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VISUAL TIME SIGNALS FOR MARINERS BETWEEN THEIR INTRODUCTION AND 1947: A NEW PERSPECTIVE

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Abstract: The worldwide evolution of visual time signals for mariners during the period up to 1947 is explored in this paper. The emphasis is on their external appearance and how they were regarded by mariners for rating chronometers. The first accurate signals were established by the 1830s and the number of different locations increased steadily throughout the nineteenth century. The signals included time balls and time guns as well as many other devices under control by an astronomical observatory. By 1880, signals were widely distributed, although some earlier signals had been either withdrawn or replaced. Lists of signals prepared by the British Admiralty from 1880 onwards provide a record of over 200 visual signals for mariners that is reviewed for the first time in this study. The lists did not include time signals that were inland and unavailable to mariners, nor did they include signals of unknown veracity at minor ports. The lists did indicate when signals might be unreliable. Some locations used more than one type of signal. Results are presented in a series of tables for different geographical areas, colour coded by signal type for selected years. These are complemented by maps showing locations listed between 1880 and 1947, indicating the type of signal that existed at the time of withdrawal or in 1947 if it was still extant.

Although wireless time signals were widespread after 1920, visual signals continued to be provided at many locations worldwide and a significant number were still extant or re-established after the end of the Second World War. The total number of listed visual signals reached 220 in 1922 and declined to 64 in 1947. There were 53 listed time balls in 1880, 129 in 1919, 69 in 1939 and 26 in 1947. Electric time lights first appeared as principal signals in 1909 and replaced or complemented many time balls, giving a maximum of 41 light signals in 1934. The largest number of listed time guns was 49 in 1915.

Keywords: Time balls, time lights, time guns

1 INTRODUCTION

The development of techniques for determination of longitude using astronomical observations lasted for centuries and has been well-described by many authors (see Howse, 1997). Two principal solutions became available in the second half of the eighteenth century. They complemented each other. One was the marine chronometer, which indicated mean time at a chosen prime meridian. This prime meridian was selected by the British to pass though Greenwich Royal Observatory and was later adopted worldwide. Other countries had used different prime meridians, but it ultimately made sense to use an agreed common origin for all maritime charts. Comparison of Greenwich mean time (GMT) with local mean time then gave the longitude. Longitude could be expressed in terms of either time difference or angular distance around the earth from the prime meridian.

The other principal solution was to measure the position of the moon relative to a selected group of stars using a sextant. The longitude could then be determined using procedures and data in a nautical almanac, published annually. This second solution, often known as the method of lunar distances, required considerable time and skill but was available as a check on chronometer accuracy when a ship was remote from land and skies were clear enough for stellar observations.

The aim of land-based visual time signals for mariners was to improve the accuracy of longitude estimation in the era before wireless signals had become universally available, by allowing them to 'rate' chronometers. Ideas for such signals were first proposed by Robert Wauchope (1788–1862). The signals provided essential checks on accuracy that could not be taken for granted.

1.1 Aims of This Paper

The aims of this paper are to show how certain signals emerged as preferred solutions and how they were perceived by mariners. Their locations and principal characteristics were given in pilot guides and lists of signals. These locations are shown on maps created using Google Earth. Extensive use has been made of notices published by different authorities worldwide, and of lists published by the British Admiralty after 1880. Signals were introduced at different times and often changed from one type to another as technology progressed. This is demonstrated using a set of tables for specific geographical areas, concentrating particularly on time balls, time guns and electric light signals between 1880 and 1947.

The early time signals emerged before photography and few published images or drawings are known to exist. Some are included in this paper. Many later signals have been photographed extensively, but many others have never appeared in published images and no longer exist. Selected images are used to illustrate the variations in design.

1.2 The Astronomers Royal at Greenwich and the Board of Longitude

The Observatory at Greenwich had been founded in 1675 specifically to improve accuracy in navigation via provision of precise astronomical observations (Howse, 1993). The first Astronomer Royal, John Flamsteed (1646–1719), was appointed by King Charles II, then the British monarch. Flamsteed served between 1675 and 1719 and demonstrated that the Earth rotated at a constant rate, allowing longitude to be expressed in terms of either angular distance or time difference between two meridians. It was to be over two centuries before tiny variations in the rate of rotation would be identified.

The Board of Longitude was established by Act of Parliament in 1714 with the Astronomer Royal as an ex-officio member, to encourage solutions to the problem of longitude measurement at sea. This was paralleled by similar encouragement in other countries (see de Grijs, 2020; Howse, 1997). Initial progress was slow and erratic but accelerated rapidly in the 1740s. Flamsteed was followed by Edmond Halley, James Bradley and Nathanial Bliss. The fifth Astronomer Royal was Nevil Maskelyne (1732–1811) who served from 1765 to 1811. He was in post when it first became possible to determine longitude at sea with high accuracy using either a timekeeper or the method of lunar distances.

In recent times, Maskelyne has been presented unfairly as an opponent of John Harrison (1693–1766) who was the first to build a timekeeper that would remain accurate over a long period at sea (Sobel, 1995). Maskelyne favoured the use of astronomical measurements to estimate longitude but did not seek to profit financially from that preference (Howse, 1993). Harrison had been awarded the prestigious Copley Medal of the Royal Society in 1749, for his promising early development of timekeepers H1 to H3 (King, 1993). Harrison was eventually granted a large award in 1765, usually described as the Longitude Prize, for his H4 timekeeper. However, it still fell short of being an affordable solution. Many others made significant contributions to the development of marine chronometers that could be supplied in quantity at a reasonable price (Howse, 1997). They too received awards for their work.

Maskelyne (1763) had published a plan for an annual nautical almanac before his appointment as Astronomer Royal. This would include predictions of the lunar position relative to the stellar background during the year after publication, building on ideas and earlier measurements that originated in France and Germany (Howse, 1997). Maskelyne persisted with the plan and published the first British nautical almanac after he became Astronomer Royal (Maskelyne, 1766).

One of the last important acts of the Board of Longitude before its dissolution in 1828 was to initiate development of an observatory in the southern hemisphere at the Cape of Good Hope and appoint the Reverend Fearon Fallows (1788–1831) as its first Director in October 1820 (Gill, 1913). Despite poor support and work in difficult conditions, Fallows introduced the first precision shore-based visual time signal in about 1823, using a shuttered oil lamp (Editorial, 1835; see Kinns, 2021).

The sixth Astronomer Royal between 1811 and 1835 was John Pond (1767–1836), who was in post at the time of the Portsmouth time ball trial in 1829–1830 and presided over installation of the Greenwich time ball in 1833.

George Airy (1801–1892) was the seventh Astronomer Royal at Greenwich from 1835 to 1880 and was at the heart of time signal development during that time. Airy was a meticulous correspondent who was often approached about provision of time signals worldwide. Many of those exchanges feature in this paper. He was succeeded by William Christie (1845–1922), who served from 1881 to 1911. Their archived correspondence is a valuable reference concerning the development of visual time signals in the pre-wireless era.

1.3 Chronometer Rating

Time at the prime meridian had to be known accurately: an error of 1 second in time corresponds to an angular rotation error of 15 arcseconds, equivalent to 0.46 km at the Equator or half that at Latitude 60°. That placed heavy demands on the reliability and accuracy of chronometers. It is worth noting than an error of 1 second per day corresponds to time measurement accuracy that is close to 0.001%. A chronometer would be ‘rated’ by its manufacturer and ideally checked independently by a qualified authority before use at sea, so that its user could apply a first-order correction to the indicated time. It was not unusual for a chronometer to gain or lose 5 seconds per day, while the rate might depend on factors such as

temperature and the local magnetic field. It also depended on chronometer wear and lubrication.

A chronometer was not adjusted until return to its supplier or a qualified authority. Many ships carried several chronometers on long voyages, partly to guard against chronometer failure and partly in the expectation that an average reading, after rate correction, would be more accurate than a single measurement.

Repeat rating of chronometers at different ports was essential for accurate navigation using chronometers of average quality, as well as checks using the method of lunar distances. This is well-illustrated in the following letter concerning a voyage to Madras, which also mentioned a longitude error in the stated location of the Madras Observatory:

> December 31st, 1858.—Last evening we arrived in Madras, and by the flash of the gun I find that on applying the errors and rates to the chronometers supplied by the maker before leaving England, the best chronometer was 56½ miles too far East, and the worst one 175 miles, while the lunar errors were right to one mile, and the lunar rates to four-tenths of a second. I may add that the *Nautical Almanac* gives the longitude of the Madras Observatory as 5h. 21m. 4s., but my friend Mr. W. H. Bayley tells me that some years ago Mr. Taylor, the Astronomer here, detected a mistake in this, and that it really is, 5h. 20m. 57.3s. Major Worster, now in charge of the Observatory, also says that this is the correct longitude. (Toynbee, 1859).

In this letter, longitude is specified as time in advance of Greenwich, 1 hour corresponding to 15° angular rotation. The flash of a gun served as the Madras time signal in 1858 (Kinns, 2020c).

It was shown by John Chapman Hartnup (1806–1885), Director of Liverpool Observatory, that the main reason for the difference between rates provided by the supplier and rates measured at sea was temperature variation. It then became possible to improve longitude accuracy by measuring the rate of a chronometer at different temperatures in a laboratory facility and correcting readings at sea by monitoring temperature during a voyage (Obituary, 1886).

1.3.1 Effects of Temperature on Chronometer Rates

John Hartnup demonstrated key relationships between chronometer rates and temperature that made it possible to correct chronometer readings during lengthy sea voyages, provided that rates had been pre-determined under laboratory conditions. He evaluated the effect of temperature on the rates of one hundred chronometers in 1854 and was later able to deduce formulae for the general behaviour of chronometers (Obituary, 1886). The following extract shows how his work was applied in practice:

> In his Report for 1872 to the Marine Committee of the Mersey Docks and Harbour Board, Mr. Hartnup gives a formula for calculating the correction due to thermal error, for any temperature of a chronometer whose rate has been determined by observation in the three definite temperatures of 55, 70 and 85 degrees Fahrenheit. An example showing the advantage of such corrections to the rates of two chronometers during a voyage from Liverpool to Calcutta is given in No. 2, vol. xxxv of the Society's *Monthly Notices*.

It then became possible to check chronometers using land-based signals without the same urgency to measure the rate using repeat measurements over several days at different ports. Many owners of chronometers, including the Pacific Steam Navigation Company from 1877, sent them to Hartnup's observatory in Liverpool for the necessary calibration. Similar calibration could be carried out at other observatories worldwide. Hartnup's work was admired internationally (see The Japanese Navy, 1878, for example).

1.4 Requirements for Time Signal Accuracy

Precise measurement of longitude was needed to determine signal times. Once the longitude of the signal had been established, a transit telescope could be used to ensure that the signal was made at the same GMT and local mean time each day. These transit observations regulated astronomical clocks which often incorporated devices to drop a time ball or fire a gun automatically. Longitude could be determined initially using the method of lunar distances or observations of eclipses and occultations.

Longitude accuracy was improved in the early years by shipping a large number of carefully calibrated chronometers between observatories and averaging results. In 1845, over 60 chronometers were sent 16 times backwards and forwards between Altona near Hamburg and Pulkowa near St Petersburg while 40 chronometers were used in 1846 in a similar manner to establish the longitude difference between Altona and Greenwich (Howse, 1997: 117).

Telegraph links, including long-distance underwater cables, were later used extensively for accurate determination of longitude, following

pioneering work in the United States (Dick, 2003). Allowances had to be made for the signal propagation speed along telegraph wires, which was typically 3,000 km/sec.

The accuracy of the measured longitude between Washington and Paris improved from about one second using chronometers before 1850, to a few tenths of a second using telegraph cables in the 1860s, and to a few hundredths of a second after the introduction of wireless signals in the twentieth century (Dick, 2003: 473).

1.4.1 Random and Bias Errors

There were two types of error in the timing of land-based signals. The first was a bias error, resulting primarily from inexact determination of longitude. Sometimes, it had to be recognised after careful deliberation that there was an error in the stated longitude. One example is the longitude of Wellington in New Zealand, which was corrected in April 1874 by 1′ 33″, corresponding to a timing error of 6.15 seconds (Longitude of Wellington, 1874; see Kinns, 2017a). Another example was an error in Portugal, found using telegraphic determination by the US Navy in 1878–1879: "… the longitude of the observatory at Lisbon has up to the present time been in error more than two miles." (Green et al., 1880: 11).

Stated longitudes and signal times were subject to adjustment in Admiralty lists when more accurate determinations became available. A bias error could also result from factors such as a consistent delay in time ball release after an electric signal had been received. Sometimes, this type of error was minimised by arranging for the release signal to be sent slightly early. This approach was used in Singapore, for example (Kinns, 2021a). This would not affect determination of chronometer rates and would be announced in official notices.

The second type of error was random, resulting from factors such as imprecise transit observations or extended reliance on an astronomical clock when bad weather prevented astronomical observations. Random errors were dependent on the skill of local operators and the quality of available equipment.

Ideally, daily signals should be accurate to better than ±1 second for chronometer rating. The best-equipped observatories, such as those at Greenwich and The Cape of Good Hope, aimed for an accuracy of ±0.2 seconds in visual signals. Measurements over 5 days would then give a rate accuracy of better than ±0.1 seconds per day. Annual reports from individual observatories sometimes included statistics concerning time signal accuracy, such as *rms* errors and the proportion of signals outside stated error bands.

1.5 Early Development of Time Signals

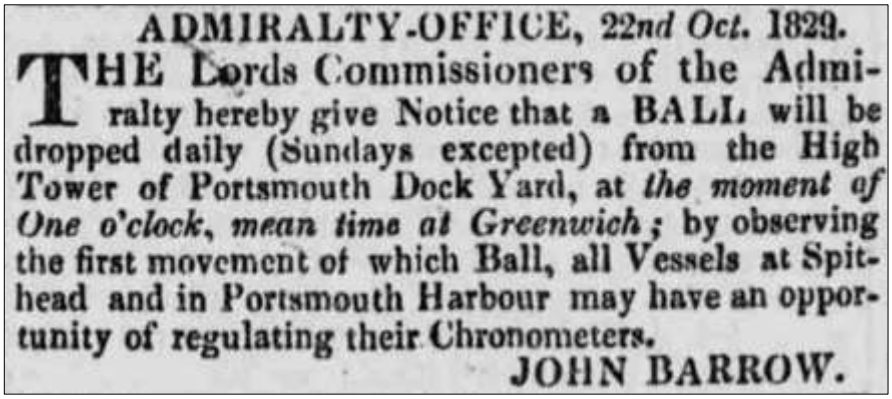
1.5.1 Robert Wauchope

Ideas for land-based time signals that could be used to rate marine chronometers were first promoted by Captain Robert Wauchope, RN in 1818 when he was in command of *HMS Eurydice* at the Cape of Good Hope and St Helena station (Wauchope, 1818; see Bartky and Dick, 1981; Kinns et al., 2021). Wauchope recognised that shore-based signals visible from ships at anchor were essential to avoid having to remove a chronometer from its location onboard. This overcame concerns that the rate might be influenced by the magnetic field due to onboard equipment made of iron as well as by any shock experienced during transfer. Wauchope worked hard to persuade others to recognise the benefits of land-based time signals regulated by astronomical observations.

1.5.2 Early Ideas

Wauchope's first ideas for visual signals used a flap to signal time to ships offshore (Wauchope, 1818) and may have been rooted in the mechanical telegraph system that was then under development for communication between the Admiralty and Portsmouth (Holmes, 1983). That telegraph system was implemented by Henry Maudslay (1771–1831) whose precision engineering company, later named Maudslay, Sons & Field, was to provide the time ball apparatus for Greenwich in 1833 after Henry's death.

Long before 1818, guns had been fired to signal approximate time but were not under observatory control. Many of the early developments, including the first operational time light in about 1823, were at the Cape of Good Hope (see Kinns, 2021b). Wauchope continued to promote land-based signals and pressed the Admiralty to introduce them in 1824, favouring a flag signal until at least 1827 (Kinns et al., 2021). Those ideas led eventually to the dropping time ball, which became the preferred visual signal. The ball would be dropped manually when an astronomical clock showed the chosen time of the signal. A key feature, promoted by Wauchope, was the use of preparatory signals, such as the hoisting of a flag or the raising of a time ball in stages, to indicate that a time signal was imminent. A time ball could be released automatically after invention of appropriate triggering mechanisms using electromagnets. However, the apparatus was



ADMIRALTY-OFFICE, 22nd Oct. 1829.

THE Lords Commissioners of the Admiralty hereby give Notice that a BALL will be dropped daily (Sundays excepted) from the High Tower of Portsmouth Dock Yard, at *the moment of One o'clock, mean time at Greenwich*; by observing the first movement of which Ball, all Vessels at Spithead and in Portsmouth Harbour may have an opportunity of regulating their Chronometers.

JOHN BARROW.

Figure 1: Time ball announcement on 22 October 1829.

expensive and required careful maintenance if it was to deliver its full potential for increased accuracy. The hauling down of a flag on receipt of an observatory signal was still being used in the twentieth century at a few locations.

1.5.3 The First Time Ball Trial

Documents located after the pioneering work by Bartky and Dick (1981) showed that the first time ball at Portsmouth, England in 1829 did not use the arrangement published by Wauchope (1830) and the location was not as previously assumed (Kinns et al., 2021). Figure 1 shows the announcement of a time ball trial in October 1829, recording that the time signal was the moment of release and that the ball was located on the "High Tower" at Portsmouth.

Wauchope sought unsuccessfully to promote a different arrangement where the signal was the time of drop by one ball diameter. This is shown in Figure 2. It was never used for operational time balls, not least because the time to drop by a specified distance might be influenced by weather conditions and sources of friction. Thanks to Wauchope's persistence, the Portsmouth trial led to the Greenwich implementation in October 1833 and to a time ball at Liverpool which entered service in January 1845, but not to operational time balls at Portsmouth or other UK locations until the 1850s or even later.

Extensive research by Paul Fuller has failed to find any mention of the first time ball in contemporary local newspapers, beyond the initial announcement in Figure 1. It remains unclear whether the 1829 apparatus was a trial arrangement to prove the concept of a shore-based signal or whether it remained in operation for some years afterwards. The Portsmouth time ball was not mentioned in discussions after 1837 that led to the 1845 Liverpool time ball, the only references to time ball design being to the arrangement at Greenwich (Fuller, 2022).

1.5.4 Early Implementations

A novel implementation, which used a stationary black ball or disc behind a shutter in a white painted building, was operational at Port Louis, Mauritius in April 1833 (Herschel, 1836; Lloyd, 1833; see Kinns, 2020b). Its development appears to have been independent of the Admiralty and it preceded the Greenwich time ball by six months.

The British East India Company recognised the merits of Wauchope's proposals and erect-

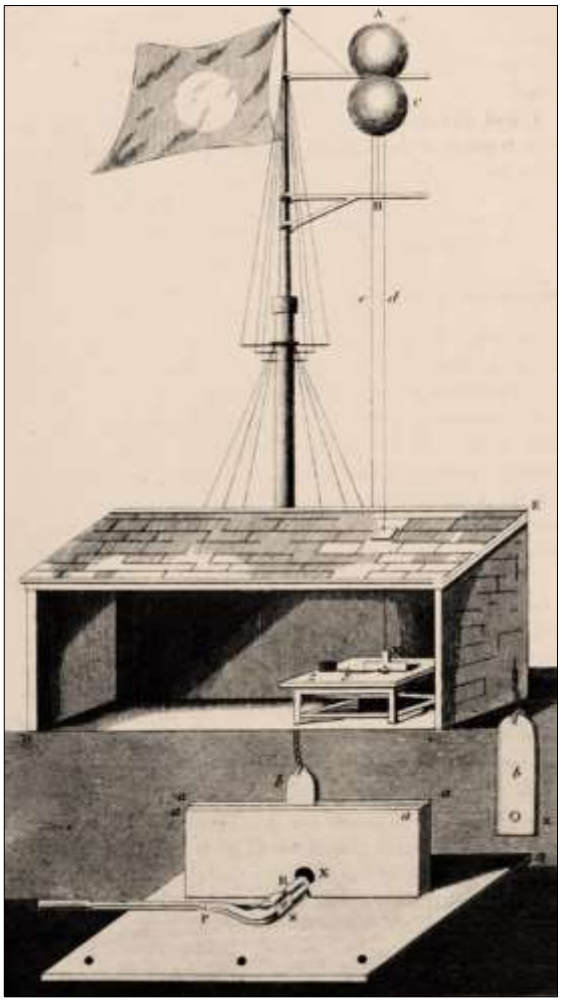


Figure 2: Wauchope's proposed arrangement (Wauchope, 1830).

ed early time signals for chronometer rating in the 1830s. These were located on the trade routes between Europe and the Far East and implemented using local resources. The first of these was a dropping ball at St Helena in January 1834, which was noted by Wauchope when he was in command of HMS *Thalia*. Another time ball was erected in Calcutta, now Kolkata, in 1835 (Phillimore, 1958). There are references to an early time ball at Madras, now Chennai, but a plan to operate a regular time ball service there may have been undermined by a reluctance to allocate resources to it. It appears that a gun was used instead until the 1850s (Kinns, 2021c). There was an early time ball at the Cape Coast Castle near Accra, now in Ghana (Maclean, 1840). The first time ball outside the British Empire was erected in 1839 by the Dutch at Batavia, now Jakarta, in Indonesia (Melvill and Smits, 1850).

An alternative approach, favoured by the US Navy for several decades after time balls and other land-based signals had been first introduced elsewhere, was to purchase only high-quality chronometers and to rate them carefully before issue to the fleet (Dick, 2003). This was at least in part due to the high cost of providing observatories and time signals along extended coastlines in the era before long-distance telegraph links from a central observatory had become feasible and reliable. The earliest public time signal in the USA was introduced in 1845, when a time ball was dropped at the Naval Observatory in Washington, DC (*ibid.*). It was not then intended as a signal for rating chronometers, which was undertaken by Observatory staff. Bartky (1983) explored the subsequent history of time balls in the United States, noting the variety of time balls that were eventually arranged around the Atlantic and Pacific Coasts, the Gulf of Mexico and the Great Lakes. The North American signals will be discussed later in more detail.

Time guns were widely used as approximate public time signals but were only of value for rating chronometers when they were under observatory control. A flash pistol was introduced at the Cape of Good Hope in 1833 (Warner, 1979). It was fired with reference to an astronomical clock. A time gun in St Helena was fired in 1834 when the time ball was seen to drop. The flash of the gun was the time signal, not sound which propagates slowly at about 330 m/sec.

A common early practice was for a gun to be fired by an army contingent at an approximate stated time. The exact time of the flash would be noted by astronomers who would make this time available to ships via a notice on the following day. An example of this practice, and criticisms of it, was published in the *Nautical Magazine* in 1841:

> For ascertaining the error of chronometers, you must note the time of the flash of the 8 P.M. gun fired at the fort, and the corresponding Madras mean time, as noted at the observatory, will be sent off the next morning from the master attendant's office; but as the flash is not always distinctly seen at the observatory, too much reliance is not to be placed on this mode of ascertaining the error. (Madras, 1841).

Development of the electric telegraph allowed time balls to be dropped and guns to be fired automatically using signals from either a local or a remote observatory. There was an important remote implementation at Deal, on the east coast of Kent in England, about 100 km from Greenwich, which used the railway telegraph system and entered service in 1855. A signal from Greenwich caused the ball to drop automatically, with a return signal to confirm the drop (Airy, 1871). The return signal was retained in 1883 when the telegraph link was altered. A detailed description of the initial arrangement and its development up to 1884 has been presented by Beresford and Combridge (1990). Although it might have revolutionised time ball operation, the use of telegraph lines to control a time ball directly made the process vulnerable to line breakages and false signals due to electric storms for example. There was a declared process for signalling an inaccurate time ball drop, but there were ongoing concerns about reliability of the telegraph signals. A more conservative approach was to regulate an astronomical clock using telegraph signals and to control the time ball drop or firing of a gun from the clock using an additional mechanism.

Charles Piazzi Smyth, the second Astronomer Royal for Scotland, introduced a time gun on the battlements of Edinburgh Castle in 1861 to complement the time ball on the Nelson Monument in Edinburgh which had become operational in 1854. It was fired automatically using a gun clock that was regulated by telegraph from the Monument.

1.6 Airy's Lists of Time Signals in 1861

George Airy had a large impact on the provision of time signals world-wide. He compiled lists of time balls that he either knew to exist in 1861 or believed to have been proposed but not implemented (Airy, 1861a; 1861b).

