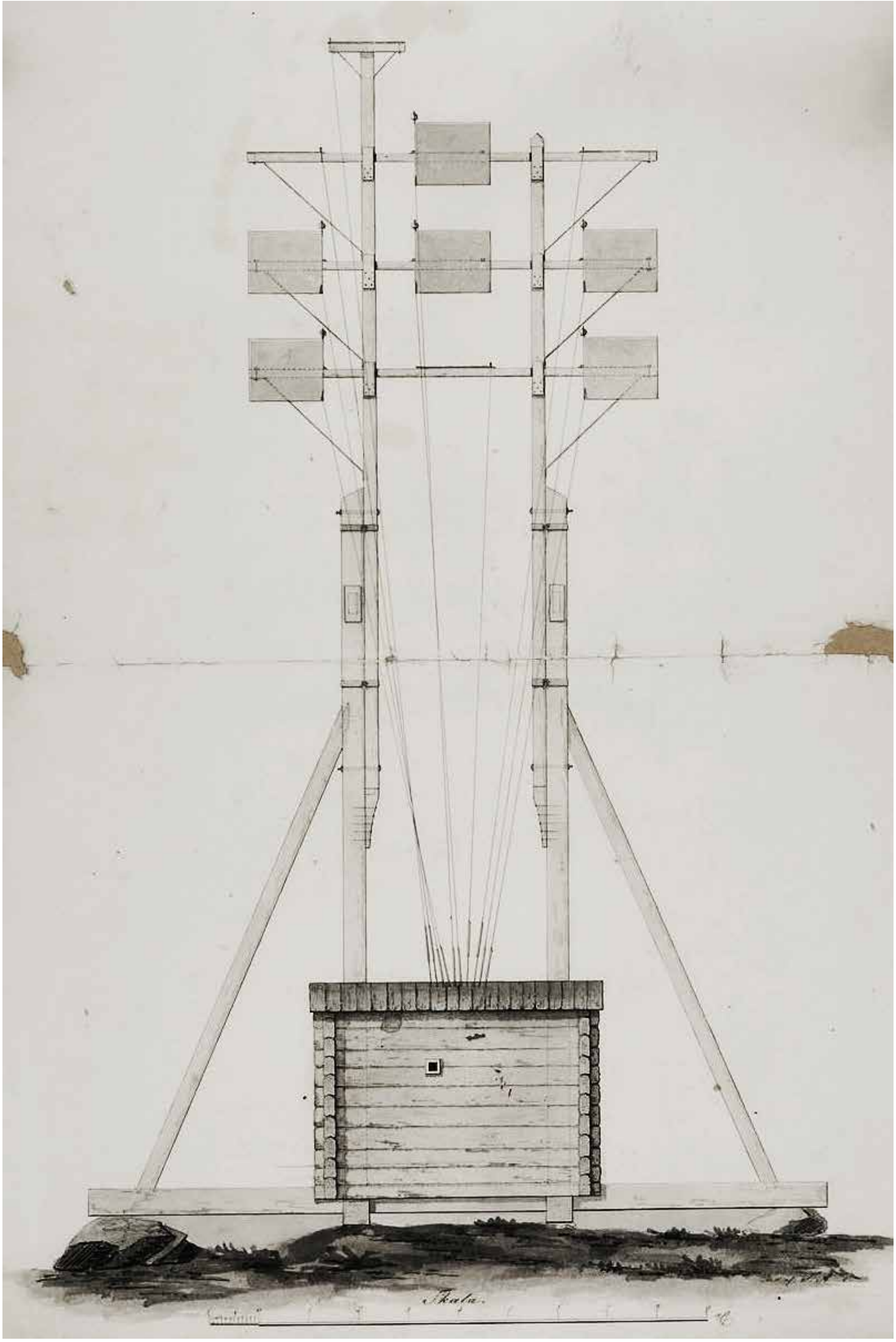

Skala.

