



Mirrors and Flags

It is easily confirmed that you can get anyone'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 :^[Note 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 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:^[Note 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:^[Note 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:^[Note 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.

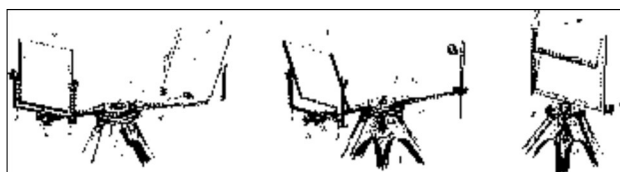


Figure 1.2 Heliographic Device.
(Source: "Hennig 1908" p. 43)

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.

Woods also reported that in the eleventh century the Moors made use of heliographs in Algeria.^[Note 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*.^[Note 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 Khevenhillier. In *Annales Ferdinandeï*, Khevenhillier

described a device that had supposedly been used during the siege of a Hungarian fortress in 1598:^[Note 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.^[Note 37]

Professor [Carl Friedrich] Gauss of Göttingen, 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.^[Note 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.

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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.^[Note 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.

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

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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.^[Note 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:^[Note 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:^[Note 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 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:^[Note 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 code book 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.^[Note 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 Traite des 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:^[Note 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 than 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 Code*.^[Note 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.^[Note 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 Cadiz in early September 1805.^[Note 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.^[Note 51]

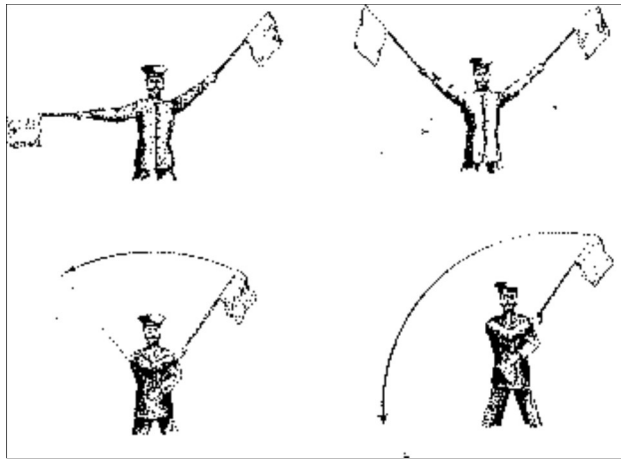


Figure 1.3 Wig-Wag Flag Signaling.

(Source: "Hennig 1908" p. 45)

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.

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 code book 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 for signaling "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*.^[Note 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.

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.



The Early History of Data Networks Gerard J. Holzmann, Björn Pehrson
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