Chapter One

Torches and Beacons

The communication network that is available to us today allows anyone to talk instantly to almost anyone else on the globe, as long as both are near one of the approximately 500 million telephones connected to the network. It is tempting to think that the inventions that have made this possible were all made within the last century. The need for effective communication with a distant party, however, did not suddenly start in 1876 when the telephone was first patented.[1] That need must have been felt every bit as much by the Egyptian Pharaohs, and their workers, as it is by us today.

How It Began

It is quite amazing to see how people have dealt with the problems of long-distance communication throughout history. References to telegraphic systems can be found in almost every period from which written records survive. A fairly obvious method to communicate is, of course, to hire somebody to deliver a message as fast as possible. Famous is the story of Phidippides, the runner who, according to legend, in 490 ran the 36.2 km (22.5 miles) from Marathon to Athens to warn the Athenians of an approaching Persian army.[2] The Persians, after having been defeated in the battle of Marathon, were on their way to what they hoped would be an undefended city.

The Greek historian Herodotus, who lived ca. 484-424, does describe an event like this in *The History*. But in his account, Phidippides did not run to Athens *after* the battle of Marathon was fought; he ran 240 km from Athens to Sparta *before* the battle started, to obtain the support of the Spartans. This is how Herodotus described it: [3]

> First of all, when the generals were still within the city, they sent to Sparta a herald, one Phidippides, an Athenian, who was a day-long runner and a professional. … This Phidippides, being sent by the generals, and after, as he said Pan had appeared to him, arrived in the city of Sparta the day after he had left Athens. He came before the rulers and said: "Men of Lacedaemon, the Athenians beg you to help them; do not suffer a most ancient city in Greece to meet with slavery at the hands of the barbarians."

Herodotus then describes the battle itself, where the Athenians successfully defeated the Persian army without the help of the Spartans. He continued: [4]

---

1 Two people filed for a patent on the telephone on 14 February 1876; one was Elisha Gray, the other was Alexander Graham Bell. By coincidence, Bell filed his claim two hours before Gray and thus obtained the coveted patent. Bell subsequently won all court cases that questioned his priority.

2 The modern distance for a marathon of 42.2 km (26 miles) is only loosely based on the distance from Athens to Marathon. It is the distance from Windsor Castle to White City Stadium in London, the course that was run at the 1908 Olympics.

3 Herodotus, The History, Book VI, 105-106.

4 Ibid., 115-116.

There is no mention in Herodotus's account that Phidippides was the first to arrive back in Athens after the battle, and then died from strain, but it is possible.

It is not too surprising that references to runners or human messengers are plentiful throughout history. They were certainly common in the days of Herodotus. The first descriptions of ancient courier systems, however, date back still farther. A recent encyclopedia says: [5]

> As early as the second millennium in Egypt and the first millennium in China, relay systems were developed using messengers on horseback and relay stations situated on major roads.

In old records, references to messenger systems can indeed be found that date back almost 4,000 years to the Egyptian King Sesostris I, who reigned from 1971 to 1928. [6]

Messenger systems were also used in ancient Babylon. In his study of the history of intelligence-gathering methods, Francis Dvornik reported, for instance: [7]

> We learn from an inscription that Hammurabi's messengers rode the long distance from Larsa to Babylon in two days, traveling, of course, both day and night.

Hammurabi was king of Babylonia from 1792 to 1750

By the thirteenth century messenger services must have been quite routine. Dvornik, for instance, refers to a log that was kept by an Egyptian guard during the reign of King Merneptah (the successor of King Ramses II), from 1237 to 1225.[8] In the fragment of the log that is preserved, we find a record of all special messengers that passed through a guard post at the Palestinian border with Syria. According to the log at least once or twice a day a messenger would pass through with either military or diplomatic missives.

Originally, the messengers traveled the normal roads between the main cities of the ancient empires. Their safety, however, was by no means guaranteed.[9]

> We read in the Babylonian archives, found in Boghazhöi, complaints about attacks by Bedouins on royal couriers, and of the closing of Assyria to Babylonian messengers.

This crime problem led to a decision by the early Babylonian kings to place royal guards at regular distances along the roads. These guards were originally intended only for the protection of travelers, but their presence led quite naturally to a number of major improvements in the messenger system. The first was the establishment of a relay system, where a message was passed from guard station to guard station, each time carried by a new runner. The second decision was to equip the guard posts with fire beacons, so that simple alarm or warning signs could be passed quickly from one end of the road to the other, without the need for a human runner.

Unfortunately, it can no longer be determined precisely when these two crucial improvements were made, but they were probably in place by 650 One of the records

---

5 Grolier's Academic American Encyclopedia 1992, in the entry for Postal Services.
6 Breasted 1906, Vol. 1, pp. 490-497; quoted in Dvornik 1974, p. 9
7 Dvornik 1974, p. 17
8 Breasted 1906, Vol. 3, pp. 630-635; quoted in Dvornik 1974, p. 7
9 Dvornik 1974, p. 18

reproduced in Luckenbill, for instance, describes the way in which the inauguration of King Shams-shum-ukin of Babylonia was celebrated around that time:[10]

> Beechwood was kindled, torches lighted. Every bêru a beacon was set up.

The bêru was an Assyrian distance unit, corresponding to a two-hour journey. It can be assumed that the beacons referred to here were not quickly improvised for the occasion, but part of a permanent network of roads and guard posts. To support this assumption, Dvornik and Fries quote from a letter containing a magical chant, found in the library of King Ashurbanipal who ruled Assyria from 668 to 626 It reads, in part:[11]

> Well, my witch, who art kindling fire every bêru and who art sending out thy messengers every two bêrus, I know thee and I will post watchmen in order to protect myself.