The Control Room and the Operators: The Puppeteers

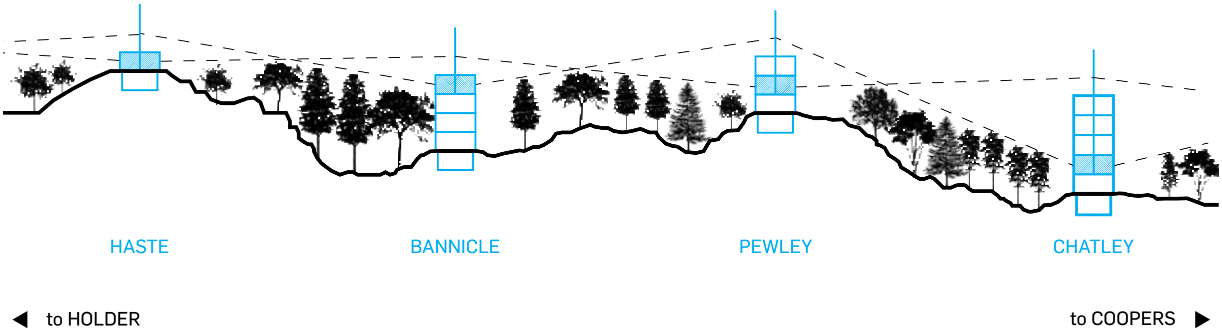
Optical telegraphs were remotely linked to an interface that a human operator could manipulate inside a control room. Chappe's device was mechanically connected through pulleys, disks, gears, belts, and cables to a miniature replica of the device inside that room. Likewise, Edelcrantz's and Murray's signaling devices each linked through strings to a small control box with ten rings, which the operator could pull with his fingers. Like puppeteers, operators could manipulate the miniature devices inside the control room, and the large apparatuses atop the tower would silently replicate the postures. Edelcrantz developed an even more sophisticated mechanism that used foot pedals to control the shutters, leaving the hands of the operator free to turn the pages of the codebook.[08]

Inside the control room, telescopes mounted on the walls pointed to the apparatuses of the nearby telegraph towers. Each relay tower had three to four operators: two watchmen, who monitored nearby towers for incoming or outgoing signals, and a third (and occasionally fourth) worker who operated the apparatus to transmit signals. A terminal station had only two operators, as it only connected to one nearby tower. Occasionally, a single highly skilled worker could both watch and manipulate the apparatus, if the telescope and control mechanism were located close enough to each other.[09] Operators replicated signs without knowing how to interpret them. Only authorized officers with frequently updated codebooks could interpret signs. This knowledge separation decoupled operations from intelligence, enhancing security throughout the entire communications system.

Opposite: Swedish shutter telegraph system. Above, left: The Furusud shutter telegraph in Sweden. Above, right: Inside an operator's room at the Furunsud telegraph.

The Building Typology: The Mechanical Puppet

In dense urban environments, optical telegraphs were often placed on top of high-rise public buildings, like churches, town halls, or bell towers. In rural areas, however, optical telegraphs developed their own typologies in which the signaling apparatuses were architecturally integrated to the building. These typologies evolved based on available materials, human factors, and communication protocols. Towers were built out of timber or masonry and were often fortified, as they constituted military targets. They often contained a kitchen, bedroom, storage for food and fuel supplies, and external water well.[10] Their design typically employed simple geometries such as rectangular or cylindrical prisms; however, more complicated types existed. T. W. Holmes, for example, mentions four building typologies in the British system: a bungalow and three-, four-, and five-story types. Selection was based on the tower's location and the size of the operator's family. Typologies, however, depended also on the landscape and network topology. In his treatise, Edelcrantz explains that on the plains or in flat landscapes telegraphs need to be positioned above



the level of fog, mist, or any mirage effects of the hot season, using the sky as much as possible as a background.[11] Furthermore, he determined the distance of towers as a function of the curvature of the earth, mirage effects, and natural geography of the landscape. The height of the control room and the signaling apparatus in the towers varied based on the location and the height of nearby trees or other obstacles, resulting in each tower having a different architectural configuration.