The first list is transcribed below (after Airy, 1861a):

> Greenwich; Deal; London (E and I Telegraph Co), City Observatory; Liverpool (E

> and I Telegraph Co), Victoria Tower; Portsmouth; Edinburgh; Glasgow (a ball was known to exist in 1859 but no particulars relating to it have been found); Cape of Good Hope (Simon's Town); Madras; Calcutta; Sydney; Quebec; Williamstown, Vic, Aus; Washington, US.

The list includes 9 in Great Britain, but not all were visible to mariners and some were intended for domestic use. Two of these were in London: in the Strand (Clark, 1852) and at the "City Observatory" at Cornhill, the home of many chronometer makers in London. Only 7 overseas were listed, of which two were in India and two in Australia. The first time ball in the USA in Washington (see later), had been established in 1845 for domestic use. Clearly the list is incomplete, because it did not include St Helena, Ascension or Batavia, for example, nor did it list Bombay. This may be because many of the early signals were established without direct involvement by the Astronomer Royal.

The single entry for the Cape of Good Hope is surprising. The first time ball at the 'Cape Observatory' was erected in 1836 and supplemented by a repeater time ball to improve visibility to ships in Table Bay (Maclear 1852; 1853; see Kinns, 2021b). The first time ball at Simon's Town was erected in 1857 and operated electrically from November 1861 (Cape Town, 1861).

Airy's (1861b) second list of projected time balls is transcribed below:

> Hamburgh (*sic*.), 1857; Copenhagen, 1857; River Tyne (Shields), 1859, Gravesend, 1860; Mauritius, 1860.

Again, the list is very short, with only two in Great Britain and three overseas. The first time signal in Mauritius (Lloyd, 1833) had been discontinued and a new time ball there was not operational until 1866 (see Kinns, 2020b).

1.6.1 The Alternative of a Semaphore Signal

Correspondence in 1860 concerning a possible time ball at Gravesend illustrates how the Astronomer Royal was asked for advice and how he responded. This is reproduced below. The approach was from Stephen Leach at the Thames Conservancy (Leach, 1860a). His letter to Airy includes the remark

> Mr Main, upon whom I called with reference to the subject, in your absence, informed me that Messrs. Maudslay & Field supplied the mechanical part of the apparatus & in order to save you trouble I have written to them for particulars.

Airy(1860) replied promptly:

> In regard to the Time Signal, if you decide on having a Ball, you cannot do better than consult Messrs. Maudslays but it has long since appeared to me probable that an efficient construction might be made on the Semaphore principle, at a much smaller expense.

Leach (1860b) wrote to Airy again a fortnight later:

> I have made a drawing of a Semaphore signal which I think would answer the purpose & which I shall be happy to submit to you. I find however a strong preference on the part of the Conservancy for a Ball, as being the commonly recognised mode of exhibiting the signal.

A few semaphore signals were used in South Africa and at a small number of other locations but most were replaced by time balls. The only semaphore time signals in Admiralty lists after 1880 were at Colombo in Ceylon (now Sri Lanka) and Madras in India. Both had been replaced by time balls by 1915.

1.6.2 Maudslay Time Balls

Airy clearly had a high regard for Maudslay, Sons & Field, which he mentioned in subsequent correspondence. They were regarded as eminent precision engineers with a reputation for quality of design and manufacture, but their price for time ball apparatus was high and only five were ever built by them. Bartky (1987) included a list headed "The last time balls (1987)", without identifying their suppliers, and he noted four that were operational: Greenwich, Edinburgh, Deal and Lyttelton (New Zealand). He also noted two others on standby: Sydney in Australia and Göteborg in Sweden. The first five were those built originally by Maudslay, Sons & Field, the one for Lyttelton having been made for Siemens Brothers (Kinns, 2009).

All used an air 'spring' to arrest the descent of the ball with a bleed valve to limit rebound. The ball was pushed up a slotted mast from below to engage with release triggers. This type of arrangement was later used widely by other suppliers. The original design for Greenwich (made in 1833) used a chain hoist. Those for Edinburgh and Deal (made in 1853), Sydney (made in 1855) and Lyttelton (made in 1873) used a rack and pinion arrangement for hoisting the ball. The design for Sydney included detailed design changes from those for Deal and Edinburgh, while the apparatus made for Siemens Brothers was a replica of the Sydney design (see Kinns, 2009 for photographs of mechanical components).

All were listed by the Admiralty in 1880 and they outlived hundreds of others, leaving a remarkable tribute to their quality of design and construction. Since 1987, other time balls have also been replicated as working memorials.

1.6.3 Alternative Signals

Other alternatives to a dropping spherical ball were used at some locations. These included cones and drums, a few of which could be collapsed as the signal. A collapsible cone was introduced at Devonport in England in June 1861 (Washington, 1861). The notice included the statement

> The time signal is not made as usual by the dropping of a ball, but by the collapse of a Cone, which, when not in use, hangs in a closed state on the Flagstaff …

The hauling down of a flag was also used as a lower-cost but less accurate alternative. Discs rotating about a horizontal axis to simulate a disappearing ball were later favoured by the Netherlands in preference to dropping time balls.

1.7 Time Signal Proliferation

Many of the earliest time balls and other time signals were developed for rating marine chronometers but time signals were soon adopted inland, inspired particularly by the development of railway networks and the desire for operation to exact timetables. Most in the British Isles were operated using electric telegraph signals from Greenwich after about 1870. Those signals were accurate, but the mechanisms used to operate the visual signal required regular checking and maintenance. A time ball on a prominent public building or the firing of a time gun was often regarded as a statement of civic prestige, but many authorities came to recognise that the costs of erection and particularly maintenance were incompatible with available budgets. It was all too common for an inaccurate time signal to become an object of derision and many time balls and time guns had short lives. The history of time signals in Wales illustrates some of the difficulties in maintaining a reliable system (Linnard, 2018).

The number of signals in Admiralty lists varied between relatively high densities in terms of distances between signals in most of Europe to much sparser distributions in other continents. Some widely-separated time signals that could not meet the desired standards of accuracy for chronometer rating were still included with appropriate warnings, because they could at least offer a spot check on time. On the other hand, unlisted signals in the British Isles might have been of high accuracy but were surplus to requirements for marine chronometer rating.

1.8 New Time Signals for Mariners between 1860 and 1880

Time signals for mariners continued to be introduced worldwide during the period from 1860 to 1880, when the first Admiralty list was published. Seven time balls in Germany were introduced in the 1870s (see later), while France introduced six time balls, a rotating disc at Cherbourg and a flag at Brest. The first time balls at Cadiz in Spain, Lisbon in Portugal and at Trieste, Fiume, Pola in Austria, now in Italy and Croatia, were established. Many more were established in the then British Empire, notably in South Africa, India, Australia, New Zealand, Canada and in island colonies on principal trade routes. Time guns were introduced at many locations, often in parallel with time balls or other visual signals. A weakness of time guns used alone was the lack of preparatory signals, such as the raising of a ball in two stages to warn observers that a time signal was imminent.

Time discs were introduced in the Dutch East Indies (now Indonesia), a falling drum was introduced at Rio de Janeiro in Brazil, while flag signals were introduced at Curaçao in the Netherlands West Indies and at Paramaribo in Suriname. Other signals included collapsible objects.

2 ADMIRALTY LISTS OF TIME SIGNALS

The first edition of the Admiralty list of time signals was published in 1880. It combined details of signals worldwide into a single document. Before then, details of signals had been specified in notices, almanacs and pilot guides published by different authorities in different countries. Many early notices about time signals appeared in *The Nautical Magazine*, which was first published in 1834. The Admiralty lists included a wide range of devices, notably time balls or other objects that were dropped or collapsed at a specified time or times. They included flags that were hauled down at stated times and time guns whose flash was the signal. The lists also included signals that could only be seen by going ashore to an office or public building. In that case, an officer would usually use an intermediate watch, rather than move a chronometer from its onboard location. The signals considered in this study are limited to those visible or audible to ships in harbour.

Decisions had to be made by the Admiralty about whether to include secondary signals that were not at major ports or were maintained and operated by private enterprise or local government. The 1880 list included a footnote about signals around the British Isles that were not in the main list, without giving details. Several were time guns and time balls, including small time balls on shop premises, and others were controlled clocks. Footnotes of this type were not included in lists for 1898 onwards. Intermediate lists published in 1888, 1892 and 1895

have not been seen by the author. Comments about the accuracy and reliability of time signals were often derived from reports by visiting ships. They were usually qualitative and served as a guide to subsequent visitors.

A typical Admiralty list entry is shown in Figure 3, indicating the signals available in China in 1922, as well as preparatory signals and procedures used in case of failure (1922 list, Part 6, 451–452).

Similar, often identical, information can be found in pilot guides issued by the United States and many other countries. Mistakes did occur and signals might be omitted accidentally or included after they had been withdrawn, but the Admiralty lists form the most comprehensive and reliable source available to the author.

2.1 Structure of Admiralty Lists

The Admiralty *List of Time Signals Established in Various Parts of the World* was published as a single document for the whole World at intervals from 1880 to 1911. Two wireless time signals in North America were included in the 1908 and 1911 lists but wireless signals were later listed separately and are excluded from the present study. Later lists, covering lighthouses and other navigation lights as well as time signals, were issued in parts covering different geographical areas. The title used from 1912 to 1920 was *Admiralty List of Lights and Time Signals*, which changed to *Admiralty List of Lights, Time Signals, Wireless Direction Finding Stations and Wireless Meteorological Signals* in 1921 and then to *Admiralty List of Lights and Visual Time Signals* in 1922–1928. These were issued in nine parts, at first annually. Later, each part was reissued every three years, with supplements in intermediate years to record changes, allowing a list of time signals to be constructed for any given year. The dates of signal introduction or modification were often noted in editions after 1911. The title was changed again in 1929–1971 to *Admiralty List of Lights, Fog Signals and Visual Time Signals*, issued in twelve parts. In a small number of cases, where a signal was on the boundary between two geographical areas, the same entry appears in two parts. The 1947 edition was effectively a fresh start, recording signals that still existed or had been introduced after the devastation of World War II.

At first, signal times in Admiralty lists were specified as local (astronomical) mean time, governed by the longitude of the signal location, and Greenwich mean time (GMT). Local times were later changed to standard times, determined by time zone allocations. In a few cases, a local Standard time was specified as well as a national Standard time. One example is the use of Rangoon Standard time as well as Burma Standard time (see later).

It had been standard practice to use time based on zero hours at noon for astronomical purposes, but this was changed to civil time in 1925, based on zero hours at midnight (Howse, 1997). Most, but not all, time balls were dropped at noon or 1 pm standard time. Some were dropped more than once per day.

In order to simplify references to Admiralty list entries, the year of the entry is stated for a given time signal in tables of results, without detail concerning page and part numbers. In a few cases, the entry is derived from a combination of the main list and corrections via supplements up to the stated year.

2.2 Specification of Latitude and Longitude

The latitude and longitude of a time signal were specified as accurately as possible. Longitude was relative to the prime meridian which passed through Airy's transit circle at Greenwich (see Howse, 1997). Modern GPS co-ordinates are not subject to this constraint and the prime meridian used for Google maps is positioned about 5 arc-seconds east of the Observatory (see Kinns et al, 2021). The difference is too small to influence locations on the maps in this paper.

2.3 Warning about Use of Sound Signals

A cautionary note about time guns was always included in Admiralty lists of time signals, with minor variations of wording between editions. The following version is from the 1908 list:

> When the flash of a gun cannot be seen, the sound of the report may be made use of as an approximate indication of the time, by allowing for the necessary interval for the sound to travel the intervening space. Sound travels about 1,090 feet in a second of time, at the temperature of 32° Fahrenheit, and the speed increases at the rate of 1.15 per second for each degree of temperature above the freezing point. In fogs, however, the use of sound is not to be relied upon, as the path of the wave may not be direct on account of the interposition of impervious clouds.

The slow speed of sound led to the production of maps for individual time guns that showed the average time delay to different locations. However, the precise delay varied with weather conditions and wind direction. The accuracy of chronometer rating was thereby reduced relative to that attainable using a time ball or the flash of the gun, but a sound signal was entirely adequate for public use when errors of a few

No.	Name.	Year established or last altered	Position. Latitude N. Longitude E.	Signal adopted.	Time of signal being made. Greenwich Mean Time.	Time of signal being made. Standard Time.
					h. m. s.	h. m. s.
5041	Hong Kong	1908	Mast north-westward of the signal station, Blackhead hill 22 17 52 114 10 29	Red ball	14 00 00	22 00 00
		1930			20 00 00	4 00 00
		1920	Observatory wireless mast	Three white lights (vertical)	0 56 00 to 1 00 00	8 56 00 to 9 00 00
5042	Swatow	...	Flagstaff on the harbour master's office 23 21 27 116 40 13	Ball	16 00 00	0 00 00
5043		...	... ...	Gun*	16 00 00	0 00 00
5044	Amoy	...	Battery on north-eastern slope of Wellington Nose, north point of Kulangsu	Gun*	16 00 00	0 00 00
5045		...	Mast at the semaphore station, south-east point of island 24 28 46 118 04 04	Flag T, International code	16 00 00	0 00 00
5046	Shanghai	...	Semaphore at the French concession 31 14 07 121 29 08?	Ball, diameter 6 feet	15 55 00 16 00 00	23 55 00 0 00 00
5047		...	Same position	Four white electric lights	0 55 00 to 1 00 00	8 55 00 to 9 00 00
5048	Chin Kiang	...	32 15 00 119 29 10	... ...	...	...
5049						
5050	Tsingtau (Kyau Chau)	...	36 04 — 120 19 —	Gun*	16 00 00	0 00 00
5051						
5052	Chifu	...	Mast eastward of Tower hill 37 32 56 121 23 30	Black ball	16 00 00	0 00 00
5053		...	... ...	Gun*	16 00 00	0 00 00
5054						

* See Note, page 441. † Local mean time.

No.	ADDITIONAL DETAILS.
5041	165 feet above high water, 462 feet above ground. Ball hoisted half way up at 5 minutes before the signal, close up at 3 minutes before the signal, and dropped electrically from the observatory, Kowloon, at 22h 00m 00s and 4h 00m 00s, Standard time. The 4h 00m 00s signal will not be made on Saturdays, Sundays or holidays. On Saturdays the signal will be made at 1h 00m 00s, Standard time. Should the time ball be out of order, the above routine will be carried out with flag "Z" on the storm signal mast. On application to the harbour master by captains of ships leaving port, who have had no opportunity of obtaining error of chronometer by above time signal, the time ball will be dropped at other times of the day. The lights are extinguished momentarily at even seconds, excepting the 2nd, 28th, 30th, 32nd and 54th seconds of each minute, between 8h 59m 00s and 9h 00m 00s, Standard time.
5042	121 feet above high water, 111 feet above ground. Ball dropped at Noon, Standard time. Signal made on Saturdays only, and is not to be depended on.
5043	Fired when the ball is dropped.
5044	Fired at Noon, Standard time. Reported unreliable.
5045	Flag hoisted at 5 minutes before the signal, and hauled down when the gun is fired.
5046	118 feet above high water, 102 feet above ground, drop 21 feet. Ball hoisted half way up at 10 minutes before the first signal, close up at 5 minutes before the first signal, and dropped at 23h 55m 00s, Standard time. It is immediately re-hoisted, and the signal repeated at Noon, Standard time. Should the signal fail, flag "U", International code, will be hoisted and kept up for about one minute.
5047	The lights are in the form of a diamond. The lights are extinguished simultaneously at each exact minute from 8h 55m 00s to 9h 00m 00s, Standard time. (A short eclipse of 1 second is given 10 seconds before the signals to attract attention).
5048	A telegraphic time signal will be sent on Mondays from Zi-Ka-Wei observatory, if asked for.
5049	
5050	Fired at Noon, Standard time. Reported inaccurate 1915.
5051	
5052	213 feet above high water, 75 feet above ground. Dropped at Noon, Standard time. Stated not to be sufficiently accurate for comparing chronometers.
5053	Fired when the ball is dropped.
5054	

Figure 3: Admiralty list entries for China, 1922, Part 6, 451-452.

seconds were inconsequential. This qualification tended to be ignored or forgotten by supporters of time guns.

2.4 Aims of the Admiralty List Study

The principal aims of this study are to explore the broad evolution of visual time signals for mariners and to identify the locations of important signals worldwide. Large numbers of signals were not included in Admiralty lists because they were either inland for domestic use or of reduced significance for marine navigation. A complete listing of visual time signals for all purposes would be at least as large again. Other lists of time signals have been published, but they are derived from many different sources and include signals that were not visible to mariners (Hite, 2014; Hülse, 2022). The present study also includes electric light signals that proliferated from 1909 onwards. Various time gun and time ball signals identified in the present study have not appeared in previously published lists.

Wireless signals became widely available after 1911 and were then listed separately from visual signals. A few time balls included in this study were operated using wireless signals.

3 EVOLUTION OF TIME SIGNALS FROM 1880 TO 1947

In order to study the evolution of time signals for mariners, the following rules and constraints have been applied:

(1) Signals must appear in the main Admiralty list(s).
(2) Signals must be visible or audible to ships in harbour (signals requiring a visit ashore are not included).
(3) There is occasional ambiguity between discs and balls, notably at Port Elizabeth in South Africa.
(4) Time signals listed for France as 'balloons' are included as time balls (see later).
(5) Duplicate signals (e.g. time balls at different locations in a port or a combination of signals such as a time gun and a time ball) are included. A distributed array of time lights was sometimes used, but those are counted as one signal only.
(6) Alternative signals (e.g. either time discs or time lights on a given day) are both included.
(7) Although not visual signals, sirens and whistles in Admiralty lists have been included as 'other' signals.

Time balls were made in many different sizes, with different drop heights. A diameter of 5 feet (1.5m) and a drop height of 10 feet (3m) were favoured dimensions, but this was far from universal and drop heights could exceed 10m. Diameters could be over 2m or as small as 0.6m. Most time balls were spherical but a few were described as egg-shaped. These dimensions, as well as time ball elevation above ground and sea level, were usually, but not always, stated in pilot guides and Admiralty lists. Many had external skins which gave the appearance of a solid body, but many others used an open wire frame. Time balls were usually black, but red paint was often used and some had coloured bands. Colours were easily changed and the time ball colour was not always stated in Admiralty lists.

Many time balls or other devices for chronometer calibration had short lives, so the total number that had been listed by the Admiralty at one time or another exceeds the maximum number identified in any one year.

Figure 4 shows how the numbers of different signals in Admiralty lists changed between 1880 and 1947. It was included to demonstrate the evolution of time signals in a recent study (Kinns, 2023). The number of visual signals peaked in the period after the First World War and declined markedly after the Second World War. Electric time lights first appeared as principal signals in about 1909 and replaced or complemented many time balls. Time guns were operated widely, many in parallel with time balls. In 1880, the starting year for the present study, the Admiralty recognised 82 visual signals: 53 time balls, 10 time guns and 19 other signals. Of these, about 55% were outside the British Empire. In 1922, there were 220 listed signals: 129 time balls, 45 time guns, 21 time lights and 25 other signals. The proportion outside the British Empire had risen to over 65%. Many were destroyed or discontinued during World War II and the number in operation during the war years is uncertain although lists continued to be published. A review in 1947 showed that there were then 64 listed visual signals: 26 time balls, 19 time guns, 14 time lights and 5 other signals.

Time lights first appeared in the 1911 list and reached a maximum of 41 in 1934. Many were simple white lights switched on for a few minutes and then extinguished as the signal, but arrays of flashing lights were also used. The unique arrangement of coloured time lights in New Zealand, which replaced time balls at Wellington and Auckland, is described later.

The number of time guns in the Admiralty lists was always smaller than the number of time balls and reached a maximum of 49 in 1915.

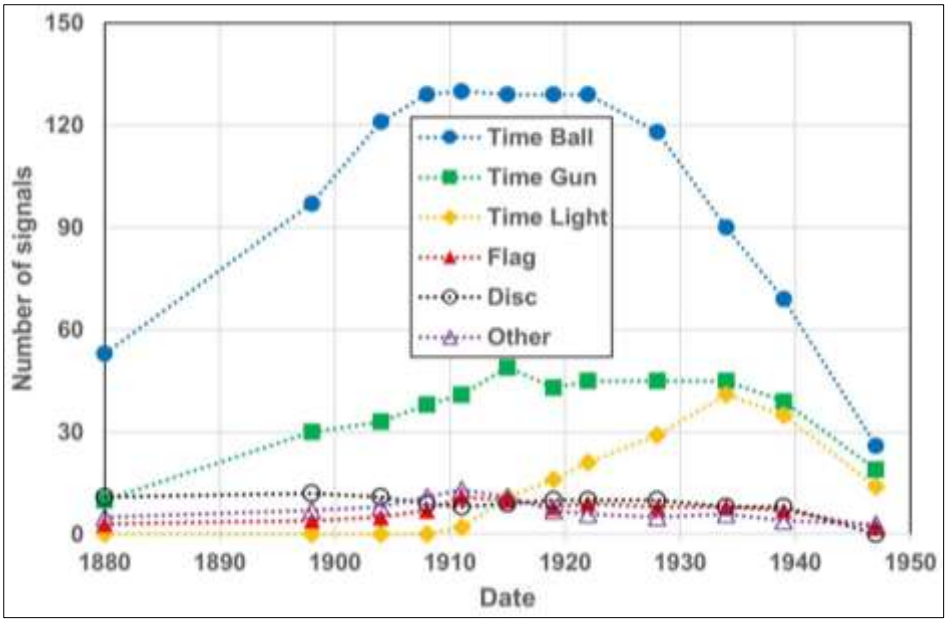


Figure 4: Evolution of time signals between 1880 and 1947 (plot: Roger Kinns).

3.1 Tabular Presentation of Results

In order to show where and when signals of different types were recognised by the Admiralty between 1880 and 1947, lists are presented in tabular form using colour coding. These are for selected years: 1880, 1898, 1904, 1911, 1915, 1919, 1922, 1928, 1934, 1939 and 1947. Rows indicate the location of the signal in the stated geographical region. Some signals were in use before or after they were listed by the Admiralty. In the early years, their inclusion or deletion would have to await publication of a new list, usually prepared using information available up to the end of the previous year. Other reasons for exclusion are likely to have varied from doubts about signal reliability to accidental omission. In a few cases, signals were still listed after they are known to have been withdrawn.

Various country boundaries, particularly in Europe, changed after World War I and World War II. For example, Trieste and other locations in the Adriatic were listed first as being in Austria and later in Italy or Croatia. Beirut was in Syria and is now in an independent Lebanon, while Helsingfors (now Helsinki), was in Russia and is now in an independent Finland. Changes like these are noted against the signal location.

Time balls are highlighted in the tables using a blue background, with text showing the colour of the ball, if stated in Admiralty lists. Time guns and other flashes from explosions are highlighted in green. Lights are highlighted in yellow, with coloured text to indicate signals that were not white lights. Discs, semaphores, cones and cylinders are highlighted in orange; flags in red; clocks, whistles and sirens in brown. The aim has been to give an immediate visual impression of how signals evolved with time in different geographical areas.

Each table has a summary at the bottom showing the number of time balls, time guns, time lights and other signals in each of the selected years. The locations in each list are primarily in alphabetical order within each country. Spellings of place names varied and were usually anglicised, but modern place names are indicated in the individual tables. The latitudes and longitudes of signals have not been specified in this simplified paper. They can be found in Admiralty lists together with details of the signal and measures taken in case of signal failure. Details of this type have been given in journal papers about time signals in individual countries but have been avoided here to allow inclusion of over 200 signals in tabular form. Signals of particular interest are described briefly in the following sections. Some are not known to have been included in other publications and many would merit further investigation, especially when the description given by the Admiralty does not match available photographs. Only a limited number of images are included in this paper, but Klaus Hülse (2022) has formed an outstanding collection of postcards that can be accessed easily and includes many of the listed signals.

Some signals have been subject to detailed investigation by the present and other authors. In a few cases, the signals appear to have been operational for longer than previously thought. One example is the time ball at East London, which was still listed in 1939 when all other time

balls in South Africa had been discontinued by the end of 1934. A few others were short-lived, such as a Lisbon time ball which was introduced in 1914 but had been superseded by a time light in 1916. Time balls at some cities in the United States, such as San Francisco, were modified or moved from one building to another (Bartky, 1983). This is also apparent from details such as signal latitude and longitude stated in Admiralty lists. Unless two balls were operated together, these are shown in one row.

3.2 Maps Showing Signal Locations Worldwide

Fourteen maps show the locations of visual signals in Admiralty lists between 1880 and 1947. Some locations used multiple signals that changed over time. These are not shown separately. Not all existed together. The following colour coding is used for the maps to describe the type of signal that was either in use in 1947 or at the latest date when a signal was listed at the specified location.