Both beacon signals and courier systems were quite familiar, at least to this writer. We can even speculate that the guard posts were placed at one bêru intervals, and that every other guard post served as a relay station for messengers; but, of course, this is only speculation.

The Biblical book of Jeremiah, from ca. 588, also contains a clear reference to the relay system:[12]

> One post shall run to meet another, and one messenger to meet another, to shew the king of Babylon [Nebuchadnezzar] that his city is taken.

King Cyrus the Great, who lived from 599 to 530, and ruled Persia the last nineteen years of his life, was credited with improvements of the courier system. Xenophon (430-355), writing more than a century later, described it in *Cyropaedia,* his biography of Cyrus, as follows:[13]

> We have observed still another device of Cyrus' for coping with the magnitude of his empire; by means of this institution he would speedily discover the condition of affairs, no matter how far distant they might be from him: he experimented to find out how great a distance a horse could cover in a day when ridden hard, but so as not to break down, and then he erected post-stations at just such distances and equipped them with horses, and men to take care of them; at each one of the stations he had the proper official appointed to receive the letters that were delivered and to forward them on, to take in the exhausted horses and riders and send on fresh ones. They say, moreover, that sometimes this express does not stop all night, but the night-messengers succeed the day messengers in relays, and when this is the case, this express, some say, gets over the ground faster than the cranes.

The system lasted. In *The History*, Herodotus describes with admiration how the relay system functioned at the time that Xerxes ruled Persia, between 486 and 465 :[14]

> At the same time that he was doing these things, Xerxes sent to Persia to tell of the present calamity. Than this system of messengers there is nothing of mortal origin that is quicker. This is how the Persians arranged it: they saw that for as many days

---

10 Luckenbill 1926, Vol. II, p. 989; quoted in Dvornik 1974, p. 19
11 Dvornik 1974, p. 19, Fries 1904, p. 117
12 Jeremiah 51:31. King Nebuchadnezzar II reigned from 605 to 562
13 Xenophon, Cyropaedia, Book VIII, 6.17-18; quoted in Dvornik 1974, p. 28
14 Herodotus, The History, Book VIII, 98

> as the whole journey consists in, that many horses and men are stationed at intervals of a day's journey, one horse and one man assigned to each day. And him neither snow nor rain nor heat nor night holds back for the accomplishment of the course that has been assigned to him, as quickly as he may. The first that runs hands on what he has been given to the second, and the second to the third, and from there what is transmitted passes clean through, from hand to hand, to its end, even as among the Greeks there is the torch-race that they celebrate in honor of Hephaestus.

The phrase "neither snow nor rain nor heat nor night …" is familiar to New Yorkers: a slightly different, and not too literal, translation was used for an inscription over the width of the main U.S. Post Office in Manhattan(one city block wide). It reads "neither snow nor rain nor heat nor gloom of night stays these couriers from the swift completion of their appointed rounds." The Persian couriers, of course, did not walk rounds but ran a relay system, but the main idea is there.

The Romans adopted a similar system of relay stations. Originally, they used human runners to transport the messages.[15] Later, when the system became larger, they switched to couriers on horseback as in the Persian system. Suetonius, who lived from 70 to 150, described it in his biography of Augustus (63 - 14) in Book II of *The Twelve Caesars*:[16]

> To enable what was going on in each of the provinces to be reported and known more speedily and promptly, he at first stationed young men at short intervals along the military roads, and afterwards post-chaises [carriages]. The latter has seemed the more convenient arrangement, since the same men who bring the dispatches from any place can, if occasion demands, be questioned as well.

Each of the Roman relay stations kept a reserve of not fewer than 40 horses and riders.[17]

In an attempt to curb abuse, messengers, called strators, were issued special licenses from the Roman emperor that qualified them for the free exchange of horses at relay stations. Over the years, responsibility for the upkeep of relay stations became a hot political issue.[18] Roman rulers alternately strived either to delegate the responsibility to local communities, to reduce the tax burden on the state, or to transfer the responsibility back to the state, to secure more consistent maintenance. In the end, neither the state nor the local municipalities were willing to cover the expenses any longer, and the system perished.

The speed of the Roman relay system was approximately 80 km (50 miles) per day for regular mail, and twice that for express mail, although these numbers might be based on human runners instead of riders on horseback. In any case, the Roman system was never praised for its speed. Even the old historians poked fun at the system. Suetonius, for instance, wrote in his biography of Julius Caesar (100-44) in Book I of *The Twelve Caesars*:[19]

> [He] often arrived at his destination before the messengers who had been sent ahead to announce his approach.

---

15 [Neal 1974]

16 Suetonius, The Twelve Caesars, Book II, 49, as quoted by Dvornik 1974, pp. 91-92 The translation in the Penguin classics edition of the same passage is less elegant.

17 Plaum 1950, [Cherry 1962]

18 Dvornik 1974, pp. 70-71, 94-98, 123

19 Suetonius, The Twelve Caesars, Book I, 57.

In the thirteenth century Marco Polo described another relay system that was used by the Mongol ruler Kublai Khan (1215-1294), grandson of the notorious Genghis Khan. Polo, who visited China between 1271 and 1295, described the system as follows:[20]

> Let us turn now to the system of post-horses by which the Great Khan sends his dispatches. You must know that the city of Khan-balik is a centre from which many roads radiate to many provinces, one to each, and every road bears the name of the province to which it runs. The whole system is admirably contrived. When one of the Khan's messengers sets out along any of these roads, he has only to go twenty-five miles [40 km] and there he finds a posting station, which in their language is called *yamb* and in our language may be rendered "horse post."
>
> … Here the messengers find no less than 400 horses, stationed here by the Great Khan's orders and always kept in readiness for his messengers when they are sent on any mission. And you must understand that posts such as these, at distances of twenty-five or thirty miles, are to be found along all the main highways leading to the provinces of which I have spoken… . The whole organization is so stupendous and so costly that it baffles speech and writing.