Transmission: Form Follows Form

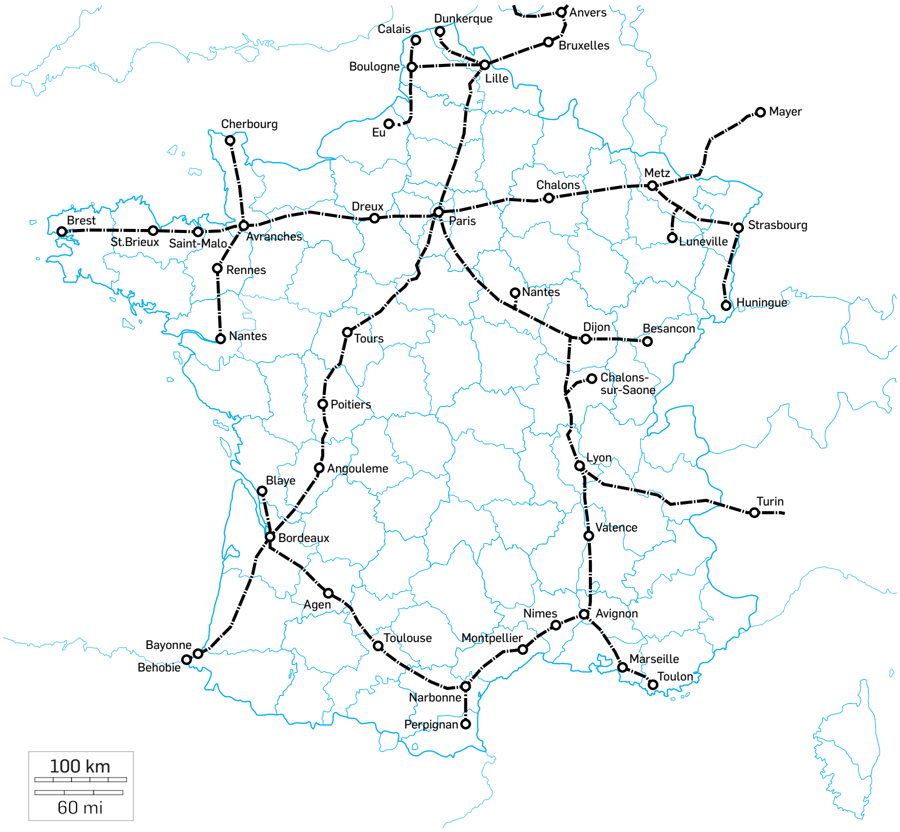
Relay towers transmitted data by copying each other's form in a domino effect. Hence, form followed form at its most literal sense. Transmission speeds were remarkably high. According to Edelcrantz, Chappe's device could manually change position every twenty seconds, sending approximately two to three signs per minute.[12] Assuming the device utilized 128 of its total 256 signs, this would be equivalent to a transmission speed of 0.5 bits per second. Edelcrantz's ten-bit code could change every eight to ten seconds, while Murray's six-bit code could change every five seconds, both giving a signaling speed of approximately one bit per second.[13] With that speed, a message could traverse the 120 stations of the Paris–Toulon line in less than twelve minutes.

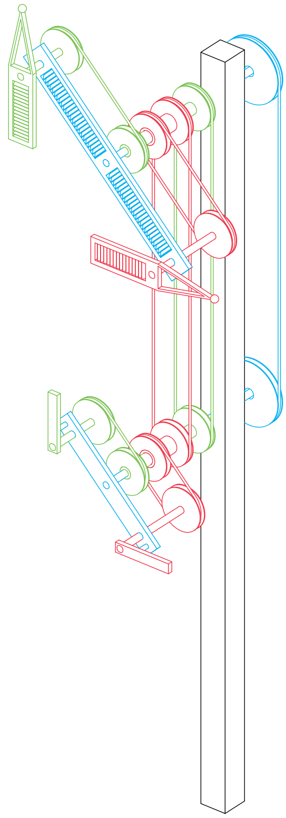
Although signs were transmitted at the aforementioned speeds, their information content depended on how they were utilized to construct messages. Two methods were used: in the first, signs pointed to predefined sentences in lookup codebooks; in the second, signs pointed to alphanumeric characters used for explicitly spelling out messages. While the second method was admittedly slower, it was also logistically simpler and cheaper as it did not rely on voluminous dictionaries that were updated and reprinted often.