Type of Signal	Font colour	Pin colour
Dropping object		
Gun or powder explosion		
Dropping object, and gun or powder explosion		
Rotating disc(s)		
Flag or siren		
Flag and gun		
Time light(s), with or without other signals		

The same colour code is used for all types of signal that were made using a dropping object. Most were time balls. The colour coding exception is Greenwich, which is highlighted in red to distinguish it from nearby time balls in England. Some locations, such as Edinburgh, used a combination of a falling object and a time gun or explosion. Signals at many locations changed to time lights in the twentieth century, sometimes as a complement or alternative to a time ball or other signal. Only Shanghai is recorded as reverting to a time ball in 1947, having used a time light as well as a time ball between at least 1911 and 1939. The evolution of signals at a specified location is shown in the separate set of tables.

Signals were more concentrated in Europe than other geographical areas, so the maps do not show a one to one correspondence to the tables. Map scales and text fonts have been adjusted according to the density of signals. There is some overlap between different maps. All signal locations have been included in at least one map, except for Honolulu in the Pacific Ocean which is remote from other listed signals.

4 SIGNALS IN THE BRITISH ISLES

Signals in the British Isles have been subdivided between England, Scotland, Wales and Ireland in Table 1. Most time balls in this table used a thin skin on a wooden frame, giving the appearance of a solid ball. Time guns were all under observatory control using automatic firing, so the flash of the gun was an accurate signal. Their locations are shown in Map 1.

The 1880 Admiralty list included a footnote listing several signals but without giving their detailed locations. These are not shown for 1880 in Table 1. Time balls at Cardiff, Hull, Inverness, Jersey, Southampton, Stockton-on-Tees, Whitehaven and Great Yarmouth were dropped at 10 am and maintained by private enterprise. The Dublin time ball, maintained by a public body and another at Sunderland, maintained by private enterprise, were both dropped at 1 pm. Time guns at Cork, Dundee, West Hartlepool, North Shields, Queenstown and Swansea were listed as maintained by public bodies and fired at 1 pm GMT. Another at Dover was fired at noon. Controlled clocks at Dumbarton, Glasgow, Leith and Waterford were listed as being maintained by public bodies and regulated by electric current received from London at 10 am.

Some, but not all, of these signals were included in lists for 1898 onwards. Many other visual signals were unlisted but were well-known locally. Time lights were never listed for the British Isles.

4.1 Time Balls

Time balls at Greenwich, Edinburgh, Deal and Portsmouth were in the main list for 1880, plus a collapsible cone signal at Devonport, but the number had been increased to nine in 1898 and reached a maximum of 12 in 1919. These were located at Chatham, Deal, Devonport, Falmouth, Greenwich, Immingham Dock, Portland, Portsmouth, Sheerness and Southampton in England; Edinburgh and Rosyth in Scotland; Dublin in Ireland.

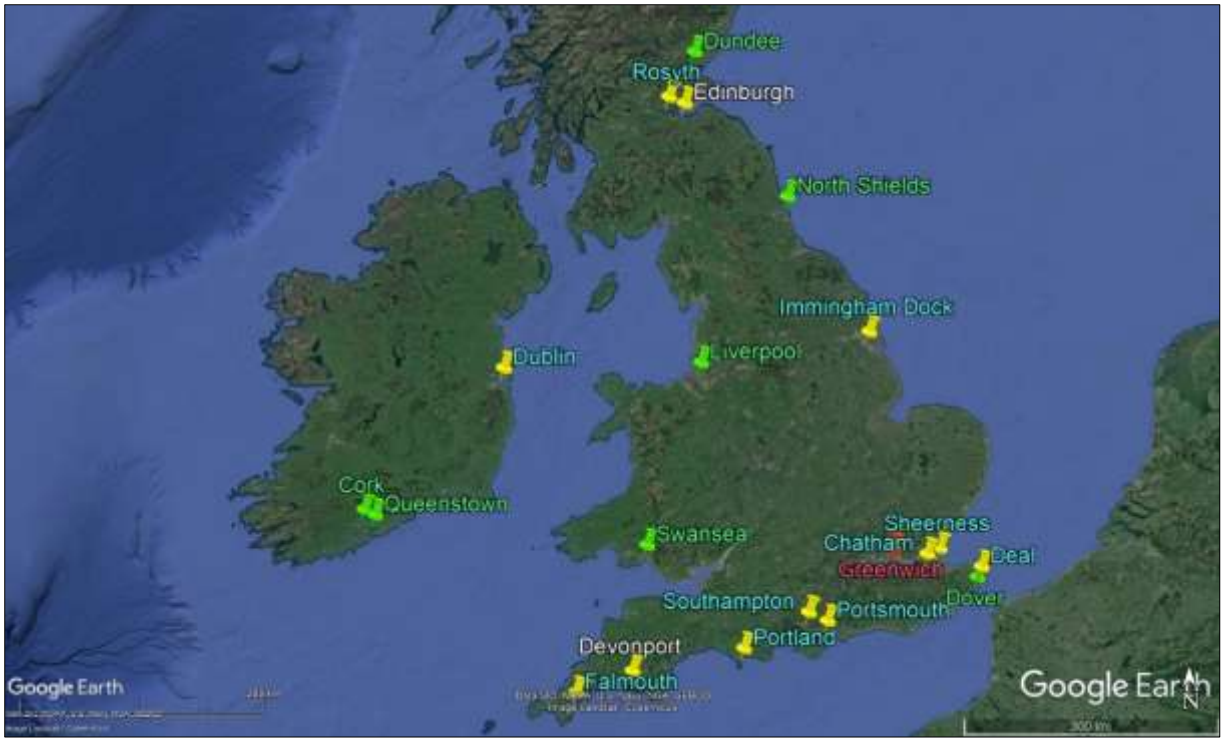
Additional time balls were introduced at various ports. Some of these unlisted signals have been restored, such as a time ball at Margate which had been introduced to celebrate Queen Victoria's Golden Jubilee in 1887 (Jubilee Clocktower, 1889).

4.2 Time Guns

Precision time guns at Edinburgh and Liverpool were followed by several others around the British Isles, so that nine were listed in 1898. These were at: Devonport, Dover, Liverpool and

Table 1: Signals in the British Isles.

Country	Location	1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
England	Chatham				TB	TB	TB	TB	TB			
	Deal	TB	TB	(black)	(black)	(black)	(black)	(black)				
	Devonport	Cone										
			TB	(black)	(black)	(black)	(black)	(black)	(black)			
			Gun	Gun	Gun	Gun	Gun	Gun				
	Dover		Gun									
	Falmouth		TB	(black)	(black)	(black)	(black)	(black)				
	Greenwich	TB	TB	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(red)
	Imm. Dock						(black)					
	Liverpool	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun
	North Shields		Gun	Gun								
	Portland				TB	TB	TB	TB	TB			
	Portsmouth	TB	TB	(black)	TB							
	Sheerness		TB	(black)	(black)	(black)	(black)	(black)	(black)			
	Southampton		TB	TB	TB	TB	TB	TB	TB			
Wales	Swansea		Gun	Gun	Gun							
Scotland	Dundee		Gun	Gun	Gun	Gun						
	Edinburgh NM	TB	TB	TB	TB	TB	TB	TB	TB	TB	TB	TB
	Edinburgh C	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun
	Rosyth						(black)	(black)				
Ireland	Cork		Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	
	Dublin		TB	TB	TB	TB	TB	TB	TB	TB	TB	TB
	Queenstown		Gun	Gun	Gun	Gun						
Signal type totals		1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Time ball, including collapsible		4	9	9	11	10	12	11	8	3	3	3
Gun, including powder flash		2	9	8	7	6	4	4	3	3	3	2
Lights		0	0	0	0	0	0	0	0	0	0	0
Other: disc, drum, flag, etc.		1	0	0	0	0	0	0	0	0	0	0



Map 1: Signals in the British Isles (map: Roger Kinns).

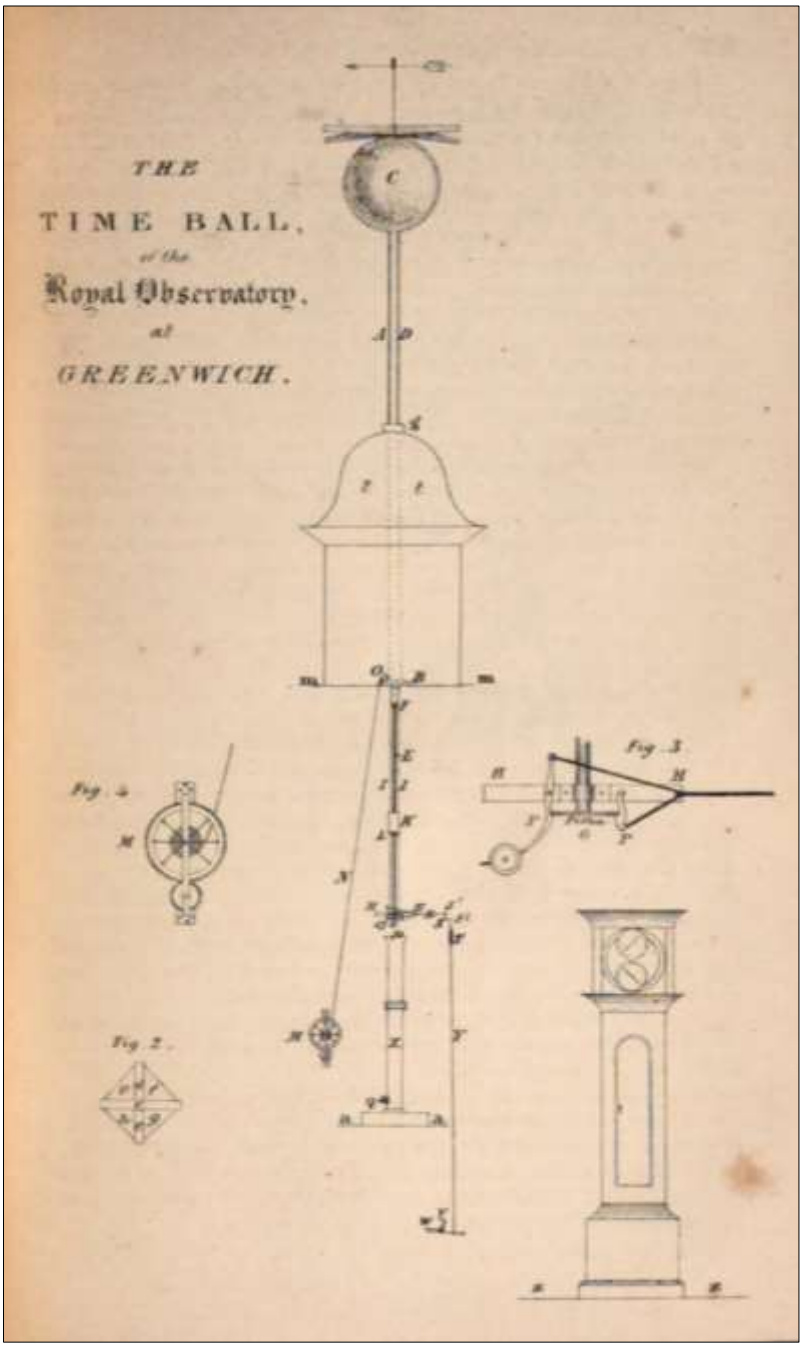


Figure 5: Diagram of the Greenwich arrangement (after *Nautical Magazine*, 1835).

North Shields in England; Dundee and Edinburgh in Scotland; Swansea in Wales; Cork and Queenstown in Ireland. Most had been withdrawn before or during the First World War, but the time gun at Liverpool continued until 1969 and that on Edinburgh Castle still continues as a tourist attraction.

4.3 Signals in England

4.3.1 Greenwich

The time ball apparatus at Greenwich set a high standard for design and accuracy when it entered service in 1833. Initially the time ball was released by an observer who watched a mean time clock, but this was changed to automatic operation using electro-magnets controlled from a modified clock in 1852 (Bateman, 2013; Howse, 1997). A diagram of the original design by Maudslay, Sons & Field was published in the 1835 *Nautical Magazine* and is re-produced here in Figure 5. A key feature was the air spring, invented by Joshua Field, to control descent of a 1.5m diameter ball weighing about 90kg. This size of ball had been selected after preliminary experiments in 1833 to establish the visibility of different sizes of ball to observers remote from the Observatory.

Figure 6: The Greenwich time ball in 2008 (author's photograph).

Figure 6 shows the time ball at Greenwich in its present form. The external appearance is as it was in 1833, except that the drop height was reduced from the original 3m to 2.4m after storm damage and the ball has changed colour from the original black to the present red. Table 1 indicates that the ball was black until at least 1939, but there is evidence that it had occasionally been painted red in the 1920s (Bateman, 2013).

4.3.2 Liverpool

The first operational time ball after Greenwich was established at Waterloo Dock in Liverpool in 1845, after many years of agitation for an observatory that could provide a service for rating chronometers. In 1837, "… a memorial was presented to the Corporation by the British Association for the Advancement of Science". Funding for an observatory at Liverpool was finally agreed in 1842. John Chapman Hartnup (1806–1885) was appointed as Director in 1843 and the observatory was fully operational in 1846. He had been elected a Fellow of the Royal Astronomical Society in 1845. His work was highly regarded internationally, with many contributions to *Monthly Notices of the Royal Astronomical Society*. Hartnup developed a multi-purpose observatory which combined its time service with the collection of important meteorological data. He offered exceptional services for in-house chronometer calibration as well as accurate external time signals.

Hartnup had foreseen the need for a second, larger time ball, so that mariners would not need to rely on the existing ball at Waterloo Dock. A large time ball with a diameter of 1.6m was constructed on the top of the Victoria Tower which was controlled by electrical signals from Liverpool Observatory in 1860. In 1864 the Mersey Docks and Harbour Board debated whether to move their time signal away from Waterloo Dock as the area needed redevelopment to cater for larger steamships. The decision to move the Observatory to Bidston on The Wirral followed long public debate. The time balls at Liverpool were discontinued when a precision time gun was introduced in 1867, so never appeared in Admiralty lists from 1880 onwards.

Hartnup suggested that a time gun could be controlled from the new observatory by telegraph and in 1867 a time gun based on the

Edinburgh system was established at Morpeth Dock on the Mersey estuary. This time gun was to become world famous for its extraordinary accuracy. Excluding wartime years, the time gun fired every day from 21 September 1867 until 18 July 1969.

4.3.3 Deal

The time ball apparatus for Deal was built by Maudslay, Sons & Field in 1853 and was operational on 1 January 1855. The original intent had been to install the time ball on the South Foreland Lighthouse, but it was decided that it should instead be installed on the Semaphore Tower at the Naval Yard in Deal (Beresford and Combridge, 1990). The design differed from Greenwich in using a rack and pinion mechanism to hoist the ball but it retained the air spring arrangement that had been introduced at Greenwich in 1833. The black ball had a diameter of 1.5m and a drop height of 3m, as at Greenwich. The design was almost identical to that used at Edinburgh in most respects (see Kinns, 2009 for a comparison of the arrangements). A major innovation for Deal was its control using an electric telegraph connection from Greenwich to London Bridge Station and from there to Deal using the South Eastern Railway telegraph. The total distance was about 100km.

The Naval Yard was sold in 1864 and the Astronomer Royal then became directly responsible for ongoing provision of the time ball service. The telegraph connections were modified in 1883, with continued use of a return signal to confirm that the ball had dropped correctly. The overall reliability of the old and new arrangements was described by Airy in his annual report (Airy, 1884; see Beresford and Combridge, 1990):

> As regards the Deal time ball, after various delays the arrangements … for sending a current to Deal, and receiving a return signal through the chronopher of the Post Office telegraphs, was brought into operation on February 29th, and has worked well since … There have been 16 cases of failure in the dropping of the Deal time ball owing to interruption of the telegraphic connections, 12 under the old system, and four since the new arrangement with the Post Office.
>
> On 19 days the current was weak, and required the assistance of the attendant to release the trigger, and on 9 days violence of the wind made it imprudent to raise the ball.

The Deal Time Ball became obsolete with the advent of reliable radio time signals and the service ended on 25 February 1927. The original apparatus is on display in the Time Ball Tower, now operated as a museum, and a modern arrangement is used to operate a replica ball. Figure 7 shows the tower in 2005.

4.3.4 Portsmouth

George Airy, the Astronomer Royal, had tried in 1855 to persuade the Admiralty to erect time balls at Portsmouth and other dockyards that would be similar to the arrangement at Deal, with operation by telegraph from Greenwich.

Figure 7: The appearance of the Deal time ball in 2005 (http://www.dealtimeball.co.uk/).

He had sought an estimate for supply by Maudslay, Sons and Field for the mechanical arrangement and consulted Portsmouth dockyard about its possible location, without any reference to the 1829 installation (Kinns et al., 2021). In the event, it was decided to use an obsolescent approach, where the Observatory signalled time to the main ball operator using a miniature pilot time ball, requiring manual intervention. The time ball location was on a sema-

phore tower that had been built in 1833. It was introduced in 1856, over 26 years after the first time ball trial there, but was poorly regarded by Airy, who fought successfully to have it changed to operation by electric telegraph from Greenwich after 1878 (*ibid.*). His objections included the low quality of the transit telescope at Portsmouth and manual operation. The time ball visible to mariners had a diameter of only 1.1m and later used the operating principle favoured at Devonport. It burned down in 1913. The modern display at Portsmouth, which includes the pendulum clocks that were regulated by telegraph and used to drop the time ball automatically, makes no mention of the 1829 trial (*ibid.*).

4.3.5 Devonport

A time ball dropped using electromagnets at Devonport near Plymouth in Devon had been under consideration as early as 1847 (Dockyard, 1847):

> Estimates are being prepared for the building of an Observatory in this yard, to be connected with a time ball on the top of the column – by electro-magnetism; the object of which is to give … the most correct means of determining the rates of the chronometers and Greenwich mean time.

The early plan to install a time ball appears to have been abandoned. Instead, Devonport installed a collapsible cone in 1861 (Washington, 1861). The same device was included in the 1880 Admiralty list and was noted in 1885 as a possible type of signal for use at other locations (The Royal Observatory, 1885). This and later signals were on Mount Wise.

A new type of time ball apparatus was introduced at Devonport in 1886, which was simpler and cheaper than earlier designs and became widely used at other locations worldwide (Lewis, 1910). The time ball had been discontinued by 1934. The apparatus is often described as using the Devonport Principle. The black ball with a diameter of 1.1m was raised using halyards and held in position by triggers that were released electrically. There was no need for a special building and it was dropped from a yard arm at Devonport. An iron frame was used at other locations. The drop height varied considerably between installations. After initial free fall, the descent of the ball could be arrested using an arrangement of pulleys, weights, springs and dampers or a friction brake. There are no surviving examples in commission.

A time gun at Devonport on the slope of Mount Wise, near the time ball, was introduced in 1887 and continued operation until 1924.

4.3.6 Other Dockyards

Time balls had been introduced at several naval dockyards by 1898 and at Portland in 1907. All of these had been withdrawn by 1934. A black time ball with a large diameter of 1.8m was introduced at Immingham Dock on the River Humber in 1916. It was still listed in 1919, but had been discontinued before 1922. A time ball at nearby Kingston upon Hull was unreliable and was not included in Admiralty lists from 1898 onwards, but had appeared in the 1880 footnote. It has been restored recently as a tourist attraction. The Immingham time ball has been lost.

4.3.7 Northeast England

A time ball at Sunderland, near the mouth of the River Wear, was noted as maintained by private enterprise in a footnote to the 1880 Admiralty list. It did not appear in lists from 1898 onwards. The provision of time signals for the River Tyne at North Shields had an intriguing history. A time gun at Newcastle and another at North Shields were introduced in 1863. Nathaniel Holmes, who was also responsible for time gun trials in Glasgow, arranged that the guns would be fired from Edinburgh in 1863 (see Kinns, 2010). Problems with telegraph connections soon led to operation by telegraph from Greenwich.

The time gun at North Shields had been mentioned in a footnote in the 1880 Admiralty list and appeared in the main lists from 1898 to 1908. There is, however, clear evidence that the time gun service had been withdrawn in 1905 (The time gun, 1905), with subsequent correspondence regretting its demise as a public signal.

4.4 Signals in Scotland

4.4.1 Edinburgh

The time ball above the Nelson Monument on Calton Hill in Edinburgh and the time gun on Edinburgh Castle are two of the most famous time signals in the world. The monument and time ball are shown in Figure 8. The history of time signal development in Edinburgh has been described in detail by Kinns (2011b).

The plan to have a time ball on the Nelson Monument was agreed by the City and Admiralty in 1846, long after an Edinburgh time ball was first suggested by Wauchope (1830). The apparatus was finally ordered from Maudslay, Sons & Field of London in 1852 and arrived in Leith during September 1853. It was erected under the leadership of Professor Charles Piazzi Smyth and extended trials were undertaken

Figure 8: A panoramic view of the time ball on top of the Nelson Monument on Calton Hill in Edinburgh (https://www.wikiwand.com/en/Nelson_Monument,_Edinburgh#Media/File:Edinburgh_Calton_Hill.jpg)

to prove its reliability in all weathers before it became an official signal in March 1854. From the outset, the ball was released by an electric telegraph signal from a clock at the nearby Royal Observatory. Frederick James Ritchie, clockmaker of Edinburgh, made important contributions to the accuracy and reliability of the signal. Smyth kept meticulous records of time signal accuracy that were open to public inspection and can still be seen at the present Observatory in Edinburgh.

The time gun on Edinburgh Castle was introduced in 1861, with automatic firing by a Castle clock that was controlled by electric telegraph from the Observatory. It set new standards for accuracy and became the preferred public signal. The gun clock incorporated a special mechanism that allowed for the fraction of a second that it took for powder to explode

after receipt of the electrical spark (Ritchie, 1861; see Kinns, 2011b). A 1.3km long wire suspended between the Monument and the Castle was used from 1861 until December 1873. It had been changed from a light to a heavier wire in 1865 after expression of concerns about safety, but this increased the load on the Monument. The wire was changed in 1873 to one using support from intervening buildings. The gun's location on Edinburgh Castle high above the City meant that it was audible over a long distance without causing damage to local property. This was in marked contrast to Glasgow and Dundee.

Smyth promoted the time gun as his preferred signal, arranging for the publication of maps that showed the time delay is sound propagation to different locations in Edinburgh and Leith. In a letter to Airy, Smyth (1878) stated:

> With the Time-Ball the first instant of the fall is recommended to observers, but is in reality always about 0.15 sec. too late, on account of the time necessarily taken up in the action of the trigger. With the Time-Gun the fire is 0.05 sec. too soon, owing to the difference of instants at which the escapement of the clock concerned is liberated, and at which the electrically controlled pendulum arrives at the end of the arc at each second.

Although the Edinburgh time signal service under Smyth's leadership was impressive, the Observatory had suffered from chronic underfunding, leading to concerns about the state of instruments and buildings (see Kinns, 2011). The Observatory was relocated from Calton Hill to Blackford Hill in 1895 and the time signals were afterwards controlled from there using extended electrical connections. The gun has been replaced several times but continues to give the one o'clock signal as a tourist attraction. The original time ball apparatus was carefully restored in 2009 and is still operable manually (Marshall, 2009). The telegraph link to the Observatory no longer exists.

An extraordinary myth that the ball weighed an implausible three-quarters of a ton was repeated in guidebooks for over 150 years. The error stems from an uncorrected mistake in an 1853 presentation that was published in 1856 (Smyth, 1853). It had actually weighed about 90kg when first installed, but its weight increased with repairs to its frame and zinc skin so that the restored ball weighs almost 200kg (Kinns, 2014). The original air spring arrangement to arrest the ball's descent is still in use but requires careful maintenance to avoid unacceptable impact loads on Nelson's Monument. Figure 8 shows the monument with the restored time ball.

4.4.2 Glasgow

The history of visual time signals in Glasgow reflects the tension between technical requirements and political sensitivities that often featured in time signal provision. The relative prestige of the Glasgow and Edinburgh observatories was an important issue at a time when the industrial city of Glasgow was often described as the second city of the Empire (Clark and Kinns, 2012; Kinns, 2011). There was no telegraphic link between Glasgow Observatory and the City until the end of 1863, but it had been demonstrated as early as September 1855 that a time ball could be dropped by telegraph from Edinburgh (see Kinns, 2011b). The complete history of Glasgow astronomy has been described by Clark (2013).