Later in his account Marco Polo points out that the 400 horses per post were not all present at the same time. At each time about 200 horses would be out in the meadows, regaining strength for a next tour of duty.

The speed of the Great Khan's messengers was apparently almost twice that of the Roman's:[21]

> When the need arises for the Great Khan to receive immediate tidings by mounted messenger, as of the rebellion of a subject country or of one of his barons or any matter that many concern him deeply, I assure you that the messengers ride 200 miles [320 km] in a day, sometimes even 250. Let me explain how this is done. When a messenger wishes to travel at this speed and cover so many miles in a day, he carries a tablet with the sign of the gerfalcon as a token that he wishes to ride *poste haste.* If there are two of them, they set out from the place where they are on two good horses, strongly built and swift runners. They tighten their belts and swathe their heads and off they go with all the speed they can muster, till they reach the next post-house twenty-five miles away. As they draw near they sound a sort of horn which is audible at a great distance, so that horses may be got ready for them. On arrival they find two fresh horses, ready harnessed, fully rested, and in good running form. They mount there and then, without a moment's breathing-space, and are no sooner mounted than off they go again, taking the last ounce out of their horses and not pausing till they reach the next post, where they find two more horses harnessed as before.
>
> … in extreme urgency, they can achieve 300 miles. In such cases they ride all night long; and if there is no moon, the men of the post run in front of them with torches as far as the next post.

In parallel with the horse post, also a relay system of human runners was employed.[22] These runners, however, did not always carry grave news of rebellions and uproar. Marco

---

20 Marco Polo, The description of the World, pp. 150-151

21 Ibid., pp. 154-155

22 Ibid., pp. 152-153. It reads:

Polo notes dryly that the Great Khan had found ways to take advantage of it for more pleasurable uses as well:[23]

> And in the fruit season it often happens that by this means fruit gathered in the morning in the city of Khan-balik is delivered on the evening of the next day to the Great Khan in the city of Shang-tu, ten days' journey away.

The *Pony Express*, which operated in the United States from April 1860 until October 1861, achieved comparable speeds to the Chinese horse post, but with more frequent switches. Each rider in the Pony Express relay rode approximately 150 km, and switched horses every 15 km. This system is said to have covered the 3,200 km distance from Missouri to California in about 10 days.

PIGEONS

Perhaps more inspiring than plain runners transporting messages, and just as old, is the description of a seemingly less reliable transmission medium: the homing pigeon. It is said that the outcomes of the Olympic Games in ancient Greece, around 776, were sent to Athens by pigeons. But even in those days this must have been old news. As noted in a book by David Woods:[24]

> … in the days of the Pharaohs the Egyptians announced the arrival of important visitors by releasing pigeons from incoming ships. This may have been common as early as 2900

The writer Harry Neal noted another ingenious use of pigeons from a few centuries later. He stated that King Sargon of Akkad, who lived ca. 2350 in Mesopotamia, had each of his

---

> …between one post and the next, at a distance of three miles apart, there are stations which may contain as many as forty buildings occupied by unmounted couriers, who also play a part in the Great Khan's postal service. I will tell you how. They wear large belts, set all round with bells, so that when they run they are audible at a great distance. They always run at full speed and never for more than three miles. And the next station three miles away, where the noise they make gives due notice of their approach, another courier is waiting in readiness. As soon as the first man arrives, the new one takes what he is carrying and also a little note given to him by the clerk, and starts to run. After he has run for three miles, the performance is repeated. And I can assure you that by means of this service of unmounted couriers, the Great Khan receives news over a ten day's journey in a day and a night… So in ten days they can transmit news over a journey of a hundred days.

[23] The quote about the delivery of fruit continues:

> At each of these three-mile stations there is appointed a clerk who notes the day and hour of the arrival of every courier and the departure of his successor; and this practice is in force at every station. And there are also inspectors charged with the duty of going round every month and examining all these stations, in order to detect any couriers who have been remiss and punish them. From these couriers, and from the staff at the stations, the Great Khan exacts no tax, and he makes generous provisions for their maintenance.

[24] Woods 1965, p. 4

messengers carry a homing pigeon.[25] If the messenger was attacked en route, he released the pigeon. The return of the pigeon to the palace was taken as a warning that the original message had been "lost," and that a new messenger should be sent, presumably via another route.