Both Chappe and Edelcrantz used codebooks in their systems. In Chappe's system, each transmission consisted of two consecutive signs, the first pointing to a page and the second pointing to an entry in that page. Chappe's codebook had ninety-two pages of ninety-two entries each, for a total of 8,464 predefined messages. Holzmann estimated that Chappe's telegraph was capable of sending up to twenty characters per minute,[14] an astonishing rate compared to the twenty-five characters per minute of the first electromagnetic telegraph in 1837.[15] Edelcrantz's system also used a lookup table with 1,024 entries. To map his device's configurations to index numbers he came up with the following: from top to bottom, he assigned the values 1, 2, and 4 to the shutters of each of the three columns. Then, for each column, he added the values of the closed shutters producing a triplet of octal numbers ranging from zero to seven. The complete code for each signal consisted of the three numbers, prefixed by letter *A* if the tenth large shutter was closed. For example, code *A636* meant a configuration in which the top two shutters of the middle column, the bottom two shutters of the first and third columns, and the tenth shutter were closed. Murray's system was simpler: with a limited range of only sixty-four entries, it was based on explicit spelling.

Optical telegraphs developed sophisticated protocols for communication, addressing, and error detection that are found today in modern telecommunication systems. In the French system, for example, only terminal stations could send or receive messages while all other stations served as relays. In the Swedish network, however, any station could send or receive messages to or from any other station. This addressing detail affected the

Above: Heights of operator room and semaphore apparatus in relation to landscape topography and tree height. A portion of the semaphore line in England.





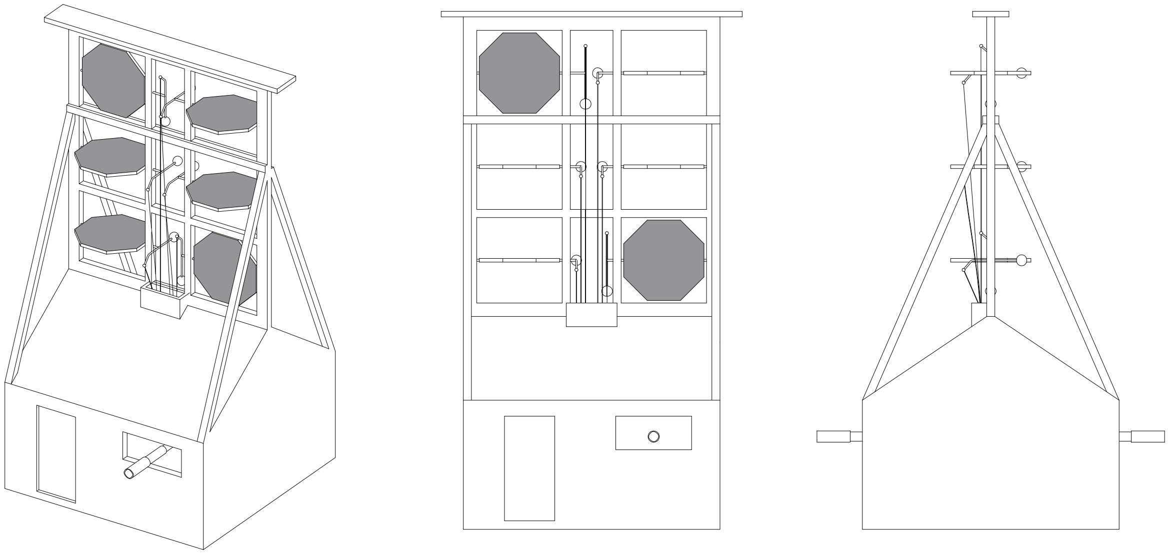
format, size, and eventually transmission speed of the messages as in the former case the messages did not include recipient or sender information while in the latter case they did.[16] Special regulations were invented to deal with message traffic, which was bidirectional and often heavy. When traffic accumulated in a station, for example, rules prioritized which message to switch and which one to hold, especially in hubs. As networks grew, so did their complexity, vulnerability, and ingenuity. Both Chappe and Edelcrantz knew that their system would be as strong as its weakest link: a single error in one relay station could shut down an entire line. Self-reporting mechanisms identified problematic nodes in the network: towers kept logs and reported their peer towers if they were slow in responding. Penalties included fines and imprisonment.[17]

Geographies of Information

Telegraph relay towers were erected at eight- to fifteen-kilometer intervals across the landscape, creating networks of various topologies. The location of each tower was of paramount importance to the reliability of the network: even one misplaced or problematic station could affect the entire line. As telegraphs had only a front and a back facade, they could be read only from a certain viewing angle, which restricted how towers could be placed. In France, a trial period of one year typically existed for new stations: during this time, stations were often moved around until a good location was found.[18]

By the early nineteenth century, optical telegraphy networks in Europe were vast and busy. More than a thousand telegraphs connected cities from Paris to Perpignan and Toulon in the south, to Amsterdam in the north, to Brest in the west, and to Venice in the east, streaming information at full capacity. In France, for example, traffic averaged several hundred messages per year, serving mostly military, governmental, and stock or commodity market purposes.[19] The Paris–Lille line was completed in 1794, with the first official message sent from Lille to Paris on August 15.