Sir Thomas Brisbane (1773–1860), former Governor of New South Wales and amateur astronomer, had retired to Edinburgh and observed initial operation of the Edinburgh time ball in 1853 (Morrison-Low, 2004). He recommended that similar time balls should be erected in Glasgow and Greenock. A time ball on the Sailors' Home on the Broomielaw on the River Clyde near the centre of Glasgow was erected in 1857, but had been discontinued by 1864. The design of the time ball machinery had much in common with the 1853 Edinburgh apparatus, but it was operated using electrical connections to a mean time clock in the Home. This clock required adjustment by hand each day to compensate for its losing rate. The accuracy of the transit telescope at nearby commercial premises was also criticised. Such manual intervention and lack of independent verification of accuracy undermined the authority of the signal. A growing problem was that the time ball could not be seen by large ships west of the city centre when general visibility was being reduced by industrial smoke pollution and construction of intervening buildings. Nevertheless, the ball remained in place for decades after the service had been discontinued (see Kinns, 2011).

An unsolicited Edinburgh initiative in September 1863 was instigated by Nathanial Holmes of the Universal Private Telegraph Company. He located time guns at three locations in the City, with another at Greenock, and fired them by telegraph from Edinburgh. They caused offence, as well as some damage to property, in Glasgow and the trials were terminated in February 1864. Holmes had also fired guns in the northeast of England from Edinburgh in 1863. Professor Grant (1814–

1892) Director of Glasgow Observatory, argued successfully that a system of slave clocks controlled from Glasgow Observatory would be far superior to either a time ball or time guns which only provided a signal once per day. He won the debate in March 1864 and his use of slave clocks was well-regarded internationally (Ellery, 1868). Nevertheless, controlled clocks were not seen by the Admiralty to offer the authority of a time ball which had a single purpose.

4.4.3 Dundee

The Dundee time gun was mentioned in a footnote to the 1880 Admiralty list and last appeared in the list for 1916. It had a chequered history, in common with other time guns where it was difficult to achieve audibility without causing damage and complaints. After negotiations with the Harbour Board, a time gun station was built in the Barrack Square. The gun was fired by telegraph for the first time from the Royal Observatory at Edinburgh on 3 September 1872 but there were early criticisms about its indistinct retort and inaccurate firing of the gun. Another problem was the effect of the gun's retort on the patients of the Dundee Infirmary, which was located only 200m from the gun. In March 1894, these complaints finally caused the town council to move the gun to a new location at Dudhope Barracks but the complaints continued. The council experimented by moving the gun to Law Hill and Balgay Hill but results were still unsatisfactory and the gun returned to Dudhope Barracks. It ceased firing on 24 February 1916 following more complaints from the Royal Infirmary, which was then full of wounded soldiers. After the end of the First World War there were unsuccessful calls for the gun signal to be reintroduced.

4.4.4 Rosyth

A time ball was introduced at Rosyth Dockyard in 1916. It was still listed in 1922 but had been withdrawn before 1928. It had a small diameter of 0.9m, half that of the ball at Immingham Dock in England which was introduced in the same year.

4.5 Signals in Wales

4.5.1 Cardiff and Newport Time Balls

A time ball at Cardiff was included in a footnote to the 1880 Admiralty list as maintained by private enterprise, but not in lists from 1898 onwards. It had been erected on the Town Hall in 1862 by the Electric Telegraph Company (Linnard, 2018). The apparatus had to be repaired frequently and was never seen as a reliable signal. It was replaced in 1887 by another time ball but that too acquired a reputation for unreliability and was finally withdrawn from service in 1893. It had been a chastening experience for Cardiff.

The Cardiff time balls were a civic undertaking, but a time ball at Newport appears to have been the personal initiative of Robert Whitehall, a local entrepreneur who traded as a jeweller and clockmaker (Linnard, 2018). He erected the ball on his premises and it is believed to have been in operation from 1876 to 1883, but its visibility to ships is uncertain. Whitehall ceased trading in 1884 and there is no further record of a Newport time ball. Unusually, the balls at Cardiff and Newport were both dropped at 10am GMT.

4.5.2 Swansea Time Guns

A time gun was established at Swansea in South Wales in October 1874. It had been mentioned in a footnote to the 1880 Admiralty list as one of several guns maintained by public bodies. It was funded by the local council and was situated on the North Pier at the entrance to the harbour. It was criticised by local chronometer makers for its inaccuracy and was replaced in 1882 (Linnard, 2018). In 1898 its location was given as 'On Old Eastern Pier', when it was fired by electricity from the General Post Office. The same description was still included in the 1908 and 1911 lists, although operational problems in 1905 had suggested that it might soon be discontinued (*ibid.*). It is possible that the Admiralty had omitted to record withdrawal of the signal prior to 1911.

4.6 Signals in Ireland

4.6.1 Dublin

Dublin established a time ball on top of the Port and Docks Board Building in 1865, but its location was some distance from the harbour. It was mentioned in a footnote to the 1880 list "… as maintained by a public body." The time ball was included in the 1898 list as being dropped by electricity from Dunsink Observatory, with similar entries up to 1916 when the ball was moved to the eastern end of Sir John Rogerson's Quay. It was then dropped using a clock that was regulated by Dunsink Observatory but continued to have limited visibility from harbour locations. By the 1920s the ball was being ridiculed in the local press, but it continued to be listed by the Admiralty throughout the 1920s and 1930s. It was still listed by the Admiralty in 1947, when it was dropped electrically using the wireless time signal from Rugby.

A plan for a second time ball to be installed on top of a new hotel on the seafront at Dún

Laoghaire in 1866 was abandoned due to financial constraints. A further plan to position a time ball on Tuskar Rock off the south-east coast of County Wexford in 1866 also foundered for financial reasons.

4.6.2 Cork and Queenstown

The earliest call for a time gun at Cork was made in 1864 but the necessary finance was not then available. The proposal was resurrected and accepted in July 1874. After some debate about whether to install a ball or a gun

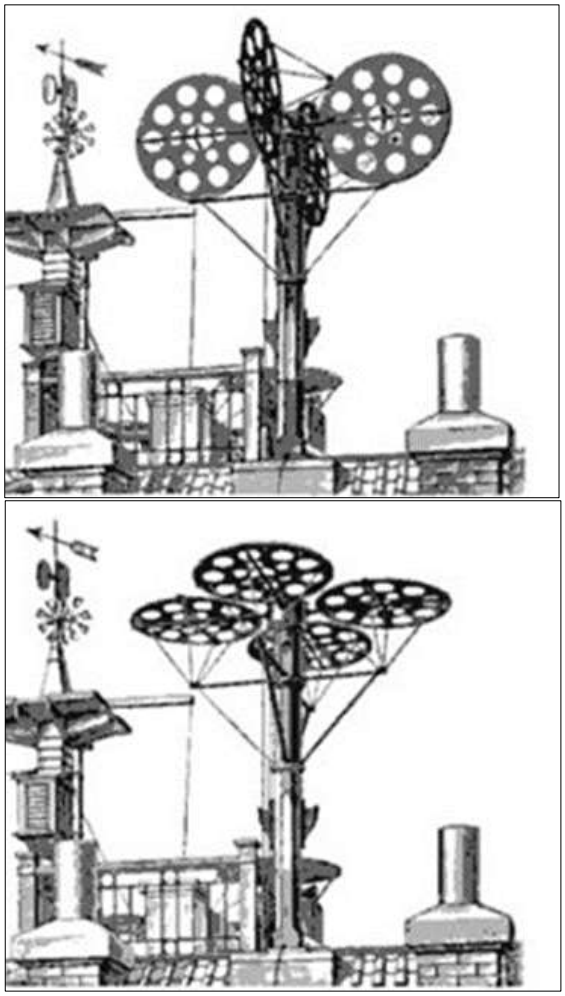


Figure 9: Time discs on the Meteorological Institute (Hite, 2014).

the Harbour Board decided to establish time guns for Cork and neighbouring Queenstown. They were advised by Frederick James Ritchie who had played a major role in implementing the Edinburgh time signals. The Cork gun was introduced in 1875, followed by the similar Queenstown gun in January 1876 (The time-gun, 1876). They were included in a footnote to the 1880 Admiralty list but appeared in the main lists from 1898 until they were discontinued.

Inconsistent operation of the Cork time gun was criticised in Parliament in 1887 (Post Office Ireland, 1887) but it remained in Admiralty lists until 1946. This contradicts the observation that the Cork gun had been discarded after the 1922 Anglo–Irish Treaty in an otherwise informative article (McCarthy, 2016). The time gun at Queenstown was not listed after 1915.

5 SIGNALS IN NORTHERN EUROPE AND RUSSIA

There were a large number of time signals in Europe, extending from the Azores in the west (considered later under Atlantic Islands) to northern Russia. Signals for northern Europe and Russia are presented in Tables 2 to 4. Their locations are indicated in Maps 2 to 4, with the Russian port of Vladivostok in Map 10. These show the emergence of time lights as a preferred signal in northern ports, with early introductions in Germany. Many of the Black Sea ports are now in an independent Ukraine.

5.1 Signals in the Netherlands, Belgium and Scandinavia

5.1.1 Netherlands

Time discs had become the preferred signal in the Netherlands before 1880 and were also used at Antwerp in Belgium. An exception was a time ball on the Rotterdam water tower, which was listed in 1911 only. It had been changed to four discs before 1915. The discs were rotated from horizontal to vertical positions 5 minutes before the signal, which was the time of return to the horizontal rest position (Hite, 2014). From a distance, the rotating discs looked like a disappearing time ball. Figure 9 shows the discs in raised and lowered locations on the Meteorological Institute. Discs at Rotterdam, Hollevoetsluis, Vlissingen (Flushing) and Nieuwe Diep (Willemsoord) were listed in 1880. Those at Hollevoetsluis were not listed after 1904 and those at Vlissingen had been discontinued by 1932. Apart from Rotterdam, the same coordinates and signal descriptions were given in 1880 and 1898.

In 1880, the Rotterdam discs were listed as being on the “Tower of Royal Dutch Yacht Club”. There were four black discs with diameters of 2 feet 8 inches (0.8m), 27m above ground. The latitude and longitude were given as 51° 54′ 30″ N, 4° 28′ 51″ E. In 1898 and later lists, the location was given as the “Gate building” with coordinates 51° 54′ 39″ N, 4° 29′ 47″ E. The disc diameters and elevation remained the same. The Gate building location was on the north bank of the Nieuwe Maas, about 1.1km WNW of the first location on the south bank.

Figure 10 shows the installation on the Rotterdam water tower which was listed from 1915

Table 2: Signals in the Netherlands, Belgium and Scandinavia.

Country	Location	1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Netherlands	Amsterdam		Discs	Discs	Discs	Discs	Discs	Discs	Discs	Discs	Discs	
									Light	Light	Light	Light
	Hollevoetsluis	Discs	Discs	Discs								
	Nieuwe Diep	Discs	Discs	Discs	Discs	Discs	Discs	Discs	Discs	Discs	Discs	
	Rotterdam YC	Discs										
	Rotterdam GB		Discs	Discs	Discs	Discs	Discs	Discs	Discs	Discs	Discs	
								Light	Light	Light	Light	Light
	Rotterdam WT				(black)	Discs	Discs	Discs	Discs	Discs	Discs	
								Light	Light	Light	Light	Light
	Vlissingen	Discs	Discs	Discs	Discs	Discs	Discs	Discs	Discs			
Belgium	Antwerp		Discs	Discs	Discs	Discs	Discs	Discs	Discs	Discs	Discs	
Denmark	Copenhagen	TB	TB	TB	TB	TB	TB	TB	TB	TB	TB	
	Elsinor	TB	TB	TB	TB	TB	TB	TB	TB	TB	TB	
Sweden	Gothenburg	TB	TB	TB	TB	TB	TB	TB	TB	TB		
	Karlskrona		(black)	(black)	(brown)	(brown)	(brown)	(brown)	(brown)	(brown)		
	Malmö		(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	
	Stockholm	(red)	(red)	(b, w)	(black)	(black)	(black)	(black)	(black)	(black)		
Norway	Bergen	TB	(r, w)	(r, w)	(red)	(red)	(red)	(red)	(red)			
										Light	Light	Light
	Carl Johans.							Light	Light			
	Oslo (Christiania)	(b, w)			(gold)							
			D (b&w)	D (b&w)	D (b&w)	D (b&w)	D (b&w)	D (b&w)	D (b&w)	D (b&w)	D (b&w)	
									Light	Light	Light	Light
	Trondheim	D (b&w)	D (b&w)	D (b&w)	D (b&w)							
						(b&w)	(b&w)	(b&w)	(b&w)			
Signal type totals		1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Time ball, including collapsible		6	7	7	9	8	8	8	8	6	3	0
Gun, including powder flash		0	0	0	0	0	0	0	0	0	0	0
Lights		0	0	0	0	0	0	3	4	5	5	5
Other: disc, drum, flag, etc.		5	8	8	7	7	7	7	7	6	6	0

Map 2: Signals in Netherlands, Belgium and Scandinavia (map: Roger Kinns).

Table 3: Signals in Germany and Danzig.

Country	Location	1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Germany (North Sea)	Bremen		(black)	(black)	(black)	(black)	(black)	(black)	(black)			
										Light		
	Bremerhaven	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)			
										Light	Light	
	Cuxhaven	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)			
										Light		
	Emden					TB	TB	TB	TB			
						Light	Light	Light	Light	Light	Light	
	Hamburg	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	
	Hamburg KW					Light	Light	Light	Light	Light	Light	
	Hamburg SP					Light	Light	Light	Light	Light	Light	
										Clock	Clock	Clock
	Hamburg CH									Clock	Clock	Clock
	Wilhelmshaven	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)		
Germany (Baltic)	Kiel, Fjord	(black)	(black)	(black)	(black)	(black)	(black)					
	Kiel, Wik				(black)	(black)	(black)	(black)	(black)			
	Kiel		Gun	Gun	Gun							
	Mürwik NA					Gun	Gun	Gun				
	Stettin					(black)	(black)	(black)	(black)			
										Light	Light	
	Swinemunde	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)			
										Light		
Gdansk (was Germany then Danzig)	Neufahrwasse (Gdansk)	(black)	(black)	(black)	(black)	(black)	(black)	(black)				
									Light	Light	Light	
	Gdynia									Light	Light	Light
Signal type totals		1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Time ball, including collapsible		7	8	8	9	11	11	10	9	2	1	0
Gun, including powder flash		0	1	1	1	1	1	1	0	0	0	0
Lights		0	0	0	0	3	3	3	4	10	7	1
Other: disc, drum, flag, etc.		0	0	0	0	0	0	0	0	2	2	2

Map 3: Signals in Germany and Danzig (map: Roger Kinns).

Table 4: Signals in Finland, Latvia and Russia.

Country	Location	1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Finland (was Russia)	Helsingfors (now Helsinki)		(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	
			Gun	Gun	Gun	Gun	Gun	Gun				
	Abo		(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	
	Uleaborg		(black)	(black)	(black)	(black)	(black)	(black)				
Latvia (Baltic) (was Russia)	Libau					TB	TB					
						Gun	Gun					
	Riga		(black)	(black)	(black)	(black)	(black)					
										Light	Light	Light
Russia (Baltic)	Kronstadt	TB	TB	TB	TB	TB	TB	TB	TB	TB	(black)	(black)
					Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun
	St. Petersburg (Petro, Lenin)	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun
									TB	TB	TB	TB
Russia (Arctic)	Archangel								(black)	(black)	(black)	(black)
											Light	Light
Russia (Black Sea)	Theodosia								Gun	Gun	Gun	Gun
	Nikolaev	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)
			Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun
	Odessa			(black)	(black)	(black)	(black)	(black)	(black)	(black)		
	Sevastopol C				TB	TB	TB	TB				
	Sevastopol Observatory				(black)	(black)	(black)	(black)	(black)			
										Light	Light	Light
	Sevastopol								Gun	Gun		
Russia (Asia)	Vladivostok		TB	TB	TB	(red)	(red)	(red)	(red)	(red)	(red)	(red)
			Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun
Signal type totals		1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Time ball, including collapsible		2	7	8	10	11	11	9	9	8	7	5
Gun, including powder flash		1	4	4	5	6	6	5	6	6	5	5
Lights		0	0	0	0	0	0	0	0	2	3	3
Other: disc, drum, flag, etc.		0	0	0	0	0	0	0	0	0	0	0

Map 4: Signals in Finland, Latvia, Ukraine and European Russia (map: Roger Kinns).

Figure 10: Time discs on the Rotterdam water tower (https://nl.wikipedia.org/wiki/Watertoren_(Rotterdam_Delfshaven).

to 1939. Its location was given as 51° 54′ 23″ N, 4° 27′ 01″ E, on the north bank of the river, about 3.3 km ESE of the Gate building on the south bank

Figure 11 shows the implementation at Amsterdam, which was included in lists from 1898 to 1939. The four black discs had diameters of 1.0m, 31m above ground.

Time lights were introduced at both locations in Rotterdam in 1921 and at Amsterdam in 1928. They were illuminated 5 minutes before the signal, which was the time of extinction.

Discs were retained for use in case of light failure until at least 1939. Only the time lights remained in 1947.

Figure 11: Amsterdam time discs (Klaus Hülse Collection).

5.1.2 Denmark

Denmark provided telegraph time signals at a large number of locations around the coast which were specified in Admiralty lists but could only be accessed by going ashore. Time balls were listed for Copenhagen and Elsinore from 1880 to 1939 but had been withdrawn by 1947. Time guns and lights were never listed for Denmark or Sweden.

5.1.3 Denmark: Copenhagen

The time ball at Copenhagen was located on the Nikolai Tower from before 1880 to after 1908. Its location was changed to the “Silo storehouse, Frihavn” before 1911. The two lo-

Figure 12: Copenhagen Nikolai Tower (Klaus Hülse Collection).

cations are shown in Figures 12 and 13. Time balls at both Copenhagen locations were described as “wicker balls” with a diameter of 1.5m and a drop height of 4.5m. Figure 14 suggests that they were more massive than early time balls at the Cape of Good Hope, for example, which used traditional wickerwork construction to reduce cost and weight (Kinns, 2021b).

5.1.4 Denmark: Elsinore

The wicker time ball at Helsingör (Elsinore) was at the “entrance to harbour”, but its diameter and drop height were not stated in the 1880 list.

It was dropped “from the mast on the Quarantine and Pilot House on the south harbour mole” and had a large drop of 12m, according to the lists between 1898 and 1908. The ball diameter was given as 1.5m with a reduced drop height of 3m between 1911 and 1939. The stated latitude and longitude were the same throughout. Figure 15 shows the second installation on a building that had a large wind direction indicator on one wall.

5.1.5 Sweden

Sweden had time balls at Göteborg (Gothenburg), Karlskrona, Malmö and Stockholm, but only the Malmö time ball remained in 1939 and all had been withdrawn by 1947. They varied in colour with time and between locations. Time balls at Göteborg and Stockholm

Figure 13: Copenhagen Frihavn (Klaus Hülse Collection).

were listed in 1880. Those at Karlskrona and Malmö were included in the 1898 list. All were dropped at 1 pm Swedish mean time (noon GMT).

The time ball at Gothenburg had a diameter of 1.2m and a drop height of 2.6m. It was at the Navigation School and was dropped on Tuesdays, Thursdays and Saturdays only. It is shown in Figure 16. It was listed from 1880 to 1934 with the same details.

The time ball at Stockholm was also at the Navigation School there and was dropped daily. It had a diameter of 0.9m and a drop height of 2.4m. It was painted red in 1880 and 1898, but the colour had changed to black with a horizontal white band in the 1904 and 1908 lists. Figure 17 shows the time ball with the second colour scheme. The time ball in lists from 1911 until 1934 had an increased diameter of 1.5m,

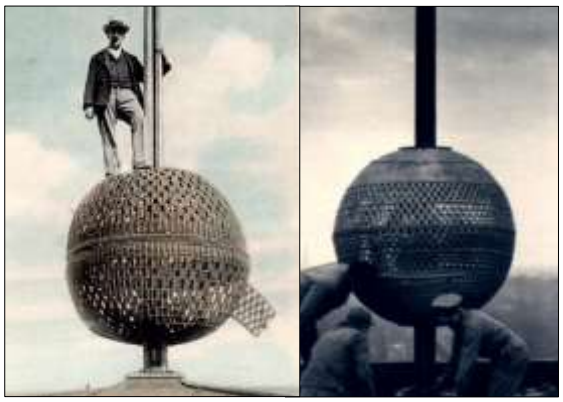


Figure 14: Copenhagen time balls (Klaus Hülse Collection).

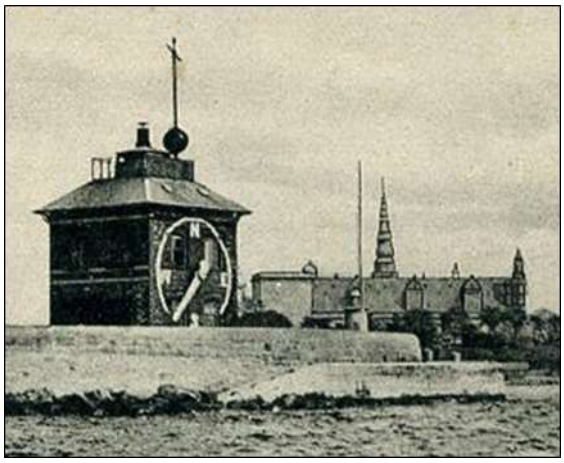


Figure 15: Elsinore time balls (Klaus Hülse Collection).

a larger drop height of 3.3m and an increased elevation. The same time ball latitude and longitude was specified throughout. Figure 18 shows the later arrangement.

The Karlskrona time ball was located on a “tower in the Dockyard”. It had a diameter of

Figure 16: Gotherburg time balls (Klaus Hülse Collection).

Figure 17 (left): Stockholm's first time ball (Klaus Hülse Collection).
Figure 18 (right): Stockholm's second time ball (Klaus Hülse Collection).

0.9m and a drop height of 3m. It was dropped on Fridays only "by wire from Stockholm Observatory". It was listed as black in 1898 and 1904 and brown from 1908 until 1934.

The Malmö time ball at the Navigation School was black with a diameter of 1.2m and a drop height that changed from 3.9m in 1898 to 3m in 1908. It was dropped daily. There were small changes in coordinates and elevation that indicated it had also been moved to a different location, still at the Navigation School. Unlike the other time balls in Sweden, it was still listed in 1939.

5.1.6 Norway

Norway used a variety of time signals, including balls, drums and lights but not guns. They were located at Bergen, Carl Johansvaern (now Karljohanvsvern), Christiana (Oslo) and Trondheim. Time lights were still listed at Bergen and Oslo in 1947.

5.1.7 Norway: Bergen

The colour of the time ball at Bergen changed over the years. Its colour was not stated in 1880, but it was listed as having red and white stripes in 1898, 1904 and 1908 and then as dark red in lists from 1911 to 1928. It was listed as a hollow iron ball with a diameter of 0.6m and drop height of 3.7m until 1908. Its location was given as the NE corner of the Observatory. The diameter of the dark red ball was unstated but it had a smaller drop height of 1.8m. The ball was dropped on Wednesdays and Saturdays only at noon local time in 1880 and later at noon Mid-European time (11 am GMT). It was replaced by a time light in 1929.

5.1.8 Norway: Carl Johansvaern

A time light was introduced in 1919 at Carl Johansvaern, then the home of the Royal Norwegian Navy. It ceased operation when a time light was introduced at Bergen in 1929. The Bergen light was illuminated five minutes before extinction at noon.

5.1.9 Norway: Christiana (Oslo)

Admiralty lists initially specified Christiana (often given as Kristiana in Norway) as the time ball location. Officially, the city name was changed to Oslo on 1 January 1925, but "Oslo (Christiana)" was listed as the location until the early 1930s.

Christiana had a time ball in 1880 with a diameter of 0.8m and a drop height of 4.5m on the roof of the Observatory. This was replaced by a drum which was listed from 1898 until at least 1939. The drum diameter was given as 3 feet 8 inches (1.05m) up to 1911, but later as 5 feet (1.5m), still with a drop height of 4.5m. The ball and the drum were both black and white and were dropped on Wednesdays and Saturdays only at noon. Lists after 1922 included the comment "Discontinued (1923)" when a time light had been introduced. The fact that it was still listed after 1923 suggests that it was retained as a reserve signal in case of light failure.

A time light was erected on a mast at the nearby Navigation School in 1922 and operated in parallel with the drum. The signal was made every 4 hours, starting at 4 am. The light was switched on about five minutes before extinction at the signal time which was stated to have an accuracy of 0.2 second. The Oslo light was still extant in 1947 when the drum signal was no longer listed.