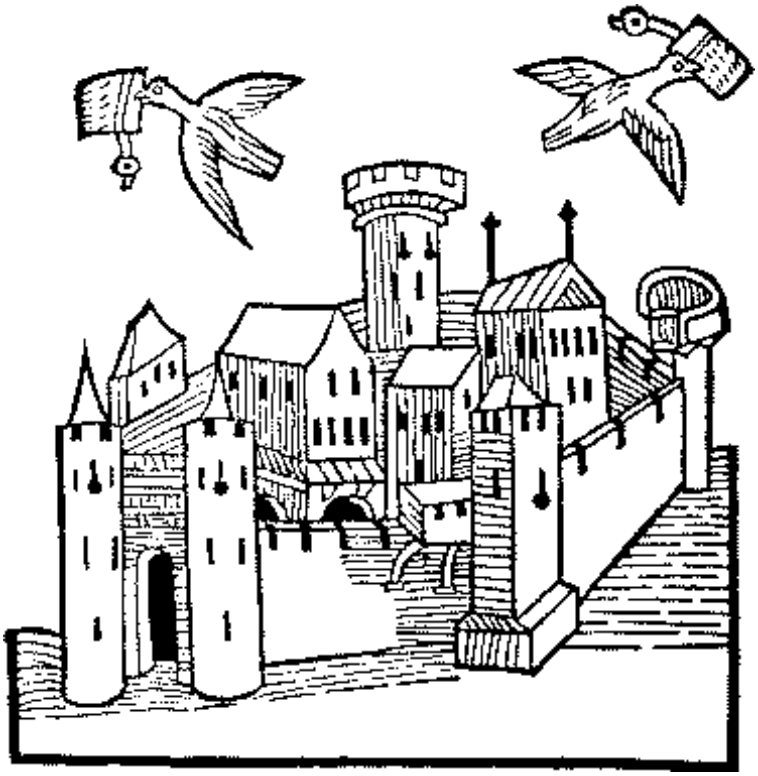

Figure 1.1 **Pigeon Post, Woodcut from 1481**.
(Coll. Bibl. de Genève, Fabre 1963" "p. 44)

Homing pigeons were also used by the Romans, around the fourth century. In 1641, John Wilkins referred to it as follows:[26]

> Lypsius relates out of Varro, that it was usual for the Roman magistrates when they went unto the theatre, or other such public meetings, whence they could not return at pleasure, to carry such a pigeon with them; that if any unexpected business should happen, they might thereby give warning to their friends or families at home.

The system was still in use some eight centuries later. Woods reports that in the twelfth century Genghis Khan (1167-1227) used a pigeon relay system to communicate messages across Asia and much of Europe.[27] Figure 1.1 displays the use of carrier pigeons in a woodcut that appeared in 1481 in *Jean de Mandeville's Travels in the Orient.*

Another seven centuries later, in 1918, the British Air Force kept over 20,000 homing pigeons, handled by 380 pigeoneers. The system was organized by Colonel A. H. Osman. Woods quoted him as follows:[28]

---

25 Neal 1974, pp. 121-122
26 [Wilkins 1641, Chapter 16]
27 Woods 1965, p. 63
28 Woods 1965, pp. 65-66

> A small balloon was constructed with a metal [release-] band worked by clockwork. To this band was attached a small basket containing a single pigeon with a message holder on its leg, and to each basket was attached a small parachute. The balloons were liberated in favourable conditions of wind and at intervals automatically released from the special ring a single basket with a bird. These were dropped into Belgian and French territory when occupied by the Germans, and in French and Flemish a request was made to the finder to supply intelligence information that was needed, at the same time giving the finder hopefulness and cheer as to the ultimate success of the allies' cause and promising reward for the information supplied.

Woods adds a sobering note.

> The Germans tried to halt this activity by replacing captured pigeons with their own birds, and then arresting and shooting anyone foolish enough to sign his name and address to the note.

With this much history, it is not surprising that pigeons were still used in 1981 by a group of engineers at a Lockheed plant in Sunnyvale, California, to transmit negatives of drawings to a test station 40 km (25 miles) away. As Jon Bentley described it:[29]

> The pigeon took just half the time and less than one percent of the dollar amount of the car (the birds worked, literally, for pigeon feed). Over a 16-month period the pigeons transmitted hundreds of rolls of film and lost only two.

Pigeons and messengers have the advantage that a message need not be specially encoded, unless this is done for security. The problem is that the messages travel no faster than a horse can run, or than a bird wants to fly. Even the first ideas that were developed for alternative systems come very close to modern signaling methods.

Mirrors and Flags

It is easily confirmed that you can get any one's attention quickly, even at large distances, by reflecting the sun into their eyes with a shiny surface. This could have been done also in antiquity, probably in a playful way, to amuse or to annoy. There are, however, indications that *heliographs* have a history of use for more serious signaling purposes as well.

HELIOGRAPHS

Consider the following passage from Xenophon's *Hellenica* (sometimes called *A History of My Times*), written in ca. 405:[30]

> On the fifth day as the Athenian ships sailed up, Lysander gave special instructions to the ships that were to follow them. As soon as they saw that the Athenians had disembarked and had scattered in various directions over the Chersonese--as they were now doing more freely every day, since they had to go a long way to get their food and were now actually contemptuous of Lysander for not coming out to fight--they were to sail back and to *signal with a shield* when they were half-way across the straits. These orders were carried out and as soon as he got the signal, Lysander ordered the fleet to sail at full speed. Thorax went with the fleet. When Conon saw that the enemy were attacking, he signaled to the Athenians to hurry back as fast as

---

29 Bentley 1988, pp 47-48]

30 Xenophon, Hellenica, Book II, 1.27

> they could come to their ships. But they were scattered in all directions …[*emphasis added*]

The phrase "to signal with a shield" is one of the earliest explicit mentions of a simple method of heliographic signaling, in this case with a burnished shield.

There are many other references to early signaling methods that may have been based on similar devices, but the oldest references are not too reliable. The writer Woods, for instance, stated that heliographs were used by the Romans between 26 and 37:[31]

> For nearly ten years during the reign of the wise but unpopular emperor Tiberius, Rome was ruled from the island of Capri. Each day he sent orders to the mainland by a type of "heliograph" which transmitted the sun's rays by means of a mirror of polished metal. Naturally this would not have been possible without a code, but no record exists of the means by which the emperor's commands were sent or received.

The original sources do not quite support this claim. There is a brief reference to a method of signaling in the biography of Tiberius (42 - 37)written by Suetonius, in Book III of *The Twelve Caesars,* but it is ambiguous. It is sometimes translated as:[32]

> Often, he would stand at the highest tower and peer at the signals he had sent to him, so that when anything had happened, messages would reach him without delay.