Above, left: The Chappe network in France, showing major cities. Above, right: Axonometric drawing illustrating how the Chappe mechanism worked. Colors indicate the individual pulley systems for manipulating the device. The blue bar controls the regulator while the green and red handles control the left and right indicators.



Optical telegraphy operated in France from 1794 to 1855, growing gradually and steadily. In 1816, a line was constructed from Paris to Calais. In 1821, a new line connected Lyons to Toulon. Two years later, Paris connected to Bordeaux, while in 1828 Avignon connected to Perpignan. By 1852, the network reached its peak with 556 stations and more than 4,800 kilometers of relay line serving twenty-nine of France's largest cities. All of these lines were operated and maintained by the French Ministry of War,[20] and employed more than three thousand workers.[21]

Similar networks connected other European countries. In 1801, Sweden had four operating lines connecting Stockholm to Fredriksborg, Grisslehamn, Signilskär, Helsingborg, and Eckerö, while in 1809, its network expanded to fifty stations linking Gävle and Landsort. In the United Kingdom, by 1808, the British Admiralty had a network of sixty-five stations that could send messages form London to Deal, on the English Channel, in about one minute.[22] Soon networks expanded in the rest of Europe, connecting cities in Norway, Finland, Denmark, the Netherlands, Germany, and Russia, as well as on the East Coast of the United States and in Australia.[23] Although optical telegraphy networks covered large areas in Europe, most national networks were incompatible and fragmented. Having different communication protocols and signaling mechanisms, there was often no means for information to smoothly flow from one system to another.