An additional time ball was listed in 1911 but appears to have had a short life. It was located on the "Tower of Glass warehouse in

the market place", shown in Figure 19. The ball was made of gilded metal with a diameter of 0.7m and a drop height of 2.4m. It was dropped electrically from the Observatory every day at 1 pm (noon GMT), except Sundays and holidays. It was no longer listed in 1915.

5.1.10 Norway: Trondheim

Trondheim (Trondhjem) had a cylindrical canvas drum signal on the roof of the Observatory in 1880, with a diameter of 1.5m and a drop height of 3.3m. It was painted black and white and was hoisted 15 minutes before the signal at noon local time. The drop time had been changed to noon Mid-European time (11 am GMT) by 1898. Its location was 63° 25′ 48″ N, 10° 22′ 5″ E. The 1898 list onwards included the comment "The Observatory is not readily visible". The drum was replaced by a time ball from 1914 until 1928. This time ball was black with a white cross and was located on "Flagstaff north of custom house" at 63° 26′ 27″ N, 10° 24′ 30″ E.

5.2 Signals in Germany and Danzig

5.2.1 Development of German Time Balls

The development of German time signals as an integrated system followed a request for information about British time balls from the Consul General of the German Empire in London that was forwarded to Astronomer Royal George Airy at Greenwich:

> I have received a communication from the Foreign Department of Berlin notifying that it is the intention of the Imperial Government to erect Time-balls at certain places hereafter to be decided upon, similar to those in use in this country at Greenwich, Liverpool, and Portsmouth, and I am directed to ask that the Board of Trade will be pleased to furnish me for the use of the Imperial Government with copies of plans at the places before mentioned. (Wilkes, 1873).

This was followed by exchanges concerning the costs of copying plans, which led to a decision that only the plans for Deal need be sent. Details about the capital cost and running costs of the Deal installation were also provided, apparently to the satisfaction of the German government (Malcolm, 1873). This correspondence suggests strongly that the Deal arrangement, using operation by electric telegraph from a remote observatory, was a key reference for development of time balls in Germany. Most had a diameter of 1.5m and a drop height of 3m, as at Deal. Later, Count Münster, the German Ambassador, provided comprehensive notes on the German time balls which had then been implemented (Münster, 1877). Details seen by the author were for Bremerhaven, Cuxhaven, Hamburg, Kiel and Neufahrwasse.

Time balls in Germany were erected from 1875. All were operated using electric telegraph signals. Many were positioned on concrete towers that were constructed specifically for the time ball but others used previously erected buildings.

5.2.2 Germany: Cuxhaven

The development of German time ball arrangements is attributed to Hugo Lentz, Leiter der Cuxhavener Wasserbauinspektion, who received a patent for his design. The first implementation was at Cuxhaven, which was operational in October 1875 (The time ball column, 2022).

Figure 19: Christiana Glass Market time ball (Klaus Hülse Collection).

Figure 20 shows the time ball at Cuxhaven and its time light replacement on the same tower in 1929. The ball was always described in Admiralty lists as black with a diameter of 5 feet, but the photograph suggests that the ball was not spherical and used open framework construction, at least for part of its existence. The list entry for 1932 states that the signal was from "an electric light over a ball-shaped beacon" which can be seen in the photograph.

5.2.3 Germany: Bremerhaven

The following information for Bremerhaven illustrates the level of detail that was provided in

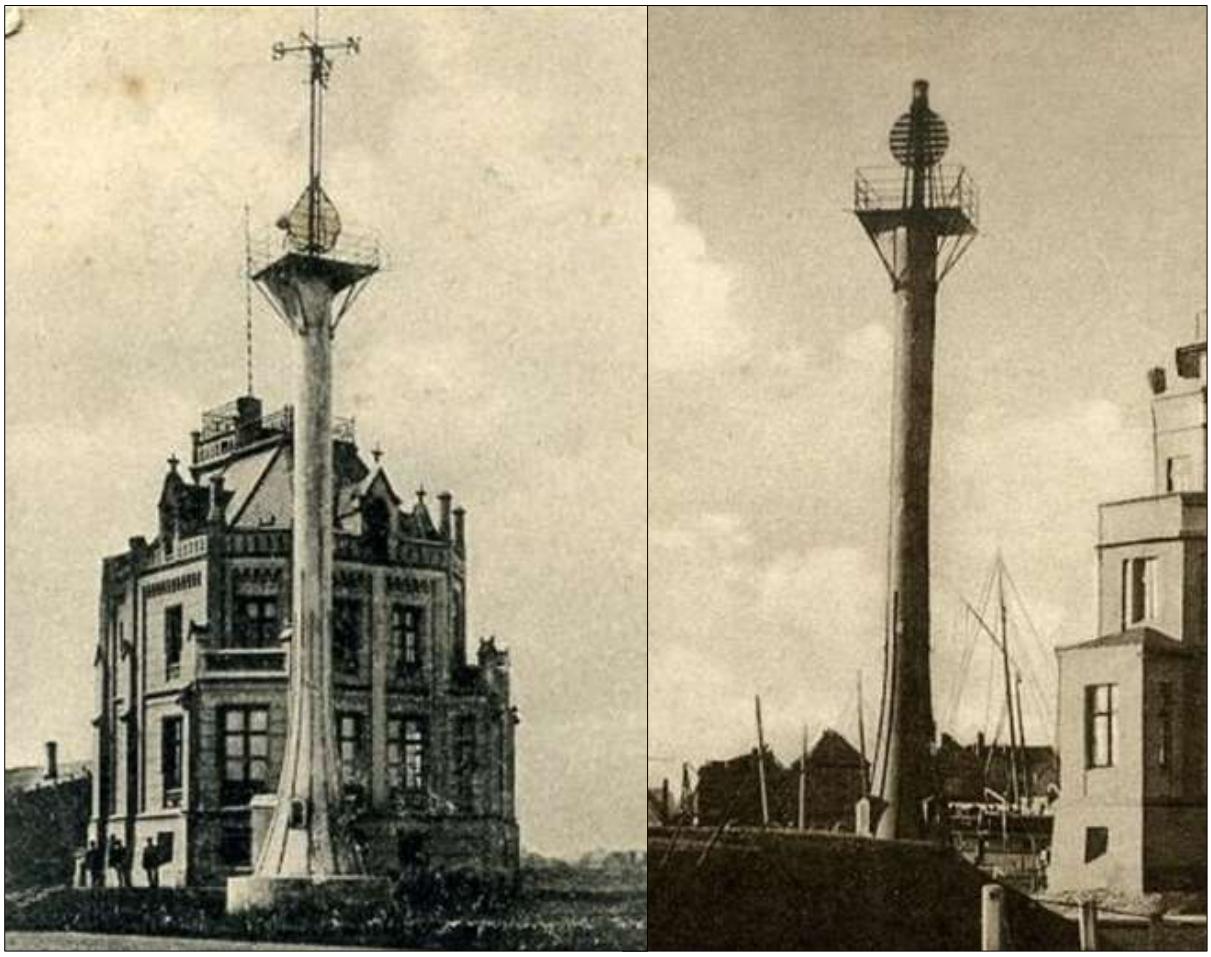


Figure 20: Cuxhaven time ball and time light (Klaus Hülse Collection).

1877 (Münster, 1877). The latitude and longitude of the time ball were 53° 33′ N, 8° 34′ E from Greenwich. It was located "137 metres Easterly from the lighthouse". The Bremerhaven time ball tower was very similar to the design for Cuxhaven. The ball was dropped twice each day, at noon Bremerhaven Time and noon Greenwich Time. The two drops were separated by 34 minutes, 16.5 seconds. Additional details are transcribed below.

> Ball 1.5 metres diameter, black, at full height 39.28 metres above high water, 36.93 metres above ground. Descends 3 metres. 10^{m} before, to half height: 3^{m} before, to whole height. If the fall not correct, then within 3^{m} a red ball 0.4 metres is raised on one of the wirecords, for 5^{m}, then a placard. If no descent, the red ball will be raised to half height and remain till the ball is dropped. If things are wrong, the red ball is kept at half height.

Two drops, at noon GMT and noon local mean time, were also specified for Cuxhaven and Neufahrwasse (see later) in 1877. However, there was a single drop at Kiel at Observatory noon and a single drop at Hamburg, where it was at noon GMT.

5.2.4 Germany: Other Locations

By 1880, time balls had been added at Wilhelmshaven and Swinemunde. All were stated to have diameters of 5ft (1.5m). Only one drop time was specified for each location in 1880. There was, however, an error in the 1880 Admiralty list, which gave the drop heights as 5 feet (rather than 10 feet) at all locations except Kiel, where the drop height was unstated. The drop was then at noon local time, except at Hamburg where it was at noon GMT. The 1898 list gave the drop height as 10ft at all locations except Kiel, where it was 11ft (3.3m) and Neufahrwasse, where it was only 7ft (2.1m). The 1898 list showed that the German time balls were then dropped twice, at 11am and noon GMT, except at Hamburg where the drop was at noon only. The same signals were extant in 1908.

By 1915, time balls had also been introduced at Bremen, Kiel (Wik), Emden and Stettin, giving a total of 11 German time balls. Figure 21 shows the time ball arrangement at Bremen which used an existing building rather than a purpose-built column. A similar arrange-

ment was used at Hamburg, as shown in Figure 22. Two large pendulum clocks were also listed for Hamburg and were still in use in 1947.

A time gun was used at Kiel and subsequently by a training ship at Mürwik Naval Academy.

5.2.5 Gdańsk Time Balls

Neufahrwasse was a district of Gdańsk (in Germany before World War I, then Danzig from 1920 to 1939 and now in Poland). The first time ball had been erected on the "Pilot's Watch-house" in 1876. A new arrangement was erect-

Figure 21: Bremen time ball (Klaus Hülse Collection).

Figure 22: Hamburg time ball (Kinns Collection).

Figure 22: Gdansk lighthouse and time ball (Kinns Collection).

ed in 1894 on the "Principal lighthouse" and the stated drop height was changed from 1.5m (1880 list) to 2.1m (1898 list). Both were stated to have diameters of 1.5m. The second time ball was dropped twice daily, at 11 am and noon GMT, corresponding to noon and 1 pm Mid-European time, as at other locations in Germany. Figure 23 shows the lighthouse in 1894 (The time ball on Gdańsk Nowy Port Lighthouse, 2022).

The history of the Gdańsk time balls and the construction of a modern working replica in 2010 has been described by Szychliński (2010). The history is also available online (The time ball, 2022). The new ball has the same open steel framework as the original with a diameter and weight of 1.6m and 76kg. The diameter, derived from original drawings, appears to have been slightly larger than the 1.5m stated by the Admiralty.

5.2.6 Germany and Danzig: Time Lights

Time lights had been introduced by 1915 at Emden and at two locations in Hamburg. The first Hamburg light was mentioned as a supplementary signal in the 1908 list, with a second signal mentioned in the 1911 list. They were subsequently given the same status as the time ball. These continued operation until at least 1939 and were operated in parallel with time balls for many years. Another time light was introduced at Gdańsk in 1927, replacing the time ball there. Additional time lights were introduced at Bremen, Bremerhaven, Cuxhaven, Stettin and Swinemunde in 1929, where they also replaced time balls. Finally, another time light was introduced at Gdynia in 1934. It was still operating in 1947. In 1934, there were ten listed time lights in Germany and Danzig.

5.3 Signals in Russia, Finland and Latvia

Russian signals ranged from the Baltic and Black Sea to the Arctic port of Archangel and to Vladivostok, on the Sea of Japan. These signals are shown in Table 4, together with those for Finland and Latvia which were part of Russia for much of the period from 1880 to 1947. Remarkably, five time balls, five guns and two lights were still listed for Russia, Finland and Latvia in 1947. In the early years, noon at Pulkowa Observatory was the signal time at several locations. This was the observatory, near St. Petersburg, that featured in 1845 and 1846 exchanges of chronometers to determine its longitude to high accuracy (Howse, 1997: 117).

5.3.1 Russia: Baltic

A time ball at Kronstadt was included in the 1880

list. The ball was made of wickerwork with a diameter of 3 feet (0.9m) and drop height of 9.5m. It was located on the "Mast of the Submarine Telegraph Office" and was dropped at noon, Kronstadt mean time. A time gun at Kronstadt was added in the 1911 list, fired from "the wall of the Commercial harbour", also at noon. The listed time ball diameter had changed to 5 feet (1.5m) in 1919, without change to other parameters, and then remained the same. The signal time had changed to noon Standard time, 2 hours ahead of GMT, by 1926. It had changed again by 1938, to be 3 hours ahead of GMT.

The time gun at St Petersburg was included in the 1880 list. St Petersburg was renamed Petrograd in 1914 and then Leningrad from 1924 to 1991, before reverting to the original name. Curiously, the Admiralty list entry was still for Petrograd in 1932. The St Petersburg gun at "Fort Peter and Paul" was initially fired at noon (Pulkowa) mean time. A time ball on "Western side of Nevaki gate" was added in 1923 and dropped at noon, which had changed from Pulkowa time to 2 hours ahead of GMT by 1926. Unlike Kronstadt, the time zone remained the same thereafter.

5.3.2 Russia: Black Sea

A black time ball at Nikolaev (Nicolaev) Observatory was listed in 1880. It had a small diameter of 0.6m and a drop height of 3m and was dropped at noon. The same ball was listed in 1898, together with a time gun that was also fired at noon. Both were still extant in 1947, although noon had been changed to 2 hours ahead of GMT by 1926.

By 1904, there was also a black time ball at Odessa. It had a diameter of 1.2m and was dropped by hand at local noon. It was located on "Mast on the office of the Russian Steam Navigation Company". It was still extant in 1934, when it was dropped at noon, then 2 hours ahead of GMT.

Two balls at Sevastopol were listed in 1908. One with an unstated colour was on a "Mast near Commander-in-Chief's house. The other, painted black, was on "Tower of the Observatory on Cape Paulovski". Initially, both were dropped at noon, Pulkowa Observatory mean time. Only the Observatory time ball was listed in 1926. It was then dropped at noon, 2 hours ahead of GMT as at other Black Sea locations, accompanied by firing of a time gun which had been introduced in 1924. The time ball was replaced by a light in 1930, which was illuminated 5 minutes before noon and flashed during the last minute before extinction. The light was still extant in 1947, but the time gun was no longer listed in 1938.

A time gun at Theodosia (Feodosiya) was introduced in 1926 and was still extant in 1947. If was fired at noon on Thursdays only.

5.3.3 Russia: Archangel

A black time ball was introduced at the far northern port of Archangel in 1922. It was on the "Mast of Naval depot" and was dropped at noon, 2 hours ahead of GMT. A time light was introduced in 1934 as the primary signal located on "Turret of Ubekoserer building". It was initiated 5 minutes before noon with a code preparatory light signal for 30 seconds, followed by a fixed light for 30 seconds, repeated until one minute before the signal. The white light was then illuminated for 45 seconds before being flashed three times before extinction as the noon time signal. A black time ball was specified as the signal should the light be out of order. The same signals were specified in 1947.

5.3.4 Russia: Vladivostok

By 1898, a time ball and gun had been introduced at Vladivostok. The ball was dropped from a mast on the Harbour Board office and a gun in front of the office was fired at noon local time, 8h 47m 33s ahead of GMT. The same times were given in 1911, with a note that the signals were unreliable in 1909. By 1919, it was listed as being on a mast at the Observatory. Its elevation had changed from 50m to 27m above the sea. Unusually for Russia, the second Vladivostok time ball was painted red. The gun had also been relocated to a platform below the mast. The ball had a diameter of 1.05m and was dropped automatically at noon. The time was the same as before. By 1927, the signals were still at noon Standard time, changed to be 9 hours ahead of GMT.

5.3.5 Finland

Finland had been part of Russia up to 1917, when it declared independence. Independence was recognised by Russia at the end of that year and by most other countries after the end of World War I. The Admiralty list for 1919, prepared in 1918, still showed Finnish ports as being in Russia.

By 1898 there were time balls at Helsingfors (now Helsinki), Abo and Uleaborg as well as a gun to complement the Helsingfors time ball. The black time ball at Helsingfors was on the "Central tower of Astronomical Observatory". It had a diameter of 1.05m and was dropped at noon Observatory mean time, when the gun on Sketadden Island was fired. By 1908, an "explosive signal" was fired from the Observ-

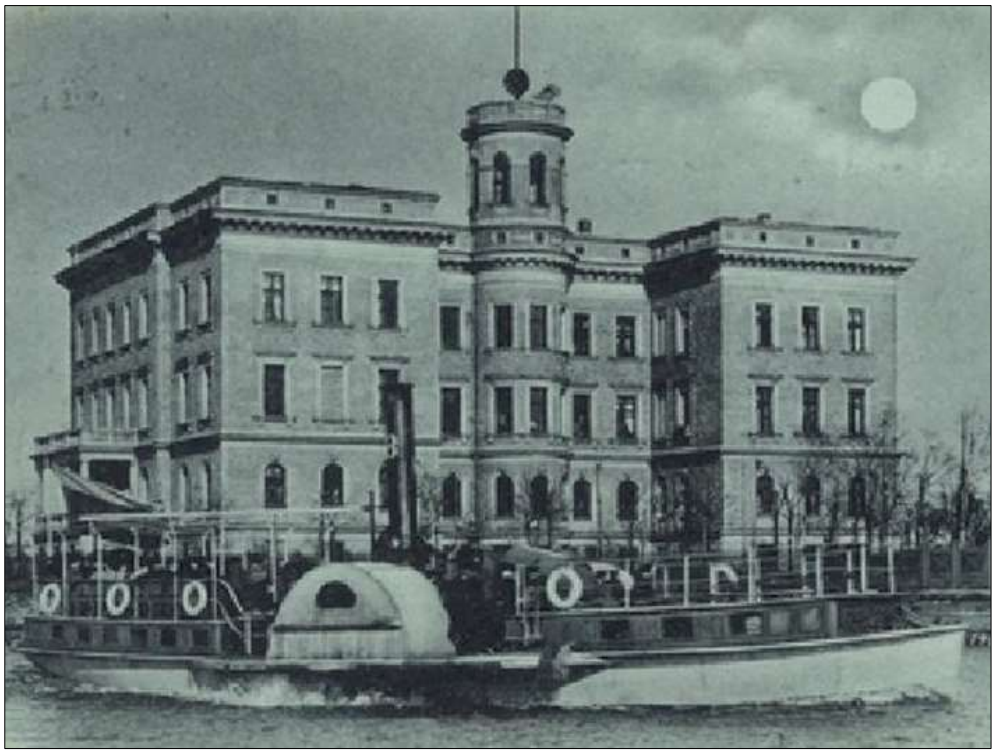


Figure 23: Riga time ball on the Sailors' Home (Klaus Hülse Collection).

atory in place of the gun. The explosive signal was no longer listed in 1926. The ball was then dropped at noon, Standard time, 2 hours ahead of GMT.

The black time ball at Abo had a large diameter of 1.8m and was located at the "Navigating School". The signal was made on Mondays only at noon, later 2 hours ahead of GMT. The signal was still listed in 1939.

The black time ball at Uleaborg had a diameter of 1.05m. Also at the "Navigating School", it was dropped at noon on Mondays only. It was no longer listed in 1926.

5.3.6 Latvia

Latvia declared independence from Russia at the end of World War I, which was lost again during World War II and in the period up to 1991. The Latvian ports of Riga and Libau were listed as being in Russia up to 1919.

A time ball at Riga was listed between 1898 and 1919. The black time ball at Riga was located on a mast at the Sailors' Home. It is shown in Figure 23. It had a diameter of 1.5m and a drop height of 4.5m. In 1898 it was dropped at 1 pm local mean time. In 1908, it was dropped at 1 pm Pulkowa Observatory mean time, 2h 1m 18s ahead of GMT and 24m 57s behind local mean time. Clocks in Riga were set to Pulkowa Observatory time, which was Standard time in 1919. The same drop time was listed in 1919. The signal was discontinued in 1921.

Time lights at Riga were introduced in 1927 and were still listed in 1947. The Admiralty list for 1934 indicated that there were 8 lamps located on a chimney near the Sailors' Home. A proportion of them were illuminated for about I minute before extinction as the signal every "full hour" of GMT.

Libau was also shown as Port Emperor Alexander III in Admiralty lists. A time ball and gun at Libau were listed in 1915 and 1919. They had been introduced in 1913. The time ball was on the "Flagstaff of Marine telegraph station". The gun was fired when the ball dropped at noon, Standard time, rather than 1 pm as at Riga. The signals were discontinued in 1921.

6 SIGNALS IN FRANCE, SOUTHERN EUROPE AND THE MEDITERRANEAN ISLANDS

The signals for France are considered with those in southern Europe and the Mediterranean islands in Tables 5 to 7. Their locations are shown in Map 5.

6.1 Signals in France

French time signals were located on the English Channel, Atlantic and Mediterranean coasts. Signals in the 1880 Admiralty list were a rotating

Table 5: Signals in France, Spain, Gibraltar and Portugal.

Country	Location	1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
France	Brest	Flag										
			(black)	(black)	(black)	balloon	balloon	balloon	balloon			
	Cherbourg	Disc	Disc	Disc	Disc	Disc	Disc	Disc	Disc			
	Dunkerque			TB	TB	TB	TB	TB				
	Fouras	TB	balloon	balloon	balloon	TB	TB	TB				
	Ile d'Aix								(black)	TB	TB	
	Lorient	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	
	Rochefort	TB	balloon	balloon	balloon	TB	TB	TB				
	Toulon	TB	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(b&w)
Spain	Cadiz	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)
	Vigo				(black)	(black)	(black)	(black)				
Gibraltar				TB	TB	TB	TB	TB	TB	TB		
Portugal	Lisbon Obs.	TB										
	Lisbon NS		(black)	(black)	(black)	(black)						
	Lisbon NR						Light	Light	Light	Light	Light	
	Lisbon wharf						Light	Light	Light	Light	Light	
Signal type totals		1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Time ball, including collapsible		6	7	9	10	10	9	9	6	5	4	2
Gun, including powder flash		0	0	0	0	0	0	0	0	0	0	0
Lights		0	0	0	0	0	2	2	2	2	2	0
Other: disc, drum, flag, etc.		2	1	1	1	1	1	1	1	0	0	0

Table 6: Signals in Italy and Sicily.

Country	Location	1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Italy (including former Austria)	Ancona					TB	TB	TB	TB	TB	TB	
						Gun	Gun	Gun	Gun	Gun	Gun	
	Brindisi					TB	TB	TB	TB			
	Genoa	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	
					(black)							
						Light	Light	Light	Light	Light	Light	
	Naples			TB	TB	TB	TB	TB				
				Gun	Gun							
	Spezia		Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	
	Taranto Ars.				Cones	Cones	Cones	Cones	Cones	Cones		
	Taranto Fort				Cones	Cones	Cones	Cones	Cones	Cones		
	Taranto		Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun		
				TB						Light		
	Trieste	(black)	(black)	(black)	(black)	(black)	(black)	(black)				
		Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	
									Light	Light	Light	
	Venice				red							
	Venice SG					Light	Light	Light	Light	Light	Light	
	Venice NS					Light	Light	Light	Light	Light	Light	
Sicily	Catania			(black)	(black)	(black)	(black)	(black)	(black)	(black)		(black)
				Gun	Gun	Gun	Gun	Gun	Gun	Gun		
	Messina			Disc								
						TB	TB	TB	TB	TB	TB	
				Gun		Gun	Gun	Gun	Gun	Gun	Gun	
Signal type totals		1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Time ball, including collapsible		1	1	4	5	6	6	6	4	3	2	1
Gun, including powder flash		2	4	7	6	7	7	7	7	7	5	0
Lights		0	0	0	0	3	3	3	4	5	4	0
Other: disc, drum, flag, etc.		0	0	1	2	2	2	2	2	2	0	0

Table 7: Signals in the Eastern Adriatic, Greece and Malta.