In a later translation, however, the complete passage appears as:[33]

> He thought, indeed, of taking refuge at the headquarters of some provincial army and had a naval flotilla standing by to carry him off the island; where he waited on a cliff top for the distant bonfire signals, announcing all possible eventualities, which he had ordered to be sent in case his couriers might be delayed.

Figure 1.2 **Heliographic Device**.
(Source: Hennig 1908, p. 43)

Neither version seems quite right. A simple bonfire could have been used to give a straight warning signal that Tiberius would have wanted to monitor, but it could not easily be used to transmit "all possible eventualities." On the other hand, it is hard to imagine that a Roman emperor would trouble himself to learn a signaling code that is complex enough to transmit arbitrary messages.

---

31 Woods 1965, p. 10 Woods gives no source

32 Suetonius, The Twelve Caesars, Book III, LXV, as quoted in Hennig 1908""p. 15, cf. also [Aschoff 1984]

33 Quoted from the Penguin Classics edition of The Twelve Caesars, which was published in 1957

Woods also reported that in the eleventh century the Moors made use of heliographs in Algeria.[34]

A first clear description of a heliographic signaling method was published in 1292 by the English author Roger Bako (often spelled Bacon, 1214-1292),in a work called *Opus Majus*.[35] There is, however, no record that it was actually used in this period.

Richard Hennig quoted a description of a heliograph from the sixteenth century author Khevenhiller. In *Annales Ferdinandei*, Khevenhiller described a device that had supposedly been used during the siege of a Hungarian fortress in 1598:[36]

> …with an art, as described by an Englishman, consisting of two mirrors and a magnet [a compass?], with which one can, at a distance of many miles, give signals to each other in moon-light.

Hennig questions the feasibility of the method. Yet, if the "magnet" was really a compass, it could have been used by the two correspondents to locate each other, before signaling began. On a clear night, the light of the moon can be reflected as easily as the light of the sun during a clear day, so the device may actually have worked.

The design of a heliographic device was not reliably documented until 1810.[37]

> Professor [Carl Friedrich] Gauss of Gottingen, Germany, invented a device to direct a controlled beam of sunlight to a distant station. It included "silvered and unsilvered mirrors" fixed at right angles to each other. The operator looked in the unsilvered mirror at the distant station. Then he turned both mirrors so the sun's image (reflected faintly from the plain surface of the unsilvered mirror) was superimposed over the distant station, automatically directing the beam from the silvered mirror in the same direction.

Though the device built by Gauss (cf. Figure 1.2) was meant to be used for geodetic survey work, it would later be used extensively by the British and the American armies as a so-called "wireless" field telegraph.

In 1869 Henry C. Mance adapted Gauss's design by adding a movable mirror that could be used to signal Morse code.[38] Since Mance was stationed in India at the time, the first body to adopt the new device in 1875 was the Indian government. It is said to have been in almost constant use by the British in India until roughly 1890.

In 1851 Charles Babbage, the builder of the so-called *analytical engine*, a precursor of the modern digital computer, also entered this arena with the invention of a "light-flashing machine," which he named an *occulting telegraph*. This is how Babbage described it.[39]

> I then, by means of a small piece of clock-work and an argand lamp, made a numerical system of occultation, by which any number might be transmitted to all those within sight of the source of light.

---

34 Woods 1965, p. 149
35 [Bergstrasser 1785, §244]
36 Khevenhiller, Annales Ferdinandei, as quoted in Hennig 1908, pp. 23-24
37 Woods 1965, pp. 150-153
38 The Morse code itself dates from 1838, see p. _tag5_1
39 Babbage 1851, p. 144

A copy of the device was presented to the Duke of Wellington.[40] In 1852, Babbage also sent descriptions to, among others, Louis Napoleon in France, and to representatives in the United States.[41] The American Congress later appropriated $5,000 for experiments with Babbage's telegraph.

Babbage also described another "sun-flashing" machine, which resembles Gauss's design more closely. The codes he proposed to use with such telegraphs, however, were only rudimentary.

The American army made an extensive use of heliographs in the 1880s, in combination with a Morse code. It is unclear if they were based on Babbage's proposal or Henry Mance's. In 1886 heliographs were used by General Nelson Miles, in his battles with native Americans in Arizona. He built a total of 27 signaling stations, 40 to 50 km (25 to 30 miles) apart. Between 1 May 1886 and 30 September 1886 a total of 2,276 messages with 80,012 words were transmitted over this network.[42] The heliograph is said to have averaged some 16 words per minute.

FLAGS

Signals can, of course, also be given with coded flags. What would be the first recorded use of a flag signal?

The first reference is rather ambiguous. It can be found in the *The Lives of The Noble Grecians and Romans*, by the Roman historian Plutarch (46-120),who referred to an event that took place in 410 In the chapter on Alcibiades he wrote:[43]

> Upon his first appearance, both sides formed a false impression; the enemy was encouraged and the Athenians terrified. But Alcibiades suddenly raised the Athenian ensign in the admiral ship, and fell upon those galleys of the Peloponnesians which had the advantage and were in pursuit.

Alcibiades had defected from the Athenian camp and fought against them in previous battles. So, when his battle ship appeared at a new battle scene, it was not clear which side he was going to take. The raising of the flag with the Athenian symbol cleared all doubt. This can hardly be considered a general method for communication, but it is not unlikely that flags of various kinds were already in use at this time to communicate standard battle orders from an admiral's ship to the fleet.

It would take a considerable time before flag signals were codified and standardized.