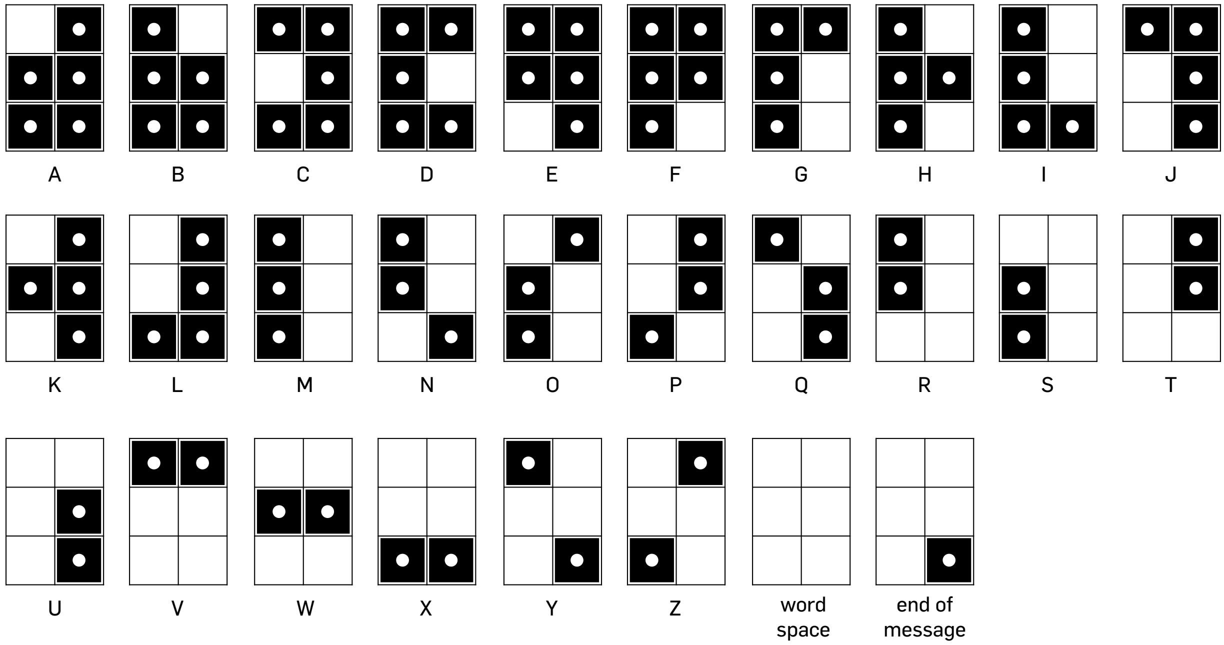
Sociopolitical Context

In the midst of the Napoleonic Wars in Europe (1803–1815), the majority of optical telegraphy networks were developed, operated, and maintained almost exclusively by governmental authorities for diplomatic and military purposes. As war and funding came to an end, telegraphs found new applications where time-sensitive information had to travel faster than material resources. Such applications included trading stocks and commodities in financial markets or operating steam-powered trains in rapidly expanding railway networks.

The new technology was not always embraced by the public. Like most communication media, optical telegraphs and their buildings symbolized instruments of governmental authority, control, surveillance, conspiracy, and oppression. In Chappe's early experiments, some believed he was trying to communicate with the Austrians and Prussians.[24] Later, during the upheaval of the French Revolution, many telegraph towers were burned and torn down with their operators nearly saving their lives from the mobs.

Despite overall skepticism, optical telegraphs constituted also technological achievements of wonder, admiration, and envy. Many inventors claimed ownership of the new invention and the patent war among them was fierce. As Edelcrantz wrote in his treatise,

Above: British admiralty shutter telegraph building.



> It often happens, with regard to new inventions, that one part of the general public finds them use-less and another part considers them to be impossible. When it becomes clear that the possibility and the usefulness can no longer be denied, most agree that the whole thing was fairly easy to discover and that they knew about it all along.[25]

The extraordinary maintenance costs, the political instability, and the rapid technological advancement of Samuel F. B. Morse's electric telegraph seized optical telegraphy and its nascent architecture permanently in 1844. It lasted fifty years and it was the fastest and most reliable communication system ever conceived until then.

Three Theses on the Architectural Internet of Optical Telegraphy

Little is known about the architecture of optical telegraphs. Within only fifty years from their first implementation until their replacement by the electric telegraph, optical telegraphs remained partly machines, partly buildings never managing to develop a mature architectural typology. Through their short evolution, though, they demonstrated a remarkably novel concept: that abstract architectural language can semantically construct and mediate urban intelligence. After portraying their techno-sociopolitical context from an architectural perspective, I conclude with three theses.

The Eighteenth Century's Smart Cites

First, *optical telegraphy networks constituted cybernetic predecessors of smart cities*. In his book *ME++*, William Mitchell portrays the urban condition of the twenty-first century as an intelligent, networked landscape that uses electronic nervous systems to serve the needs of its users in more efficient and sustainable ways.[26] It is fair to say that nearly two centuries ago, optical telegraphy created a mechanical nervous system with a similar rhetoric but a more tangible implementation. Optical telegraph networks merged synergistically human operators, mechanical interfaces, and telescopes with decision makers and financial institutions, creating self-regulating cybernetic systems with urban-scale feedback loops.[27] Brokers in Paris could arbitrage from rising trading prices in Amsterdam in a matter of minutes. Train stations could inform awaiting passengers of the imminent delay of an arriving train in nearly real time. Military commanders could organize their army and fleet in response to enemy's tactics. And corporate businessmen could send frequent optical mails, or "omails," to arrange time-sensitive deals.

Form as a Medium of Information

Second, *information was manifested through abstract architectural language, both the control and interpretation of which were critical in closing the feedback loop of intelligence*. While

Above: The British admiralty alphabet code.