Country	Location	1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Croatia (including former Austria)	Fiume	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	
		Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	
	Lussin Piccolo		Discs	(black)	(black)	(black)	(black)	(black)	(black)			
	Pola	(black)	(black)	(black)								
					Shutter	Shutter	Shutter	Shutter				
		Gun	Gun	Gun	Gun	Gun	Gun	Gun				
	Sibenik (Sibenico)					Gun	Gun	Gun	Gun	Gun	Gun	
										Flag		
Albania	Durazzo											Gun
Greece	Piraeus							(black)	(black)	(black)	(black)	(black)
								Gun	Gun	Gun	Gun	Gun
	Salonika								Gun	Gun	Gun	
Malta	Valetta PT	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)		
	Valetta CH		(red)	(red)								
	Valetta				Gun	Gun	Gun	Gun				
Signal type totals		1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Time ball, including collapsible		2	4	5	3	3	3	4	4	3	2	1
Gun, including powder flash		2	2	2	3	4	4	5	4	4	5	2
Lights		0	0	0	0	0	0	0	0	0	0	0
Other: disc, drum, flag, etc.		0	1	0	1	1	1	1	0	1	0	0

Map 5: Signals in the Mediterranean, surrounding countries and the Azores (map: Roger Kinns).

disc at Cherbourg, a flag at Brest and time balls at Lorient, Fouras, Rochefort and Toulon. These are believed to have been introduced in the 1870s.

6.1.1 Early Signals at Nice

Although not official signals, a time ball and a time gun were operated at Nice in the 1860s by Thomas Coventry, an English amateur astronomer. They were described in a letter by him to the *Horological Journal* with an attachment which suggested that the signals had been in use since 1861 (Coventry, 1865). He had "… established a time-ball on the roof of his hotel, where he has a small observatory …" and was supported by "… a retired artillery-man …" who fired a gun at a ruined castle when the ball was seen to drop at noon. The extract below indicates that the signals had been opposed

initially by French officials and that Coventry (1865) had to pay for the signals from his own resources throughout their lives. It also suggests that time guns were used in many seaside towns as approximate signals for domestic use.

> The advantage of this standard of time to a population that has hitherto been regulated by rough sundials is immense, and is at length, after a period of four years, duly appreciated. Much opposition was at first experienced at the introduction of mean time; and the discharge of a gun for non-military purposes was considered a great infringement of conservative principles. It was only on appeal to high authorities in Paris that this boon was conceded, and then only on condition that every expense connected with it should be defrayed by the owner of the time-ball, which has been cheerfully complied with. This is certainly the first introduction of anything of the kind in France, beyond a morning and evening gun in seaport towns, but it is only wonderful how so great a public benefit can be so generally neglected.

Coventry died in 1869 (Obituary, 1869). The Nice time service ceased when he no longer funded its operation, possibly some years before he died. The cannon at the "Fort de Mont Alban", high above the city, is believed to have operated from 1861 to 1866. Another cannon was operated by municipal authorities after 1875 (Découverte des horloges, 2022). There was no mention of the Nice time ball in that reference: those noted all appeared in Admiralty lists.

6.1.2 French Time Signals in Admiralty Lists

France used a wide range of time signal types, some of which were not used elsewhere. A conventional time ball at Brest was replaced by a balloon, a term used to describe a collapsible ball which could be expanded in preparation for the signal. Earlier time signals at Fouras and Rochefort, listed as balloons by the Admiralty, may have operated as conventional time balls. A disc which could be rotated about a horizontal axis was used at Cherbourg.

Before 1911, times were defined by Observatories in France, usually Paris. The times changed to GMT in March 1911, specified in France as Paris time retarded by 9 minutes 21 seconds (Howse, 1997: 151). Most signals in France were repeated two minutes after the first signal at 10 am throughout their lives. Time guns and time lights were not listed for chronometer rating in France between 1880 and 1947.

6.1.3 Brest

In 1880, a flag was used for the time signal at Brest. It was at the "Observatory of the Nautical Schools" and was hauled down at noon, Brest mean time. This had been replaced by a black ball with a diameter of 1.8m by 1898, dropped at 10 am and then again at 10.02 am, Paris mean time. It was still listed as being at the Observatory. The same details were listed in 1911. The signal changed again to a black "balloon" in that year, with a 1.8m diameter, apparently at the same location as the earlier time ball. It was expanded 5 minutes before collapse as the signal at 10 am GMT (Standard time at Brest), then expanded again and collapsed at 10.02 am GMT. The unusual arrangement is shown in Figure 24. It appears to

Figure 24: Brest time balloon (Klaus Hülse Collection).

have consisted of a set of interconnected rings, rather like a Chinese lantern. The likely procedure was that a halyard would expand the framework. Release of the halyard would collapse the ball.

6.1.4 Cherbourg

Admiralty list entries for Cherbourg specified a disc signal with a diameter of 0.9m from 1880 to 1928 at the "Marine Observatory, Vigie des Onglet, Quay Napoleon". It was removed from the 1929 list. Figure 25 shows how it was located. The mast to the right of the steps has

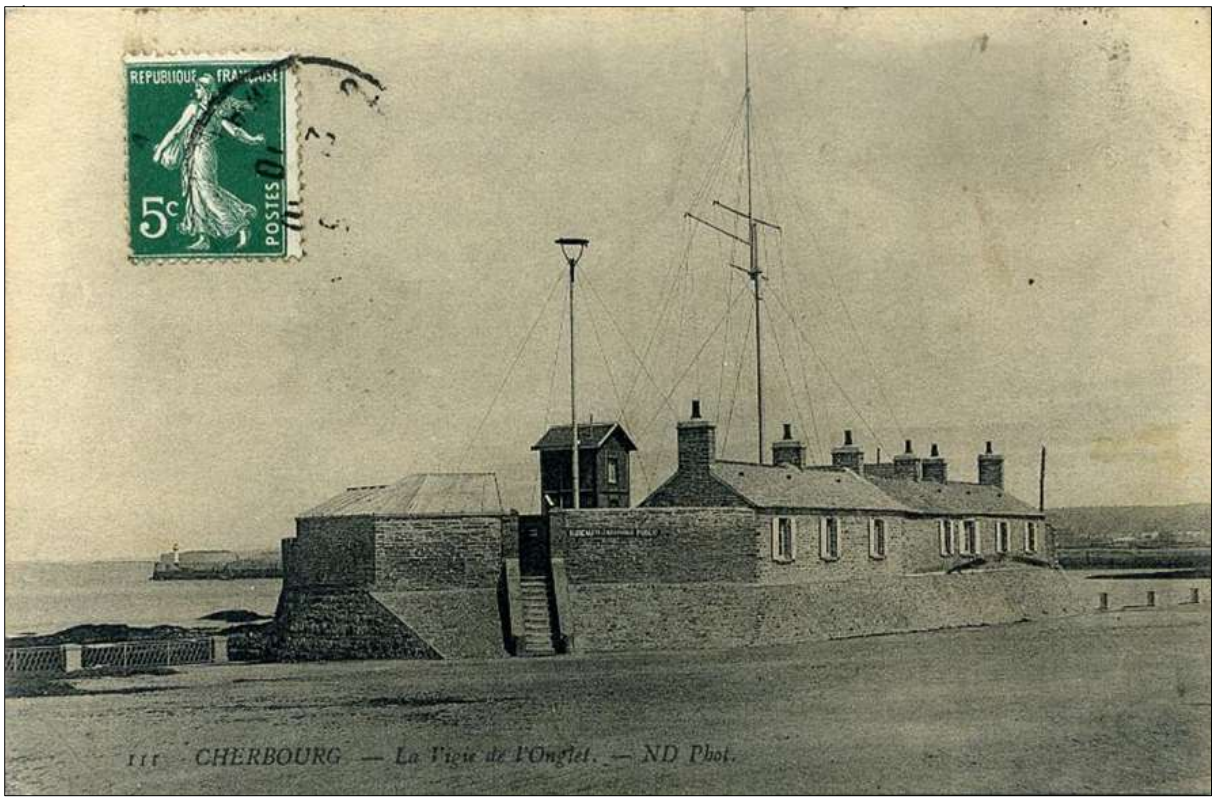


Figure 25: Cherbourg time disc (Klaus Hülse Collection).

an inverted 'U' support for the time disc, whose horizontal axis is supported at the tips of the 'U'. The disc was rotated to the vertical position 5 minutes before the signal. Its return to the horizontal signified the exact time. When not in use, the disc was set at 45°. In 1880, the signal was at noon only, Paris mean time. In 1898 and later lists, the signal was at 10 am, repeated at 10.02 am.

Figure 26: Dunkerque time signal (Klaus Hülse Collection).

6.1.5 Dunkerque

The Dunkerque time ball first appeared in the 1904 list and had been removed by 1927. It was on Lengenaer Tower and had a diameter of 0.9m and drop height of 3m. The signal was at 10 am, repeated at 10.02 am, Paris mean time, changed to GMT in 1911. The arrangement in Figure 26 suggests that the "ball" may have been a double cone.

6.1.6 Fouras, Rochefort and Île d'Aix

The time balls at Fouras (Basque Roads) and on the St. Louis Tower at Rochefort were included in the 1880 list. They were dropped then at the same time, 2 minutes 50.4 seconds behind GMT noon (close to local noon at both places) repeated 2 minutes later. Both time balls had been listed as "balloons" in the 1898 list, dropped at 10 am and 10.02 am Paris mean time. The times later changed to GMT. The associated descriptions are confusing, because they refer to balls with drop heights of 13m and 11m. They were again listed as balls from 1915 onwards with the same drop heights. This suggests that collapsible and rigid balls were interchangeable at Fouras and Rochefort and that dropping of the ball was the signal. At Brest, the signal was ball collapse. The Fouras time ball was replaced by a time ball at Île d'Aix in 1924, which was still listed in 1939. This was dropped at 10 am and 10.02 am throughout its

life. The nearby Rochefort time ball was not listed after 1927.

6.1.7 Lorient

A time ball at Lorient (L'Orient) was listed from 1880 until 1939. Initially, it was dropped at noon, L'Orient mean time. Up to at least 1908 it was located on a "Mast at the harbour tower" and had a diameter of 0.9m. It was then 16.5m above ground with a drop height of 13.5m and was dropped at 10 am and 10.02 am Paris mean time. From 1911 onwards, its location was given as "peak of harbour tower mast", 43m above ground with a drop height of 6m. Its elevation had been increased substantially, but its drop height was much smaller than before. The ball was dropped at 10 am and 10.02 am GMT. A replica working time ball is now in place on the tower at Lorient (Prévost, 2020).

6.1.8 Toulon

The time ball at the Mediterranean port of Toulon was located on "Signal Staff at the Naval Observatory". It had a small diameter and drop height of 0.6m and 1.8m and was dropped initially at 11 am and 11.02 am Toulon mean time. This had been changed to 10 am and 10.02 am Paris mean time in the 1898 list, with a further change to 10 am and 10 am GMT in 1911. It was still extant in 1947. The time ball is shown in Figure 27.

6.2 Signals in Spain, Gibraltar and Portugal

6.2.1 Cadiz and Vigo

Only two signals were listed for Spain between 1880 and 1947. These were time balls at Cadiz and Vigo. The time ball at Cadiz had been erected before 1880 and was still in operation at the San Fernando Observatory in 1947. The black ball had a diameter and drop height of 1.5m and 3m respectively, like most of the German time balls and the time balls at Edinburgh and Deal, but its supplier has not yet been identified. The black ball at Vigo was at the Meteorological Observatory and had a smalller diameter of 0.9m. It was listed in 1911 but withdrawn before 1927.

6.2.2 Gibraltar

The 1.8m diameter time ball at Gibraltar was dropped from a yard arm at the Naval Signal Station high on Windmill Hill, with a large drop height of 18m. The listed time ball had been erected in 1903 and initially dropped at noon GMT (1904 list). It was dropped every hour during daylight from 1905 until its withdrawal in the 1930s. There were no entries for Gibraltar in the 1880 and 1898 lists. The stated dimensions are not consistent with an engraving of a small ball at the signal station in Gibraltar, which was probably used for some other purpose at an earlier date.

6.2.3 Lisbon

All the listed time signals in Portugal were at Lisbon. A time ball on the flagstaff of the Marine Observatory was listed in 1880. It was replaced by a time ball at the Naval School which was erected during the 1880s and listed until 1916. It was then withdrawn and replaced by time

Figure 27: Toulon time ball (Klaus Hülse Collection).

lights at two other locations in Lisbon. These were at the National Ropery and the Custom House Wharf. Each signal was "made from a lantern mounted on piles, and with three faces, 5 feet high and 6½ feet wide; in the middle of each face an horizontal line of light". The signal was made every two hours from 8 am to 8 pm GMT and the lamps were respectively 35m and 30m above ground level (1919 to 1939 lists).

6.3 Signals in the Mediterranean and Adriatic

The signal at Toulon in southern France has been considered previously.

6.3.1 Italy

Time signals were distributed around the coast of Italy including Trieste which had been in Austria before the First World War. A time ball and gun at Trieste were listed in 1880, together with a gun at Genoa. Several unusual signals are described in detail with a brief description of other Italian signals. Time in Italy, including Sicily, was based on GMT from 1893 (Howse, 1997: 148). Usual practice was to provide a noon signal, but some time lights were extinguished as the signal at 12.05 pm.

6.3.2 Genoa

The time gun at Genoa was at Fort Castellaccio, on a hill northeast of the port. It was a precision signal. By 1880, a preparatory flag was hoisted on the Hydrographic Office 5 minutes before the gun was fired. It was hauled down 30 seconds before the gun was fired electrically from the Office at noon Genoa mean time. The same procedure was used in 1898 but the gun was then fired at noon, Mid-European time, one hour ahead of GMT. A black time ball at Genoa was included in the 1908 and 1911 Admiralty lists. The apparatus there is known to have used the Devonport principle (Lewis, 1910). It was at the “Semaphore of S. Beningo” and was dropped three times daily, at 10 am, noon and 3 pm. The gun was fired at noon only. The time ball was not included in the 1915 or later lists, but the gun was still listed in 1939.

Electric lights at Genoa were introduced in 1914 and replaced the time ball at San Beningo. The lights were switched on 5 minutes before extinction as the signal at 10.05 am, 12.05 pm and 3.05 pm. The same lights were listed from 1932 to 1939 as at the “Semaphore at Cape Faro”, apparently 7 seconds of arc (about 200m) further south than before.

6.3.3 Trieste

The Trieste time ball was included in the 1880 list. It had a diameter of 0.9m with a drop height of 7m. It was located on the NW side of the lighthouse and was dropped at noon, Trieste mean time. A gun was also fired at noon. The same arrangements were listed in 1898, except that noon had changed to Mid-European time. The ball was at the same location in 1908, but the drop height had been reduced to 4m.

Electric time lights at Trieste had been introduced by 1926 and replaced the time ball. They were located on a “Framework iron column on top of barracks at end of Fratelli Bandiera mole” and switched on 5 minutes before extinction at 12.05 pm. The time gun continued to be fired at noon but was noted as unreliable from 1926 to 1939.

6.3.4 Taranto

The first signal at Taranto was a time gun at St. Angelo Castle, which had been introduced by 1898 and fired at noon. A time ball located on a signal staff at the entrance to the Arsenal was also listed in 1904 and 1908 and dropped at noon. It was no longer listed in 1911 when the signal was made using two black cones at two locations: at the entrance to the Arsenal and at Fort St. Angelo. They were dropped electrically at noon.

A red time light at Taranto was added in 1933 and also included in the 1934 list. It was at “Extremity of arm extending from signal mast at Fort St. Angelo semaphore station”. It was switched on 3 minutes before extinction at noon. The Taranto signals had been withdrawn by 1938.

6.3.5 Venice

A red time ball at Patriarcale Observatory in Venice was included in the 1908 and 1911 lists and dropped at noon. It was discontinued in favour of time lights at two locations by 1915. These were on the “Eastern turret of San Georgio” and at the “Naval Station, highest part of Sylos Factory”. They were switched on at noon and extinguished as the signal at 12.05 pm.

6.3.6 Other Locations in Italy

A time ball at Naples was listed between 1904 and 1922, accompanied initially by a time gun that was not listed in 1915 onwards. The ball was on a flagstaff on Maschio Angioino. The gun was on the SE bastion of St. Elmo Castle.

A time ball and gun were used at Ancona from 1913. The ball was located at the “Semaphore on Mt. Cappuccini”. They were still listed in 1939.

A time ball at Brindisi was introduced in 1914 and listed until 1928, but there was no time gun there. It was on the eastern mast of the wireless telegraph station.

Spezia used a gun on a “Bastion at root of Lagora mole”, fired at noon. It was listed in 1898 and was still extant in 1939.

6.3.7 Sicily

Listed time signals in Sicily were at Catania and Messina, with first entries in 1904.

In 1904, Messina used a black and white disc signal, accompanied by a gun. A time ball had been introduced by 1908. The ball was chequered red and white and was located on the tower of the Observatory. Neither signal was listed in 1911. Another time ball at Messina

was operational in 1912 and a gun at Fort Gonzanga was again in use. The second ball with an unstated colour was located at the northeast end of Fort San Salvadore. The time ball and gun were still listed in 1939.

Catania used a black time ball accompanied by time gun which were still listed in 1934, but not in 1939. The ball was located on the roof of the Benedictine convent. A new time ball had been re-established at the Astronomical Observatory by 1947.

6.3.8 Eastern Adriatic

The eastern shore of the Adriatic had been part of the Austro-Hungarian Empire (listed as Austria) and then of Italy after the First World War. Many locations are now in Croatia.

There was a black time ball and gun at Fiume in 1880 which were still listed in 1939. Initially, the black time ball was located on a staff at the inner end of the breakwater. By 1908, it had been relocated to "An iron framework on the top of a low square tower" near the western end of the Maria Teresa mole.

There was a black time ball at Pola (Pula) in 1880, located on the SW bastion of the Harbour Castle which was changed to a six feet square shutter signal in 1910, on the roof of the "Imperial Hydrographic office". The signal was made at 11 am when required. It was made at noon daily, accompanied by firing of a gun at the Harbour Castle. Its extraordinary operating procedure is described below:

> The signal at 23h 00m 00s, Standard time is made only when required by vessels of the Austrian Imperial Navy.
>
> The shutter is closed at 22h 45m, and opened by hand, in such a manner that the sky can be seen through the frame of the apparatus, at 23h 00m 00s, Standard time. Ten or more signals will follow the first at intervals of one minute, the shutter remaining open for 10 seconds after each signal. When the series is completed, the shutter will be rapidly opened and closed a number of times.
>
> The signal at Noon, Standard time, is made daily.
>
> The shutter is closed at 5 minutes before the signal, and opened, by hand, at Noon, Standard time. (1919 list).

The Pola signals had been discontinued before 1927.

The signal at Lussin Piccolo was also unusual. It was listed in 1898 as two black circular discs which were rotated from the vertical to the horizontal position as the signal, so appears to have been similar to signals used at various locations in the Netherlands. It was later described as a time ball at the same location, "formed by two black vertical discs" (1922 list). The ball was dropped electrically from the Imperial Nautical School.

Either a single time gun or a time gun volley at Fort Santa Anna in Sibenik (Sebenico) was listed between 1915 and 1939. It was fired at noon. An accompanying flag signal was listed for the first time in 1934. It was raised 5 minutes before noon and hauled down when the gun was fired but had been withdrawn by 1937.

6.3.9 Albania

A late introduction was a noon gun at "Torrioni di Durazzo" in Albania. It was introduced in 1939, listed in 1940 and was still extant in 1947.

6.3.10 Greece

A black time ball and gun at Piraeus were introduced in 1920 and were still listed in 1947. The ball was located on a mast on the lighthouse at the south side of the harbour entrance. It was dropped at 8 am and noon, 2 hours ahead of GMT. Another time gun on a white tower at Salonika had been introduced in 1926. It was still listed in 1939, but not in 1947.

6.3.11 Malta

A black time ball at the Auberge de Castille in Valetta was listed from 1880 to 1934. It had a small diameter of 0.9m but a large drop height of 6.5m at an elevation of over 100m. The drop height had been further increased to 15m in 1934. A red time ball at the Custom House was also listed in 1898 and 1904. It had been operational before the end of 1881 and had originally been painted black (Mediterranean-Malta, 1881). It had been withdrawn by 1908. Its diameter, drop height and elevation were 1.4m, 4.2m and 18m. A time gun fired from the Upper Barracca Saluting Battery was listed from 1911 to 1922, but not in earlier lists despite the known existence of a time gun at Valetta before 1880.

7 SIGNALS IN AFRICA, THE MIDDLE EAST AND MAURITIUS

Table 8 shows listed signals in Africa, the Middle East and Mauritius from 1880 to 1947. Their locations are highlighted in Maps 6 to 8.

Visual time signals in South Africa, from the earliest signals for Table Bay in the 1820s, have been described previously with extensive references to original sources and many drawings and photographs (Kinns, 2021b). Those in West Africa and Mauritius have also been described in detail (Kinns 2020b; 2021c). This section includes additional information from

Table 8: Signals in the Middle East, Africa and Mauritius.

Area	Location	1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Middle East	Aden: Ras Marbut				Flag	Flag	Flag	Flag	Flag	Flag	Flag	
					Gun	Gun	Gun	Gun	Gun	Gun	Gun	
	Aden: Shamshan				Flag	Flag	Flag	Flag	Flag	Flag	Flag	
	Beirut					TB	TB	TB	TB	TB	TB	TB
North Africa	Egypt: Alexandria		(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)
			Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun
	Egypt: Port Said		(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)
	Eritrea: Massawa									TB	TB	
East Africa	Djibouti							Gun	Gun	Gun	Gun	
	Mozambique: Laurenzo Marques			TB								
					Light	Light	Light	Light	Light	Light	Light	Light
	Mozambique Beira									Light		
	:Dar es Salaam					Gun						
South Africa	Cape Town Docks	TB	TB	TB	TB	TB	TB	TB	TB	TB		
	Cape Town	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun
	Durban		TB	TB	TB	TB	TB	TB	TB			
	East London		TB	TB	TB	TB	TB	TB	TB	TB	TB	
	Port Alfred	TB	TB	TB								
	Port Elizabeth	Disc	(black)	(black)	(black)	(black)	Disc	Disc	Disc			
	Simon's Bay	Disc	Disc									
				(white)	(b, w)	(b, w)	(b, w)	(b, w)	(b, w)			
West Africa	Angola: St Paul de Loanda		TB	TB	TB	TB	TB	TB	TB	TB	TB	
									Light	Light	Light	Light
									Gun			
	Ghana (was Gold Coast): Accra		Flag	Flag	Flag	Flag	Flag					
			Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	
	Ghana: Takoradi									TB		
										Gun		
	Senegal: Dakar					(black)	(black)	(black)	(black)	(black)	(black)	(black)
Mauritius	Port Louis SM	(black)	(black)	(black)	(black)	(black)	TB	TB	TB	TB	TB	
	Port Louis PO				(white)	(white)	(white)	(white)	(white)	(white)	(white)	(white)
Signal type totals		1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Time ball, including collapsible		3	9	11	10	11	11	11	11	11	9	5
Gun, including powder flash		1	3	3	4	5	4	5	6	6	5	2
Lights		0	0	0	1	1	1	1	2	3	2	2
Other: disc, drum, flag, etc.		2	2	1	3	3	4	3	3	2	2	0

Admiralty lists that had not been seen previously by the author and extends the scope to include North Africa, the Middle East and East Africa.

7.1 Signals in the Middle East

7.1.1 Aden

Aden (now Yemen) used flag signals at two locations: Ras Marbut and Shamshan. Both were listed from 1911 to 1939, but neither was regarded as sufficiently accurate for rating chronometers. A gun was also fired when the flag was dipped at Ras Marbut. An accurate telegraph signal was received daily at the Eastern Telegraph Company's office at Ras Marbut and chronometers could be compared there.

7.1.2 Beirut

Beirut, initially in Syria and now the capital of an independent Lebanon, had a time ball in 1914 that was still listed in 1947. It was located on the main building of the American College.

7.2 Signals in North Africa

7.2.1 Egypt

Egypt had time balls at Alexandria and Port Said. Both were painted black, established before 1898 and still listed in 1947. They were operated electrically from the observatory in Cairo about 200km from either time ball. The Alexandria and Port Said time balls, as well as an inland time ball at Cairo, used the Devonport principle (Lewis, 1910).

In 1898, official time throughout Egypt was mean time at the Great Pyramid of Gizeh, 2h 4m 30.5s ahead of GMT. This had been changed by 1908 to Egyptian Standard time, two hours ahead of GMT.

Map 6: Signals in NE Africa and Aden (map: Roger Kinns).

Map 7: Signals in NW Africa, the Cape Verde Islands and St Helena (map: Roger Kinns).

7.2.2 Egypt: Alexandria

The Alexandria time ball was at the Signal Station, Fort Napoleon (Caffarelli). It is shown in Figure 28. It was 4.5m above ground and 35m above the sea. The ball was dropped twice daily throughout its life. The drop times were initially at noon, Gizeh mean time and noon Alexandria mean time, which was 1h 59m 43s ahead of GMT, giving an interval of 4m 57.5s between drop times. These times had been changed by 1908 to 10 am GMT and 11h 0m 27s GMT, so the interval was then 1h 0m 27s. These drop times were retained subsequently. A time gun at the fort was fired at the time of the first drop only.