There are indications that in the late ninth century the Byzantine Navy had started developing a more systematic approach. Very little documentation seems to have survived. Dvornik wrote:[44]

> During naval operations, the captains of the ships were expected to observe the "pamphylus" of the admiral, who gave orders by signaling from different sides and heights of the central flagship with banners of various colors, or with fire and smoke. A whole code of signals existed with which the commanders and their

---

40 Cf. Woods 1965, p. 151
41 Babbage 1851, p. 146, Hyman 1982, pp. 225-226
42 Woods 1965, p. 155
43 Plutarch, The Lives of The Noble Grecians and Romans, p. 253
44 Dvornik 1974, p. 157

> crews had to be acquainted. Part Nineteen of the strategic treatise ascribed to the Emperor Leo the Wise (866-912) gives numerous instructions as to the kinds of signals to be used and how the signaling should be handled. Unfortunately, the need for secrecy prevented the author from explaining the various signals then in use.

In fourteenth century Europe, things were not much more advanced than in the time of Alcibiades. Woods wrote:[45]

> Between 1337 and 1351 the British Navy lists two signals in their old "Black Book of the Admiralty." The first was to hoist a flag of council high in the middle of the mast, to notify all captains to come aboard the admiral's flagship for a meeting. Hoisting another flag aloft reported the sighting of the enemy.

By the late seventeenth century things still had not progressed much. A codebook issued for the British Navy in 1673 defined 15 different flags, each with a single predefined meaning, which was probably not too different from what had been used since antiquity.

The first significant improvement was made in 1738, when the Frenchman de la Bourdonnais introduced a numerical code for flags. He proposed to use ten colored flags to indicate the numbers from zero to nine. With three sets of such flags, all separately colored, 1,000 code combinations could be made. The Frenchman Ignace Chappe (Claude Chappe's brother, see Chapter Two) wrote in 1824 that he considered it a regrettable mistake that the system of de la Bourdonnais had never been adopted by the French Navy.[46]

In 1763, another Frenchman, Sebastian Francisco de Bigot, the founder of the Marine Academy in Brest, published a new code book *Tactique Navale ou Traitedes Evolutions et des Signaux.* The book, for the first time ever, specified a true protocol for the use of coded flags.

De Bigot's book had three parts. The first, and largest, part listed 336 distinct flag signals for signaling predefined events or commands from ship to ship. It introduced some important protocol rules, such as the definition of a "preparatory signal flag" for synchronization, the requirement that a receiver acknowledge all signals received by repeating them, and the use of "repeater vessels" to allow for broadcasting signals to an entire fleet. The second part of the book, *Table de Manieres*, contained an alphabetical index of all signals listed in the first part. Each signal was given a number, allowing for a quick cross-referencing of related signals. The third part of the book gave standard maneuvering diagrams for ships. As Woods noted:[47]

> Thus the book permitted a captain to look up an unknown signal in the index of part 2, locate the meaning from part 1, and study the evolution from the diagram in part 3. Cannon, flares, and lights were supplied for transmitting an identical code during night or fog.

Although the book was translated and published in England in 1767, it took more then two decades before the British Navy developed a comparable system with numeric codes. In 1790, the British admiral Lord Richard Howe became commander-in-chief of the British Channel Fleet, and introduced a new signal book, which became known as *The Howe*

---

45 Woods 1965, p. 32
46 Chappe 1824, p. 90
47 Woods 1965, pp. 36-37

Code.[48] Howe's code used ten colored flags to represent the numbers from zero to nine, and six additional flags to represent a small number of special control codes, e.g., for acknowledgements, and terminations. The numerical flags were used in combination with a small dictionary of 260 numbered entries, which was extended to 340 entries in 1799.

The range of the dictionary was extended considerably in 1800 by Admiral Sir Home Popham.[49] Popham's new signal book, *Telegraphic Signals of Marine Vocabulary*, was adopted officially by the British Royal Navy in 1803. In Popham's code, the ten colored flags from the Howe code were designated to represent either the numerals from zero to nine, or the letters A to K in a single flag hoist, the letters I and J sharing a flag. Fifteen combinations of two flags gave the remaining letters of the alphabet. The code also included an index of 3,000 numbered sentences and phrases, in three series. Each series had its own indicator flag; the signals in each series were made with combinations of three flags, hoisted together.

Fifty copies of Popham's code book were issued to the British fleet at Cadizin early September 1805.[50] The battle of Trafalgar, which took place the next month, put the new code to its first test. Flag signaling codes were used extensively by both the French and the British, as indicated by the following description.[51]

> Accordingly he [French admiral Villeneuve] hoisted the signal to weigh anchor, and at six in the morning of 19 October the [British] frigate Sirius, waiting outside Cadiz, signaled to the fleet below the horizon "Enemy have topsails hoisted." An hour later it hoisted signal no. 370, "Enemy ships are coming out of port." The hoists were made to the next frigate in the signaling chain, Euryalus, which in turn signaled no. 370 to Phoebe with the accompanying admonition--superfluous in a service schooled to such discipline--"Repeat signals to lookout ships west." And so no. 370 traveled down the chain, from Phoebe to Naiad, Naiad to Defence (a line-of-battleship), Defence to Colossus and Colossus to Mars, standing in Nelson's line of battle itself, 77 km (48 miles) from the mouth of Cadiz harbour. The news reached Nelson at 9:30. He immediately ordered "General chase southeast" and steered to place the fleet between Cadiz and the Straits of Gibraltar. The opening move of the battle of Trafalgar had begun.