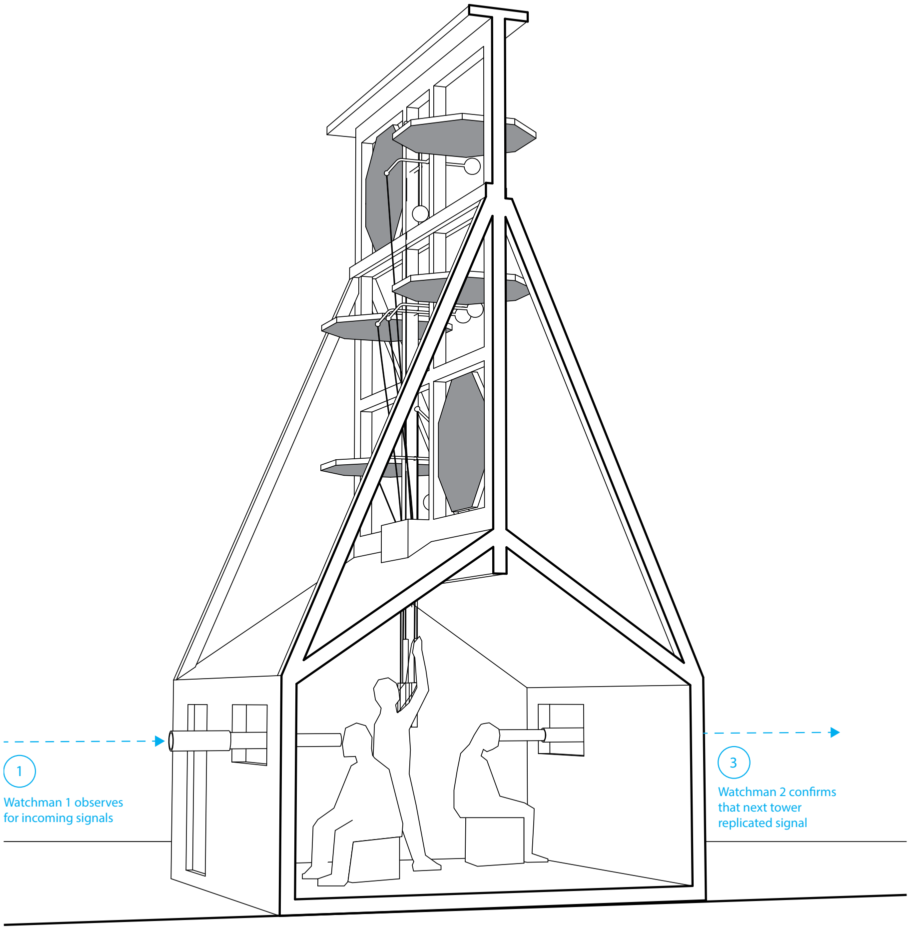


Diagram illustrating how the British shutter telegraph worked.

in Mitchell's rhetoric intelligence is mediated through digital bits, in Chappe's, Edelcrantz's, and Murray's it was mediated through physical space and geometry. This is not to argue that manipulating form is a better medium than flipping digital bits. But in a contemporary discourse on intelligent environments where materiality, information, and human perception seek new models for seamless integration, such rhetoric gives new directions for critical exploration.

Optical telegraphy illustrated both how form can mediate information and how in turn communication requirements can drive architectural, urbanistic, and planning decisions. On the one hand, it produced a self-referring, signifying, and performative (almost postmodern) architecture.[28] On the other hand, its (almost modern) language—abstract and functionalistic—derived through experiments instead of imitation. The form in this case was the medium, not the message.[29]

Form as a Manifestation of Computation

Third, *optical telegraphs were early manifestations of architectural computing automata*. Through their reconfigurable forms, optical telegraphs not only represented information bits but also stored them in their finite formalistic states. Furthermore, by the highly mechanized process by which human operators executed tasks without knowing their meaning, optical telegraphy introduced basic concepts of computation in which routines, when followed methodically, produce logical and consistent outcomes. With their strict procedural protocol of finite states and lookup tables, the constrained inputs and outputs of their control rooms, and the separation of execution from interpretation, optical telegraph towers resemble urban manifestations of architectural Turing machines.[30] No one knows where this technology, idea, and typology would have been taken, had information and computation theory been known then.

Optical telegraphy has often been coined as history's *mechanical Internet*, a term with an emphasis on the mechanisms with which the telegraphic apparatuses worked. Throughout this essay I favor *architectural Internet* as a new term with an emphasis on the medium through which intelligence was implemented. Information etymologically means giving shape to communicate knowledge. Nowhere in the history of communications has this term been more literally implemented than in the eighteenth century's optical telegraphy networks. And nowhere in the history of architecture has knowledge been most closely associated with built form. In an architecturally mediated internet, "form follows information" and "form follows form" would probably be the two most succinct principles of essence.