Map 8: Signals in Southern Africa and Mauritius (map: Roger Kinns).

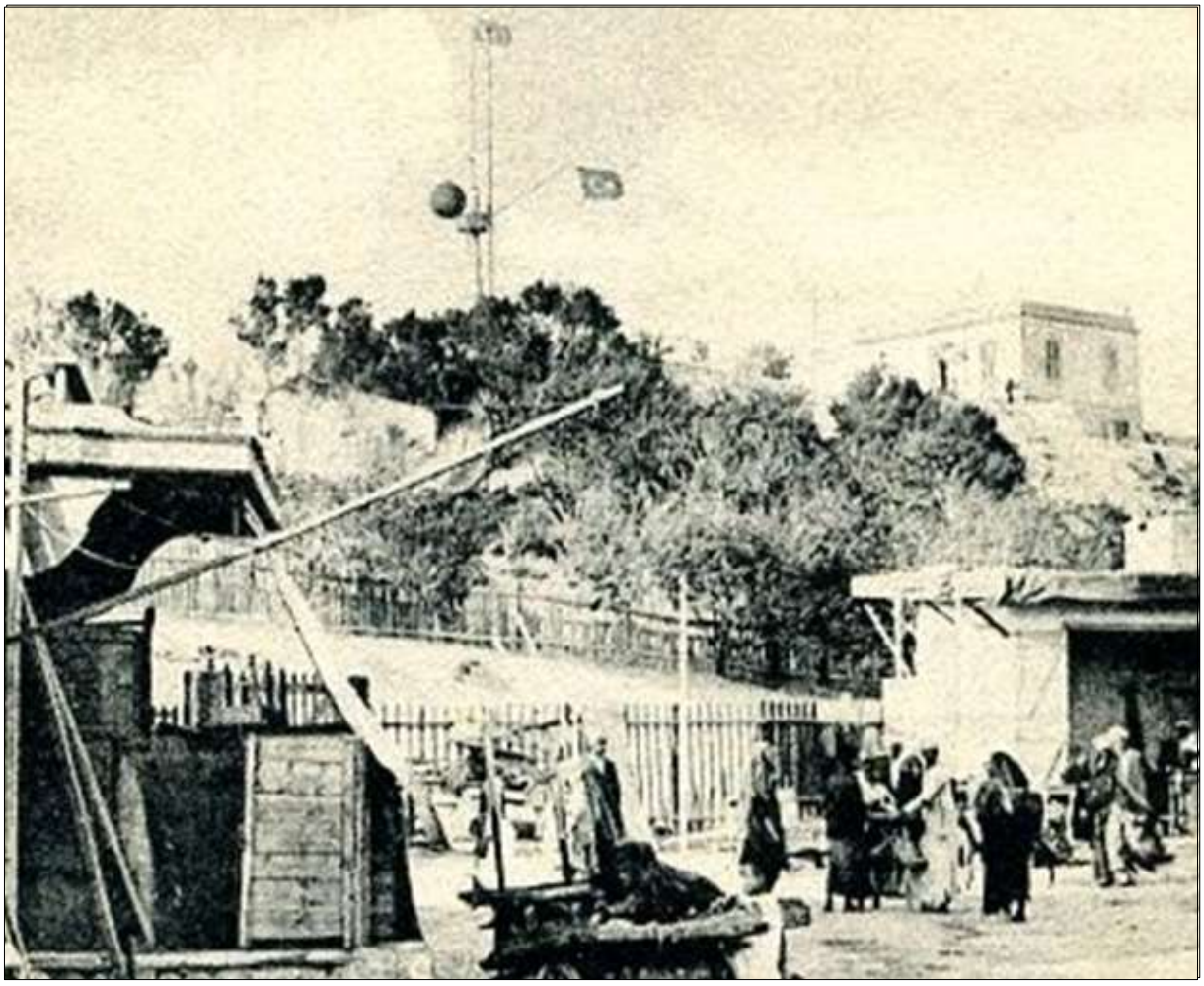


Figure 28: Alexandria time ball (Klaus Hülse Collection).

7.2.3 Egypt: Port Said

The Port Said time ball was on a lighthouse tower, giving an elevation of 60m above sea level near the Mediterranean entrance to the Suez Canal. The lighthouse was completed in 1869, shortly before the canal was opened. The time ball is not shown in an 1882 engraving (Lighthouse, 1882) and is likely to have been added in the 1890s, following introduction of the Devonport principle. The ball had a diameter of 4½ feet (1.35m) and a drop height of 3m, corresponding to 2.2 ball diameters. It was supported on an "Iron lattice work mast 30 feet high on top of high lighthouse" and was dropped three times each day from Cairo.

In 1898, the time ball at Port Said was dropped at 8 am, noon and 4 pm Port Said mean time, which was 2h 9m 15s ahead of GMT. By 1908, the drop times had been changed to 8 am, noon and 4 pm Standard time and remained the same thereafter. Figure 29 shows the time ball during its period of operation. Figure 30 shows details of the time ball arrangement after the apparatus had been decommissioned. The lattice mast can be seen clearly, but the apparent drop height has been reduced to about 1.6 ball diameters. The slotted mast would have allowed the ball to be pushed up using a rack and pinion mechanism, rather than raised using halyards.

Figure 29: Port Said time ball (Kinns Collection).

7.2.4 Eritrea

A time ball at Massawa on the Red Sea was established on the mast of the wireless station at Abd-el-Kadir in 1930 and was still listed in 1939.

7.3 Signals in West Africa

Listed signals in West Africa were sparsely distributed, from the most northerly at Dakar in Senegal, near to the Cape Verde Islands, to St Paul de Loanda in Angola. Other signals existed, but their accuracy is uncertain. A time ball at Takoni in Nigeria is known to have been regulated from Angola, but its characteristics have not been found and it appears to have had a short life (Kinns, 2021c).

7.3.1 Senegal: Dakar

Dakar is at the western end of the Cape Verde peninsula, with the Cape Verde Islands further west. It was the most northerly of the signals in Sub-Saharan Africa. Senegal had been a French colony, becoming independent in 1960.

Time signals at Dakar did not feature in early Admiralty lists, but there was a time ball there for a limited period before 1911. The following notice was published in 1911, indicating that an earlier time ball had been re-established:

> Referring to Notice to Mariners No. 19(966) of 1909, the French Government has given further notice that the time signal at Dakar,

Figure 30: Port Said time ball after decommissioning (copyright, Joel Carillet; reproduced with permission).

> west coast of Africa, has been reestablished.
>
> The signal consists of a black ball 3 feet in diameter dropped on a mast located at the southeastern angle of the Arsenal Grounds.
>
> It is hoisted 5 minutes before and dropped at 11h. 09m. 41.5s., Greenwich mean time, corresponding to 10h. 00m. 00s., Dakar mean time. The ball is immediately rehoisted and dropped again 2 minutes later.
>
> Should the signal fail a red flag is shown from the mast and the signal will be repeated 10 minutes after the first ball was dropped. (Notices, 1911: 315)

In the above notice, times appear to have been based on zero hours at midnight, not zero hours at noon as usually expected for time ball data before 1925.

The Dakar time ball was included in Admiralty lists from 1915 to 1947. It was described as being on "Tower of Captain of Port's Office on south-east angle of arsenal". The black ball continued to be dropped twice daily, at 10 am and 10.02 am, as at most French ports.

7.3.2 Gold Coast: Accra

A time ball at the Cape Coast Castle in the Gold Coast (now Ghana) was erected in July 1839 but may not have existed for long. A flag and gun signal at Accra were listed by 1898 but had changed location before 1915. The principal flag signal had been discontinued by 1922. The gun at Accra was described as a "maroon" located at the Post Office from 1919 onwards, with the qualification

> Greenwich time is received daily, Sundays excepted, at 10h 00m 00s from London by post office chronograph, but, being retransmitted though several stations, is not exact.

It would not have been a satisfactory signal for rating chronometers but was still listed in 1939.

7.3.3 Gold Coast: Takoradi

Takoradi, now joined with Sekondi in Ghana, is about 200 km WSW of Accra and was an important port. A time ball at Takoradi was introduced in 1930. Its characteristics are shown in the following entry for Takoradi:

> A time signal is made from the Prince of Wales Clock Tower. The time used is that of Greenwich meridian from January 1 to August 31 and that of 5° E. (0h. 20m. fast on Greenwich mean time) during the remainder of the year. Simultaneously with the dropping of the time ball a gun is fired from the harbor signal station. (Sailing Directions, 1932: 75).

The time ball was operated in conjunction with a time gun. Unusually, the local time was advanced by 20 minutes between 1 September and 31 December each year. The drop time was not stated in the notice, but was given as noon GMT, also noon Standard Time, for the period 1 January–1 September in the 1933 Admiralty list. It was discontinued before 1939.

7.3.4 Angola: St Paul de Loanda

Although there was no entry in the 1880 Admiralty list, the time ball at St Paul de Loanda was operational in 1879:

> A Time Ball is hoisted half-mast on the staff of the observatory tower at 0h. 50m. p.m.; close up at 0h. 55m.; and dropped at 1h. 0m. p.m. mean time, St. Paul de Loando (sic).
>
> *Note*. —It is reported that dependence cannot always be placed on the accuracy of this time ball. (Nautical Notices, 1879).

The 1898 Admiralty list indicated that times of the preparatory signals were 5 and 2 minutes before the time signal, which differed from those indicated in 1879, but were consistent with later notices (Africa Pilot, 1916: 396). A 1912 notice indicated that the time of the signal was changed from 1 pm local mean time to noon GMT on 1 January 1912 (Notices, 1912: 393). The times of the preparatory signals were again listed as 10 and 5 minutes before the signal from 1919 to 1939. Figure 31 shows the time ball in its lowered position above the Observatory tower. It was listed until 1939.

The time ball was complemented by a time light after 1924. The time light, but not the time ball, was still listed in 1947. It was stated to be accurate to 1.0 second. The light was positioned on the Observatory tower, switched on at 8:55 pm Standard Time (one hour behind GMT) and then switched off at 9 pm as the signal. A fixed red light indicated the position of the time signal.

7.4 Signals in South Africa

South Africa used an extraordinary range of time signals, including the first shuttered lamp in 1823, a flash pistol under observatory control in 1833, one of the earliest time balls in 1836 and a wide range of subsequent time ball types. A time gun was used at Cape Town from 1807. It was not then under observatory control but became a precision signal in 1865 when it was fired electrically. The history of the various signals has been described by Kinns (2021b), drawing particularly on work by Evans (1993).

7.4.1 Early Signals in South Africa

The following statement about early signals at the Cape of Good Hope was published by the

Figure 31: Loanda Observatory (Klaus Hülse Collection).

Editor of the *Nautical Magazine* in 1835 as an introduction to the time ball service at St Helena that started in January 1834 (Editorial, 1835: 658). It provoked a reaction from Robert Wauchope (1836), which led to acceptance of his claim to invention of land-based visual signals:

> The plan of communicating time by signal from observations, being coeval with the improvement of chronometers, is of recent date. The advantages of it are great to seamen, and it has been a matter of some surprise to us, that even within the few last years it has not been more generally adopted. We remember it to have been employed successfully by the Rev. Mr. Fallows, when he was astronomer at the Cape of Good Hope, about the year 1820. His plan was to eclipse a light at the moment of eight o'clock (mean time) by means of a shutter. The light was distinctly seen by the shipping in the roads, and the officers being on the look-out, were enabled to obtain a rate for the chronometers on board.

The article also mentioned rocket signals proposed by Captain Owen before going on to describe the St Helena arrangement. Wauchope's (1836) response did not contradict the statement about the shuttered lamp:

> I had pointed out the advantages to be derived from the plan for communicating time by means of telegraphs so far back as 1818, in my remark-book transmitted to the Admiralty when in command of the Eurydice, at that time on the Cape and St. Helena station. Sir Jahl. Brenton was then naval commissioner at the Cape, and an extract from a letter of his, dated 15th November, 1833, to Mrs. Wauchope, will, I think, establish my prior claim to the invention, before the Rev. Mr. Fallows, (who, it appears, was astronomer at the Cape in 1820,) or Captain William Owen, R.N.

This statement indicates that Wauchope had never met Fallows, who arrived at the Cape in 1821 and died in 1831.

The shuttered lamp was an important development. A key feature of the signal would have been the preparatory opening of a shutter to alert ships: closure, which made the lamp disappear, was the exact time signal. Fallows did not arrive at the Cape until August 1821. Its initial date of operation is likely to have been in 1823 (Bartky and Dick, 1981). Curiously, this lamp was not mentioned by Gill (1913), suggesting that early records at the Cape Observatory had been lost. Instead, Gill referred to an unsophisticated time ball during Fallows' tenure, which is probably a myth (Bartky and Dick, 1981; Warner, 1979).

A flash pistol and powder magazine for "visually signalling time" were purchased in January 1833 (Harding, 1971), and

> Early in 1833 Henderson started a new time service … a brass barrel percussion pistol for the making of night signals to vessels in Table Bay, for the regulation of their chron-

Figure 32: Table Bay time gun, 1993 (photograph: Willie Koorts).

> nometers … with this gun and a pocket chronometer, Henderson each night climbed onto the roof of the Observatory and fired a charge of black powder at an advertised time. … (Warner, 1979: 32).

7.4.2 Table Bay Gun

By 1807 a noon gun was fired from the Imhoff Battery on the seaward side of the Castle in Cape Town. It was one of the means by which ships in Table Bay "… could determine the error and rate of their chronometers." (Warner, 1979: 47). The accuracy of the gun signal is likely to have been modest in its early years of operation, as it was not controlled from an astronomical observatory. It would have had high precision from 1864 onwards, when it was fired electrically from the Observatory.

The history of the Cape time guns has been described by Bissett (1964). In February 1892, time signals at noon and 1 pm were discontinued in favour of a single signal at noon, GMT. The gun was moved from the Imhoff Battery to the Lion Battery on Signal Hill in August 1902. From midnight on 28 February 1903, the whole of South Africa adopted a time zone based on longitude 30° E, two hours ahead of Greenwich. The gun was then fired at noon, South African Standard Time. The noon gun is still operating and is a popular tourist attraction. Figure 32 shows the gun being fired for the first time after installation of new electrical connections.

7.4.3 Astronomers at the Cape Observatory

The Reverend Fearon Fallows (1788–1831) was appointed as the first Director of the Observatory by the British Board of Longitude in October 1820. He served at the Cape from August 1821 until his premature death in July 1831 but never received timely support from the Board or Admiralty for development of his staff and facilities. The Observatory buildings had been erected by the end of 1827 but the instruments were not fully operational until 1829. Thomas Henderson (1798–1844) was appointed to succeed Fallows in October 1831 and arrived at the Cape in April 1832. He resigned in May 1833, in protest at the conditions under which he had to operate. He returned to Edinburgh, where he became the first Astronomer Royal for Scotland.

Thomas Maclear (1794–1879) was appointed to succeed Henderson in July 1833 and arrived at the Cape in January 1834. During his long tenure, the Observatory was expanded with the erection of new buildings and additional instruments. From 1834 to 1838 Maclear worked closely with Sir John Herschel at the Cape. Many of their exchanges are recorded in *Herschel at the Cape* (Evans et al., 1969). Charles Piazzi Smyth (1819–1900), later to succeed Henderson as the second Astronomer Royal for Scotland, became Maclear's assistant in 1835 at the age of sixteen. Maclear presided over the introduction of the first time balls in South Africa.

Sir David Gill (1843–1914) was Director of the Cape Observatory from 1877 to 1906 (Obituary, 1914). Gill (1913) gives biographies of the Directors who preceded him.

7.4.4 The Cape Observatory Time Balls

An Observatory time ball was in operation from October 1836 (Bartky and Dick, 1981). The arrangement in 1852 was described by Maclear (1852), who reported that its location had not been changed since its erection in 1836. The

Figure 33: Cape Observatory time ball (from drawing by Herschel, 1837).

ball diameter was 1.5m, as at Greenwich, and dropped from a yard arm. The 1852 notice suggested that it would have to be moved because of new construction that interrupted its line of sight from Table Bay. Maclear concluded with observations concerning time ball reliability and achieved accuracy.

In the early years of operation of the 1836 apparatus, the ball had to be replaced on several occasions. This was noted by Charles Piazzi Smyth, when he was an assistant to Thomas Maclear, and influenced his choice of design for Edinburgh (Smyth, 1853a; 1853b). This is illustrated by the following remark:

> The author had several years' personal experience within 1837 and 1845 with this ball or balls, for several were made, and literally used up, so difficult was it found, with mere simple workmanship, to secure the perfect action, which Mr Field, of the firm of Maudslay and Field, had obtained by the adoption of a cylinder of compressed air to break the fall of the ball's descent. (Smyth, 1853b).

Figure 33 shows a detail from a camera lucida drawing that was made by Sir John Herschel in January 1837, not long after the time ball was first erected. The complete drawing is included in *Herschel at the Cape* (Evans et al., 1969: Plate 12).

A 'repeater' time ball was constructed on Lion's Rump in July 1853. This repeater ball was initially under manual control and dropped when the Observatory time ball was seen to fall.

Details of the time ball at Lion's Rump were issued on 13 December 1853 (Maclear, 1853). It was pointed out that observers should subtract one second from the time of ball release to give the exact time of 1 pm. Maclear (1863b) noted later that "… an order for a trigger to drop the lever arm ball on the Lion's Rump was given by the Colonial Government …" during 1861. A "lever arm bal" would be a possible description of the arrangement that was used at Port Elizabeth (see later).

The Observatory time ball was relocated north in May 1860 because it had become hidden by trees (Evans, 1993). It was replaced in 1863 with a new apparatus, which was described in a published notice (Maclear, 1863a). The ball was painted red with a black central band and had a diameter of 5½ feet (1.7m). The notice pointed out that the new apparatus was erected about 45m SW of the original. The apparatus was supplied by Sandys & Co. in London using a rack and pinion mechanism for hoisting the ball and an air spring to arrest its descent (Maclear, 1863b; 1863c). Its design was generally similar to that used at Edinburgh, Deal and Sydney. It was designed to give a drop height of 5.5m, which was unusually large for a rack and pinion hoisting arrangement and required strengthening of the mast to allow operation in a windy environment (Maclear, 1863b).

There is no known photograph of the installation described by Maclear, but the photograph of an Observatory time ball in Figure 34 suggests that there were significant further changes to the apparatus. The drop height is clearly much less than 5.5m and the ball slid down a mast that did not have the square section described by Maclear. The Observatory time balls were not included in Admiralty lists from 1880 onwards.

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7.4.5 Alfred Docks

The time ball at Alfred Docks was operated from the Cape Observatory and was the principal signal for Table Bay. The Observatory time

Figure 34: Cape Observatory time ball after 1863 (courtesy: Ian Glass).

balls were not mentioned in Admiralty lists and are presumed to have been withdrawn after the Docks time ball entered service. Its early history is obscure, but it is believed to have been erected in 1873 (Spencer Jones, 1993). The Docks time ball was included in the 1880 list. A mechanical system manufactured by Maudslay, Sons & Field for Siemens Brothers in 1873 was thought to be destined for the Cape (Sells, 1883). However, there is strong evidence that the single apparatus built by Maudslays for Siemens Brothers in 1873 was a replica of the 1855 apparatus for Sydney and was installed at Lyttelton (New Zealand) rather than at the Cape (Kinns, 2009; 2017; Kinns and Abell, 2009). There is no record of supply by Siemens to the Cape. No other details of the Docks arrangement before 1894 have been found.

Figure 35: Alfred Docks time ball after restoration (photograph: Michael Peel).

In 1894, a new time ball was "… erected in a conspicuous position near Resident Engineer's Office of the Cape Town Docks." (Evans, 1993). From 18 April 1895, return signals to the Observatory confirmed that the ball had commenced and finished its drop. The Docks time ball was dropped at noon, rather than 1 pm as at other locations in South Africa. Drawings of the 1894 installation show that the ball diameter and drop height were 1.5m and 3m and that the height of the centre of the ball in its raised position was 9m above ground (see Kinns, 2021b). It was then a single-storey building, with part of the time ball apparatus in a deep basement. The time ball elevation was increased by adding another storey in 1904.

It is difficult to make sense of Admiralty list entries for Table Bay in various respects. The Docks time ball height above water was listed as 16m up to 1919 and then 22m in 1922 and later, with no change in the 11m height above ground; they should change by the same amount if the tower height is changed. None appears to be correct. The drop height was recorded as 6 feet (1.8m) in all the Admiralty lists, which was incorrect from 1894 onwards; it may have been correct for the first time ball at the Docks listed in 1880.

The tower was declared a National Monument in 1982, but the time ball was then an immovable fibreglass replica. The Cape Town waterfront was redeveloped during the 1990s and it was decided to recreate the time ball that was withdrawn in 1934, using a replica of the original apparatus (Glass et al., 1997). Restoration started in 1997 under the direction of the late Gabriël Fagan (1925–2020), a renowned architect and conservation specialist. The original time ball apparatus had been lost, but the Department of Mechanical Engineering at the University of Cape Town built a working replica. The time ball could be dropped again at 1 pm under electrical control from the South African Astronomical Observatory. It is an iconic landmark, but the ball is now stationary.

Figure 35 shows the Docks time ball after its restoration to the 1934 condition. The height

Figure 36: Lever arm ball at Port Elizabeth (Klaus Hülse Collection).

of the centre of the raised time ball above ground is now about 14.5m, 5.5m higher than its 1894 elevation.

7.4.6 Simon's Bay

The Admiralty list entries referred to Simons bay and then Simon's Bay, rather than Simon's Town. A common spelling is now Simonstown. It is the location of the South African Navy's largest base.

The first time ball at Simon's Bay was erected in 1857. It was regulated using a portable transit telescope, until telegraph lines had been constructed between the Observatory and Simon's Bay. Electric operation was announced in *The Times* (Cape Town, 1861). The time ball had been replaced by a time disc before 1878, but the disc arrangement had become worn and failed frequently in 1896 and 1897. The disc was replaced by a time ball at the same location which became operational on 14 April 1898. The time ball was listed as being white in 1904, changed to black and white chequered in 1908 and later lists. The signal was delisted in 1932.

7.4.7 Port Elizabeth

Admiralty lists and other sources indicate changes between a disc and a ball at Port Elizabeth, but photographs suggest that either description may have been used for the same installation. The same latitude and longitude were specified throughout and there were no reported changes to its lighthouse location, during the period from 1880 to 1930. The signal had been withdrawn by 1931. It appears that a ball was located at the end of a lever arm which was pivoted about its centre. The upper end of the lever was connected to the operating apparatus, allowing the lever to be rotated to the horizontal position. The ball, or disc, could then rotate in a circular arc with an initial vertical drop. This arrangement was unique to Port Elizabeth and is shown in Figure 36 (see Kinns, 2021b).

The relative locations of time signals at Port Elizabeth, Port Alfred and East London are shown in Map 8. The Port Elizabeth signal was established first and remained in use longest of the three signals. It was followed by the Port Alfred signal and then the signal at East London.

7.4.8 Port Alfred

The time balls at Port Alfred and East London did not appear in the report for 1878 (Royal Observatory, 1878). The ball at Port Alfred

was, however, noted in the 1880 Admiralty list. The ball was dropped from a staff near the West Mole. It had an elevation of 8m above ground and a drop height of 5.5m. The same entry was included up to 1908. The signal was discontinued in 1911 (Notices, 1911a).

7.4.9 East London

The time ball at East London was dropped from an iron frame at high elevation. It was described as being on Signal Hill. The drop height was 4.5m. The apparatus would have been much simpler than those used at the Observatory in 1863 and at Alfred Docks after 1894.

The time ball at East London was still listed by the Admiralty in 1939 as controlled from the Cape Observatory, when other time balls had been withdrawn by 1934. From 1911 onwards it was pointed out that "The ball falls slowly, and is not to be relied on within one second. Not visible alongside the wharves." Its apparently extended period of operation is surprising, given the limited value of the signal.

7.4.10 Durban, Natal

In 1882, David Gill, Director of the Cape Observatory, asked the Government of Natal to establish an astronomical observatory at Durban in anticipation of the Transit of Venus on 6 December that year (Natal Observatory). A site for the observatory was chosen in the southwest corner of the Natal Botanic Gardens. Edmund Neville Nevill *aka* Edmund Neison (1849–1940) was appointed Government Astronomer of Natal and Director of the Observatory. Following the formation of the Union of South Africa in 1910 the post of Government Astronomer of Natal was abolished and the Observatory was closed in 1911.