---

48 Lavery 1989, p. 261
49 Chapter Five, p. _tag5_2
50 Keegan 1988, pp. 49-53
51 Ibid., p. 53

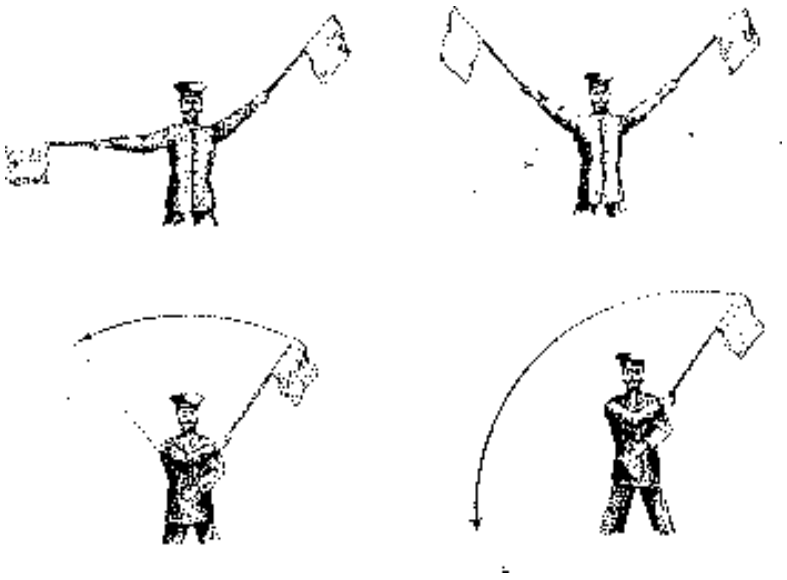

Figure 1.3 **Wig-Wag Flag Signaling**.
(Source: Hennig 1908, p. 45)

Just before the battle, Nelson signaled a final instruction that would become famous in Britain: "England expects that every man will do his duty." Since it was not one of the predefined phrases, it had to be spelled out with individual flag hoists. Of the nine words, eight were in the codebook and could be signaled with single hoists of three flags each. The word "duty," however, was not in the code, and had to be spelled out with single- and double-flag hoists.

After the battle, Popham's code became known as the *Trafalgar Code*, an indication that it was considered a success. In 1813 Popham issued new signal books, extending the range to 6,000 predefined sentences and phrases, and 60,000 words.

WIG-WAG

All the flag signaling methods mentioned so far clearly dealt with ship-to-ship communications, and were not intended to be used on land. In 1856 an American army doctor named Albert James Myer (1827-1880) changed that with a system he called *wig-wag signaling.* He proposed a method of signaling with either flags or torches, which allowed for two basic motions, that is, a wave of the flag or torch to the left or to the right. Myer's code also defined the acknowledgement of messages, using special codes forsignaling "not understood," or "understood."

The wig-wag method was adopted by the American Army in January 1860. Myer even obtained a U.S. patent, No. 252, for his system titled *An improved system of signaling*.[52] The patent issued on 29 January 1861. Even though the simpler Morse code already existed, it did not replace Myer's code until 1886, some twenty-five years later.

Flag signaling was standardized in 1857 with the publication of a first international code. It was last revised in 1934.

---

52 Since 1836 U.S. patents have been numbered consecutively, but in 1861 patents were sometimes issued two numbers. The (low) number 252 was probably the additional number, used for numbering patents consecutively within a year.

So far, we have seen four different methods for sending messages over a long distance: runners, pigeons, heliographs, and flags. Each of these methods has a much longer history than one would expect. At least two of these methods led to the development of sophisticated, semi-permanent, signaling networks, such as the courier relay systems of the Persians and the Romans, and the heliograph networks used by the Americans in Arizona.

There are two other signaling methods that we have not discussed in detail yet, each also with a remarkably long history: fire or light signals, and semaphores. Both of these methods would reach a level of sophistication that was not reached by any other method.

Fire Beacons

Many Americans can quote the lines of Longfellow's ballad celebrating the ventures of the American patriot Paul Revere (1735-1818):[53]

> One if by land, and two if by sea
> And I on the opposite shore will be
> Ready to ride and spread the alarm
> Through every Middlesex village and farm.

The poem refers to a simple code that had been used in 1775 by Revere during the Revolutionary War. Here is how Revere described it in a letter he wrote later to Dr. Jeremy Belknap:[54]

> If the British went out by water, to show two lanterns in the North Church steeple; and if by land, one as a signal, for we were apprehensive it would be difficult to cross the Charles River or get over Boston Neck.

[Image not included]

Figure 1.4 **The Line of Beacons from Troy to Mycenae**.

This was, of course, not the first time that a light signal was used to encode a message. A first reference to the systematic use of fire signals to transmit messages can be found in descriptions of the siege of Troy by the Greek army, which is now assumed to have taken place in approximately 1184. At least three different sources, Homer, Aeschylus, and Vergil, describe such signaling methods, sometimes in elaborate detail.

One of the oldest sources is Homer's *Iliad*, written in approximately 700 It contains the following passage:[55]

> Thus, from some far-away beleaguered island, where all day long the men have fought a desperate battle from their city walls, the smoke goes up to heaven; but no sooner has the sun gone down than the light from the line of beacons blazes up and shoots into the sky to warn the neighbouring islanders and bring them to the rescue in their ships.