Acknowledgments: The author would like to acknowledge Tekniska Museet in Stockholm and the Archives and Special Collections at Harvard University for their generous help in accessing their archive materials.

01. See Gerard J. Holzmann and Björn Pehrson, *The Early History of Data Networks* (Los Alamitos, CA: IEEE Computer Society Press, 1995), 26–29.
02. Nicolò Barbaro, *Diary of the Siege of Constantinople, 1453*, trans. J. R. Jones (New York: Exposition Press, 1969).
03. Holzmann and Pehrson, *The Early History of Data Networks*, 31–44.
04. Ibid., 51–53.
05. For a thorough description of Chappe's device see M. Chappe (Ignace Urbain Jean), *Histoire de la télégraphie* (Paris: L'auteur, 1824).
06. See Abraham Niclas Edelcrantz, "A Treatise on Telegraphs" (1796), translated and republished in *The Early History of Data Networks*, 129–78.
07. T. W. Holmes, *The Semaphore: The Story of the Admiralty-to-Portsmouth Shutter Telegraph and Semaphore Lines, 1796 to 1847* (Ilfracombe, UK: Stockwell, 1983).
08. Holzmann and Pehrson, *The Early History of Data Networks*, 105.
09. Holmes, *The Semaphore*.
10. Ibid.
11. Holzmann and Pehrson, *The Early History of Data Networks*.
12. Operators could change the device in one to two seconds, but they held each signal for twenty to thirty seconds to ensure reception from the remote towers.
13. Gerard J. Holzmann, *Design and Validation of Computer Protocols* (Englewood Cliffs, NJ: Prentice Hall, 1991).
14. Considering a rate of twenty characters per minute, about two to three words of ten characters each could be sent per minute.
15. Holzmann and Pehrson, *The Early History of Data Networks*.
16. Ibid.
17. Holmes, *The Semaphore*.
18. Duane Koenig, "Telegraphs and Telegrams in Revolutionary France," *Scientific Monthly* 59, no. 6 (December 1944): 431–37.
19. Holzmann and Pehrson, *The Early History of Data Networks*, 75.
20. Koenig, "Telegraphs and Telegrams in Revolutionary France."
21. Gerard J. Holzmann and Björn Pehrson, "The First Data Networks," *Scientific American* 270, no. 1 (1994): 124–29.
22. Holzmann and Pehrson, *The Early History of Data Networks*.
23. Tom Standage, *The Victorian Internet: The Remarkable Story of the Telegraph and the Nineteenth Century's On-Line Pioneers* (New York: Bloomsbury, 2014).
24. Koenig, "Telegraphs and Telegrams in Revolutionary France."
25. Edelcrantz, "A Treatise on Telegraphs," in *The Early History of Data Networks*, 129–78.
26. See William J. Mitchell, *Me++: The Cyborg Self and the Networked City* (Cambridge, MA: MIT Press, 2003).
27. For an analysis of the synergies between human administration, software, and hardware in applications of optical telegraphy see Alexander J. Field, "French Optical Telegraphy, 1793–1855: Hardware, Software, Administration," *Technology and Culture* 35, no. 2 (April 1994): 315–47.
28. For an analysis on the role of architectural language as a signifying medium, see Charles Jencks, *The Language of Post-modern Architecture* (New York: Rizzoli, 1977).
29. A paraphrase of Marshall McLuhan's quote "the medium is the message"; McLuhan advocated the importance of media over the content it caries in shaping social perception. While optical telegraphs used shape to construct content, their form was decontextualized from meaning. See Marshall McLuhan, *Understanding Media: The Extensions of Man* (New York: McGraw-Hill, 1964).
30. Turing machines, formalized by computer scientist Alan Turing, are hypothetical computing automata that compute by manipulating strings of symbols through finite states and rule tables. For a thorough description see Alan Mathison Turing, *The Essential Turing: Seminal Writings in Computing, Logic, Philosophy, Artificial Intelligence, and Artificial Life; Plus The Secrets of Enigma* (Oxford: Clarendon Press; New York: Oxford University Press, 2004).

Image Credits

047: Chappe (Ignace Urbain Jean), *Histoire de la télégraphie* (Paris: L'auteur, 1824).

048, 049: Tekniska Museet, Stockholm.

050: Illustration reproduced based on Holmes, *The Semaphore*, 89.

051–054: Illustrations by the author.