---

53 Longfellow, Tales of a Wayside Inn, 1863. "Paul Revere's Ride," St. 2. As reproduced in [Bartlett 1855/1992]

54 [Bartlett 1855/1992, 339:4]

55 Homer, Illiad, Book XVIII, 210-213. Penguin Classics edition, 1950, p. 342

Table 1.1 **Aeschylus's Line of Beacons.**

Location	Modern Name	Altitude (m)	Distance (km)
Troy	Troy	100	0
Mt. Ida	Kaz Dagi	1774	55
Lemnos	Skopia at Limnos	430	154
Mt. Athos	Athos	2033	70
Macistus	Kandilion at Euboea	1209	177
Messapius	Ktipas	1020	30
Cithaeron	Elatias	1410	25
Mt. Aegiplanetus	Mt. Jeraneia	1370	30
Arachnaean Hgt	Arna	1199	50
Mycenae	Mycenae	150	20

Two other passages can be found in the play *Agamemnon*, written by the Greek dramatist Aeschylus, who lived 525-456. Aeschylus described how fire beacons were used to signal the fall of Troy to Mycenae, over a distance of roughly 600 km. This is how the play begins:[56]

> Watchman--I pray the gods a deliverance from these toils, a remedy for my year-long watch, in which, couching on my elbows on the roofs of the Atreidae, like a dog, I have contemplated the host of the nightly stars, and the bright potentates that bear winter and summer to mortals, conspicuous in the firmament. And now I am watching for the signal of the beacon, the blaze of fire that brings a voice from Troy, and tidings of its capture; …

A little further, the line of beacons is described in detail.[57]

> Chorus--And at what time hath the city been sacked?
>
> Clytaemnestra--I say in the night that hath now brought forth this day.
>
> Chorus--And what messenger could come with such speed?
>
> Clytaemnestra--Vulcan [Hephaestus], sending forth a brilliant gleam from Ida; and beacon dispatched beacon of courier-fire hitherward. Ida, first to the Hermaean promontory of Lemnos, and third in order Athos, mount of Jove [Zeus], received the great torch from the isle, and passing over so as to ridge the sea, the might of the lamp as it joyously traveled, the pine-torch transmitting its gold gleaming splendor, like a sun, to the watch towers of Macistus. And the watchman omitted not his share of the messenger's duty, either by any delay, or by being carelessly overcome by sleep; but the light of the beacon coming from afar to the streams of the Euripus gives signal to the watchmen of Messapius, and they lighted a flame in turn and sent the tidings onward, having kindled with fire a pile of withered heath.
>
> And the lamp in its strength not yet at all bedimmed, bounding over the plain of the Asopus, like the bright moon to the crag of Cithaeron, aroused another relay of the courier fire. And the watch refused not the light that was sent from afar, lighting a

---

56 Aeschylus, Agamemnon, 1-34, as quoted in Shaffner 1859, pp. 22-24 See also the translation of Richmond Lattimore in The Complete Greek Tragedies, Univ. of Chicago Press, 1959, Vol. 1, pp. 35, 43-44

57 Ibid., 278-316

> larger pile than those above mentioned; but it darted across the lake Gorgopis, and having reached mount Aegiplanetus, stirred it up in unscathing strength, they send on a mighty beard of flame, so that it passed glaring beyond the headland that looks down upon the Saronic frith, then it darted down until it reached the Arachnaean height, the neighboring post of observation, and thereupon to this roof of the Atreidae here darts this light, no new descendant of the fire of Ida.
>
> Such, in truth, were my regulations for the bearers of the torch fulfilled by succession from one to another; and the first and the last in the course surpassed the rest. Such proof and signal do I tell thee of my husband having sent me tidings from Troy.

Later in the story, Clytaemnestra's enthusiasm about her husband's return apparently diminishes somewhat. When Agamemnon finally returns to Mycenae, he is murdered by Clytaemnestra and her lover.

The locations of the beacon stations can be found on modern maps, although some of the names have changed. Richard Hennig, in 1908, calculated the approximate distances between the stations that Aeschylus names.[58] Volker Aschoff also listed the approximate altitudes and verified the feasibility of a communication across this line.[59] The information is summarized in Table 1.1.

The inclusion of Mount Athos in the chain is the hardest to understand. It appears that a beacon placed at the 792 meter high Mt. Kochylas at the island of Skyros could have replaced the beacon at Athos, and perhaps also the one at Lemnos, by signaling directly to Mount Ida. Nevertheless, with the given altitudes, each beacon along the line that Aeschylus specified, would indeed have been visible from its neighboring stations. Aschoff calculated that on a clear night a stack of wood of roughly 5 to 10 meters high suffices to produce enough brightness to bridge the longest link in the chain, from Athos to Macistus.[60] This is well within the realm of possibility. It is not likely, though, that such a system could have been used for anything other than the transmission of a pre-arranged signal.

The Roman poet Vergil, who lived 70-19, described another use of fire signals during the siege of Troy. This is from *The Aeneid*:[61]

---

58 Hennig 1936, p. 23

59 [Aschoff 1984]

60 Aschoff reported that to cover an average of 150 km on a clear night takes a fire with a light output of between 10^4 and 10^5 candela. At this distance, such a fire produces an image with a brightness of 10^{-6} to 10^{-7} lux, which is near the minimum that can still be seen. He also measured that a large fire produces about 0.2 candela/cm^2, from which the minimum size of the stack can be derived. A candela is a unit for measuring light intensities. Originally it was defined as a the amount of light produced by a single candle. It is now standardized more precisely as /60th of the amount of light produced by one cm^2 blackbody (i.e., a perfect radiator) that is heated to the melting temperature of platinum. One lux is the illumination projected on a surface by a light source of one candela at a distance of one meter. For comparison, daylight has a brightness in the order of 10^4 to 10^5 lux. At dusk this reduces to about 10^2 lux.

61 Vergil, The Aeneid, Book II, 254-259. Penguin Books, 1951, p. 304-305. In the original Latin, the sentence referring to the signal light reads:

> … et iam Argiva phalanx instructis navibus ibat a Tenedo tacitae per amica silentia lunae litora nota petens, flammas cum regia puppis extulerat, fatisque