It is believed that Nevill erected a time ball in 1883, controlled by Natal Observatory. It was relocated in 1904 and continued under control from Natal Observatory until 1911. The time ball service continued from 1911 under control from the Cape. It was removed from Admiralty lists after 1931. The time of the drop was 1 pm, Natal Standard time until 1 September 1912, when it was changed to noon, South Africa standard time. Both times were 2 hours ahead of GMT.

The first time ball at Durban was located "At 3 cables N.N.W. ½ W. from Sandy point, North side of Entrance to port." (Admiralty lists, 1898; 1904). The time ball had been relocated in 1904 and the new location was given as "On the Bluff 260 yards S. 83° W. from the Bluff lighthouse" (Admiralty lists 1908 *et seq*). Its latitude and longitude changed from 29° 52′ 30″ S., 31° 03′ 00″ E. to 29° 52′ 44″ S., 31° 03′ 42″ E.

7.5 Signals in East Africa

7.5.1 Djibouti

A time gun at the French colony of Djibouti was established in 1919 and was still listed in 1939. It was regulated by telegraph from the Paris Observatory.

7.5.2 Mozambique: Lorenzo Marques

A time ball had been in operation at the Lorenzo Marques Observatory before 1904 and was still listed in 1908, but not in 1911. The time signal changed to electric lights in 1909. This is thought to be the earliest use of electric time lights as principal time signals worldwide and one of the longest lived. It was still listed in 1947.

The unusual light signal remained the same throughout its life. A horizontal line array of 7 lights was illuminated within a black triangle whose corners were highlighted with additional green lights. The array was illuminated 5 minutes before each time signal at 3 hour intervals, giving 8 signals every day without intermediate flashes.

7.5.3 Mozambique: Beira

Another light signal was introduced at the port of Beira in 1931, further north and east than Lorenzo Marques. The simple time light at Beira was illuminated three minutes before extinction at 10 am and 9 pm local standard time, 2 hours ahead of GMT. It had been discontinued before 1947.

7.5.4 Dar es Salaam

A time gun was established in 1913 at Dar es Salaam, then in German East Africa. The colony became British in 1916 and was renamed Tanganyika, now part of Tanzania. The gun was still listed in 1917, but not in 1919 or later. Figure 37 shows the time gun in operation.

7.6 Signals in Mauritius

7.6.1 Shuttered Time Signal

The first service for rating chronometers at Port Louis, Mauritius started in April 1833, six months before the Greenwich time ball was operational (Lloyd, 1833). It was established by John Augustus Lloyd (1800–1854) who had been appointed Surveyor-General and Civil Engineer in 1831. He was an extraordinarily talented army officer who soon developed a well-equipped observatory and a time service (Kinns, 2020a; 2020b). He was widely respected in the scientific community for his earlier survey work in Panama and had presented papers to the Royal Society and the Royal Geographic Society. His reputation and friend-

Figure 37: Dar es Salaam time gun (Klaus Hülse Collection).

Figure 38 (left): Painting of proposed observatory by John Augustus Lloyd, 1832 (courtesy: UK Hydrographics Office).
Figure 39 (right): Painting of proposed time signal by John Augustus Lloyd, 1832 (courtesy: UK Hydrographics Office).

ship, but not the time signal, were noted by Charles Darwin (1836) when he visited Mauritius during the voyage of HMS *Beagle*. Lloyd departed Mauritius in 1849, leaving a legacy of engineering and astronomical achievements. He was later a Special Commissioner for the Great Exhibition (Supplement, 1851). He died of cholera in Constantinople, now Istanbul, on military service in 1854 (Obituary, 1855).

Lloyd's chosen arrangement, described in a paper communicated by Sir John Herschel, was unlike the design for Greenwich (Herschel, 1836). It used a stationary black 'sphere' on a white background behind a shutter whose complete closure, not the moment of release, signalled the exact time. Both the paper and the original notice (Lloyd, 1833) refer to a sphere, but this may have been a euphemism for a painted disc on a white background. Lloyd was a talented watercolourist and his set of paintings of the proposed observatory have survived in the archives of the UK Hydrographic Office (Lloyd, 1832). Two of these paintings are shown in Figures 38 and 39 . Whether the black disc was changed to a sphere in a room behind the shutter before announcement of the service is unclear, but the painted disc would have been a simple and effective solution.

One of the earliest daguerreotype cameras was used in Mauritius to photograph the observatory buildings. The available images are from the opposite side to the time ball or disc,

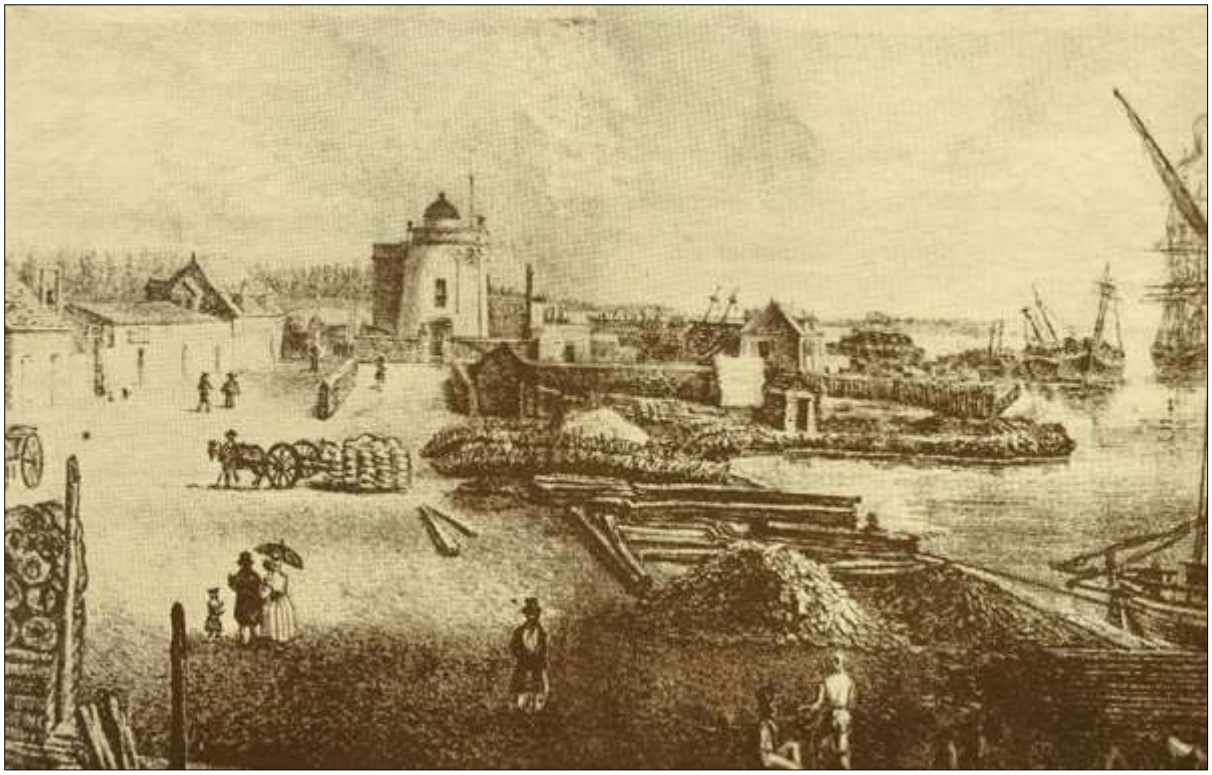


Figure 40: Lithograph showing Observatory in Port Louis by Dureau, 1840 (courtesy: Jacques Pougnet).

so do not provide any clarification of the time signal design. They show a large square building next to the observatory tower which was not included in the watercolours. Figure 40 shows an engraving that was made from an 1840 lithograph by Dureau. A notice concerning withdrawal of unpopular charges for chronometer calibration was published (Lloyd, 1836), but no further evidence of continued operation has been found. The harbour has been developed extensively since the Old Colonial Observatory was demolished, so its site is no longer on the waterfront.

There is photographic evidence that a conventional time ball had been erected on the roof of the old observatory, possibly for experimental purposes before the tower was demolished to facilitate harbour development. Mauritius almanacs were published from 1853 onwards, which included a report from the Observatory. There was no mention of a time ball service until 1866, although Airy (1861b) had been approached about a new signal before 1861.

7.6.2 Time Balls on Signal Mountain and at the Port Office

A new time ball was erected high on Signal Mountain in 1866. The time service appears to have deteriorated with only an intermittent flag signal for an extended period (Caleb Quotum, 1870). It was rejuvenated when the new Royal Alfred Observatory at Pamplemousses became operational in 1874. Lists of time signals from 1880 onwards include a black ball on Signal Mountain with a diameter of 1.8m and a drop height of 3.6m. The Signal Mountain time ball was hand operated after a hurricane in 1892 which wrecked the electric time ball apparatus. It ceased to be the principal signal in 1907.

A white ball with a diameter of only 1.2m and a larger drop height of 6m was introduced as the new principal signal near the Port Office in March 1907 after its erection in the previous year. It is shown in Figure 41. The 1908 Admiralty list was prepared before introduction of the new service but indicated that the Signal Mountain time signal had been changed to a pair of cones, whose moment of separation was the time signal (see Kinns, 2020b). It was described as “2 cones, bases together; upper cone white, lower cone black (diamtr. 6 feet).” No confirmation of this arrangement has been found in Mauritius: other announcements refer only to a ball.

The following extract from the 1913 *Almanac* described the official signals:

> The new time ball erected, in 1906, on the Port Tower at an elevation of 80 feet is dropped electrically by the Standard clock of the Royal Alfred Observatory at 1 p.m. 60th meridian time 4 hours East of Greenwich …
>
> Hourly signals are also sent to the Port Office and to Messrs. Guillemin & Co., Jew-

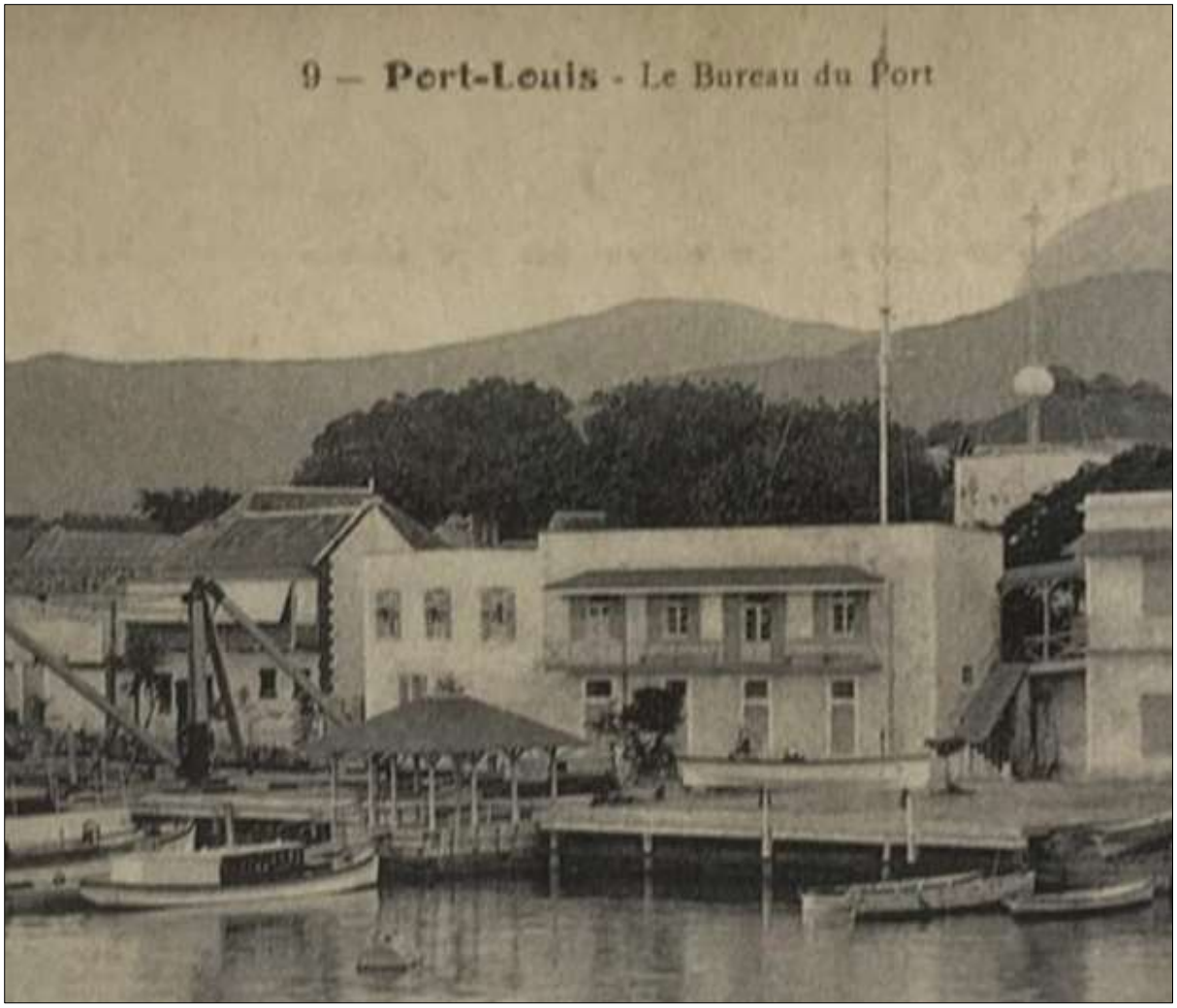


Figure 41: Port Louis Port Office time ball (courtesy: Jacques Pougnet)

ellers, Port Louis for the purpose of regulating Marine Chronometers.

Another signal was added in the 1915 *Almanac*: "… and the electric lights are lowered at 8 p.m. all over Port Louis, Beau Bassin, Rose Hill, 4 Bornes, Moka and St. Pierre." The practice of dimming lights, apparently unique to Mauritius, continued until at least 1930. It was never mentioned in Admiralty lists (Kinns, 2020b).

The performance of the Port Office time ball was reported in *Mauritius Almanacs*, after 1907. The time ball on Signal Mountain was no longer mentioned, but it continued to appear in Admiralty lists from 1911 as a repeater ball "Dropped, by hand, when the ball on the port tower is dropped." It appears that it was no longer the responsibility of the Observatory and was operated independently by staff at the Signal Station on top of Signal Mountain. Its latitude and longitude, which appear to have been stated correctly in 1880 and then incorrectly in some later editions, were not stated at all after 1911. It was finally withdrawn altogether in 1945, but the Port Office ball was still in use in 1947. It had been controlled using wireless signals since 1929, following cessation of astronomical observations at the Royal Alfred Observatory.

8 SIGNALS IN ASIA

The evolution of time signals in Asia is shown in Tables 9 to 12. Their locations are highlighted in Maps 9 and 10.

8.1 Signals in India and Ceylon

The history of time signals in the Indian subcontinent was reviewed in a recent paper which includes transcriptions and quotations from original sources (Kinns, 2020c). Signals from 1880 onwards are shown in Table 9. The earliest time balls in India were erected at Calcutta, Madras and Bombay.

8.1.1 Calcutta: Early Signals

The first time ball in Calcutta, now Kolkata was described in *Historical Records of the Survey of*

Table 9: Signals in the Indian Sub-Continent.

Area	Location	1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
India: Bombay (now Mumbai)	Castle: NE Bastion	TB	TB	TB	TB	TB	TB	TB	TB			
		Clock	Clock	Clock	Clock	Clock	Clock	Clock	Clock			
	P&V Docks		TB	TB	TB	TB	TB	TB	TB	TB	TB	
India: Calcutta (now Kolkata)	Fort William	TB	TB	TB	TB	TB	TB	TB	TB	TB	TB	TB
	Port Office		TB	TB	TB	TB	TB	TB	TB	TB	TB	TB
			Flag	Flag	Flag	Flag	Flag	Flag	Flag	Flag	Flag	Flag
	Kidderpore D			TB	TB	TB	TB	TB	TB	TB	TB	TB
India: Madras (now Chennai)	Port Office	Sema.	Sema.	Sema.	Sema.	Sema.						
	Harbour Office						(red)	(red)	(red)			
	Fort St George					Gun	Gun	Gun	Gun	Gun	Gun	Gun
Andaman Ils	Port Blair							TB	TB	TB	TB	TB
India (now Pakistan): Karachi	Merewether P		TB	TB								
	Manora Point			TB								
	Baba Island				TB	TB	TB	TB	TB	TB		
Ceylon (now Sri Lanka)	Colombo	TB										
			Sema.	Sema.	Sema.	Sema.						
							TB	TB	TB	TB	TB	
Signal type totals		1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Time ball, including collapsible		3	5	7	6	6	8	9	9	7	6	4
Gun, including powder flash		0	0	0	0	1	1	1	1	1	1	1
Lights		0	0	0	0	0	0	0	0	0	0	0
Other: disc, drum, flag, etc.		2	4	4	4	4	2	2	2	1	1	1

Map 9: Signals in India, Ceylon and Southeast Asia (map: Roger Kinns).

India. (Phillimore, 1958: 114–115). It started operation in January 1835 and is one of the earliest known time balls. The archived records relate to what is now known as the Great Trigonometrical Survey of India, led by Sir George Everest (1790–1866). Everest, after whom the mountain is named, was Surveyor General of India from 1830 to 1843. Everest saw time signals for mariners as a distraction from the main work of the survey. The following extract concerning Calcutta shows his reluctance to sanction the diversion of staff to time ball provision. It also shows that the primary time ball was at the Surveyor General's Office and that a repeater time ball was operated by the Army. "The Semaphore" was at Fort William, and

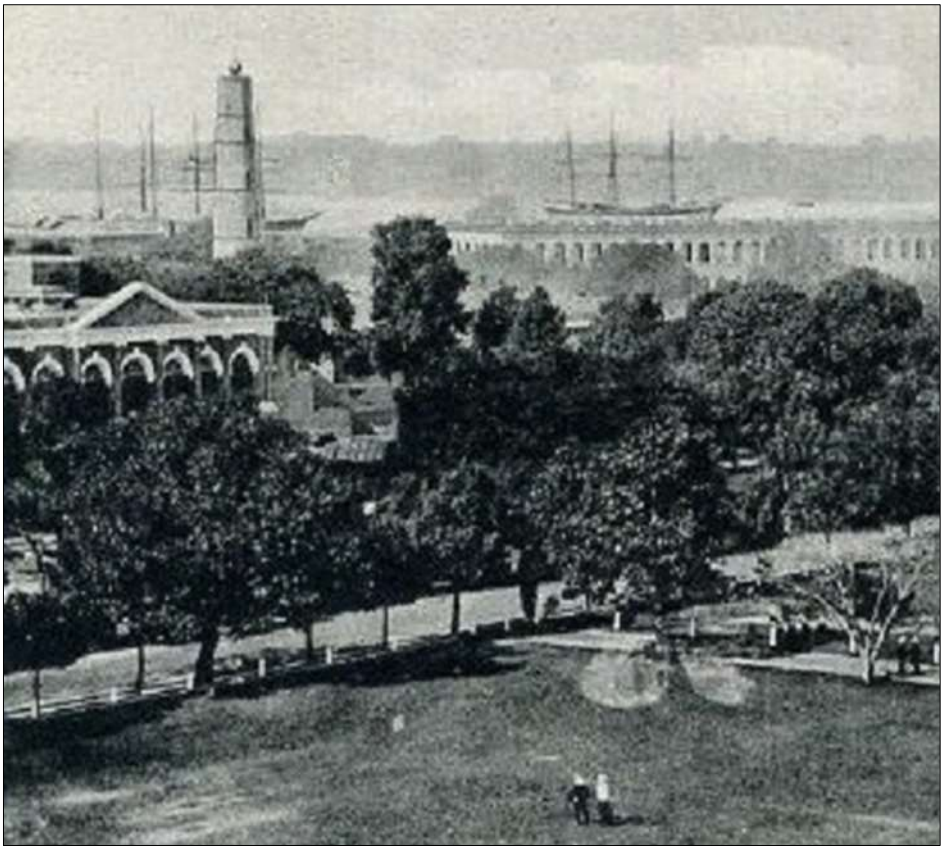


Figure 42: Calcutta time ball at Fort William (Klaus Hülse collection).

> … the signal for showing mean time commenced on the 28th January last [1835], and has been continued every day since (Sundays excepted). The signals are made by hoisting a black ball to the top of the staff on the office 5 minutes before noon, and as a preparatory signal to be followed up immediately at the Semaphore. Then at the exact mean noon, as indicated by the clock and chronometer, the ball is dropped down instantaneously, while the same is done at the Semaphore under the management of a non-commissioned officer … The service was interrupted from 16th July, owing to the move of the office to new quarters and the signals were not resumed until 10th May 1837 … The signals now proceeded regularly, even though Government refused any special allowance for the staff employed, or for the engagement of an extra assistant on Hindu holidays. In April 1838 De Penning's reference to the extra work thrown upon the computing office called down an indignant order from Everest to the effect that nothing whatever should interfere with the computations, and the signals were only allowed to continue on that understanding.

Another extract refers to occasional failures to drop the repeater time ball promptly in 1839. The extract below indicates that "The Semaphore" and "The Fort" are both references to Fort William and that a repeater time ball there started operation in 1835:

> From 1855 the signal was changed to 1 p.m. instead of noon, and in 1858 a new time ball was installed at Fort William operated from the Surveyor General's office by electricity. (Phillimore, 1958: 115).

A time ball at Calcutta had been noted in 1861 (Airy,1861a). The installation had suffered significant deterioration by 1862 (East India, 1863: 74). The braking arrangement appears to have used a piston in a wooden cylinder to provide an air spring. The use of wood suggests that it was designed and built in India and may have been part of the 1835 arrangement.

8.1.2 Calcutta: Signals after 1880

Another new time ball at Fort William was announced in 1880, using an electric apparatus that would also fire a gun (Electric time-ball for India, 1880). The apparatus was designed by Alfred Varley and supplied by Messrs. Siebe and Gorman. It was similar to that designed by Maudslays in the 1850s, using a rack and pinion hoisting arrangement and an air spring to control its descent. Part of the article was reproduced by Kinns (2020c). The gun was not mentioned in Admiralty lists. The tower is shown in Figure 42.

Figure 43: Bombay Castle time ball (Klaus Hülse Collection).

The Admiralty lists do not mention a time ball at the Surveyor-General's Office, which would have been invisible to mariners and was unnecessary when electrical connections were established. Another time ball at the Port Commissioner's Office was listed in 1880. It was accompanied by a flag that was used both as a first preparatory signal and as a listed signal. Another time ball had been installed at Kidderpore (Kidderpur) Docks by 1904. All three time balls and the flag were still listed in 1947.

8.1.3 Bombay: Colaba Observatory and the Castle

Samant and Samant (2016) noted that the first time ball at Bombay was erected at Colaba Observatory in 1840. It was moved subsequently to the "Bombay Castle Flag Tower" and continued until 1928 (Samant and Samant, 2016: 5).

The following notice was published in 1853:

> THE TIME-BALL at the Observatory having been taken down for the purpose of making a larger one, and refitting the gear, apparatus, &c. there will be no Ball dropped, or Time given to the shipping in harbour (except the flash of the evening Gunfire) till the alterations &c. have been completed. (The Time Ball, 1853).

The evening gun was not an accurate signal, often being in error by over one minute, but the exact time of the flash was usually published a day or more later.

A significant article was published in July 1936 (The Time Ball, 1936). Its author has not been identified, but it contains an apparently authoritative history of the Bombay time balls. The content relating to the Castle is transcribed below:

> The ball was superseded by a flag, but, following complaints that this was not easily visible, the ball was restored and remained in operation until 1865 when it was removed to the Castle Flag Staff Tower. Here it continued to work until 1928, together with a large clock fitted with a second hand and electrically connected to the master clock at the Observatory.

A report on the performance of the time ball from 1 May 1861 to 30 April 1862 was favourable "At Bombay, the time ball has been dropped daily, Sundays and holidays excepted, without a single failure." (East India, 1863: 74).

Tenders for construction of a time ball tower at the Castle were invited in March 1866 (Morland, 1866a). A flag was used as the substitute signal until the transfer had been completed:

> Notice is hereby given that until the completion of the removal of the Time Ball to the new Tower on the North East Bastion of the Castle, time will be given daily, from the Colaba Observatory, by dropping a Flag at 1 p. m. (Morland, 1866b).

The controlled clock near the Castle time ball was one of very few noted in Admiralty lists from 1880 until 1928. It cannot be seen in Figure 43 so it may have been introduced at some time after the time ball.

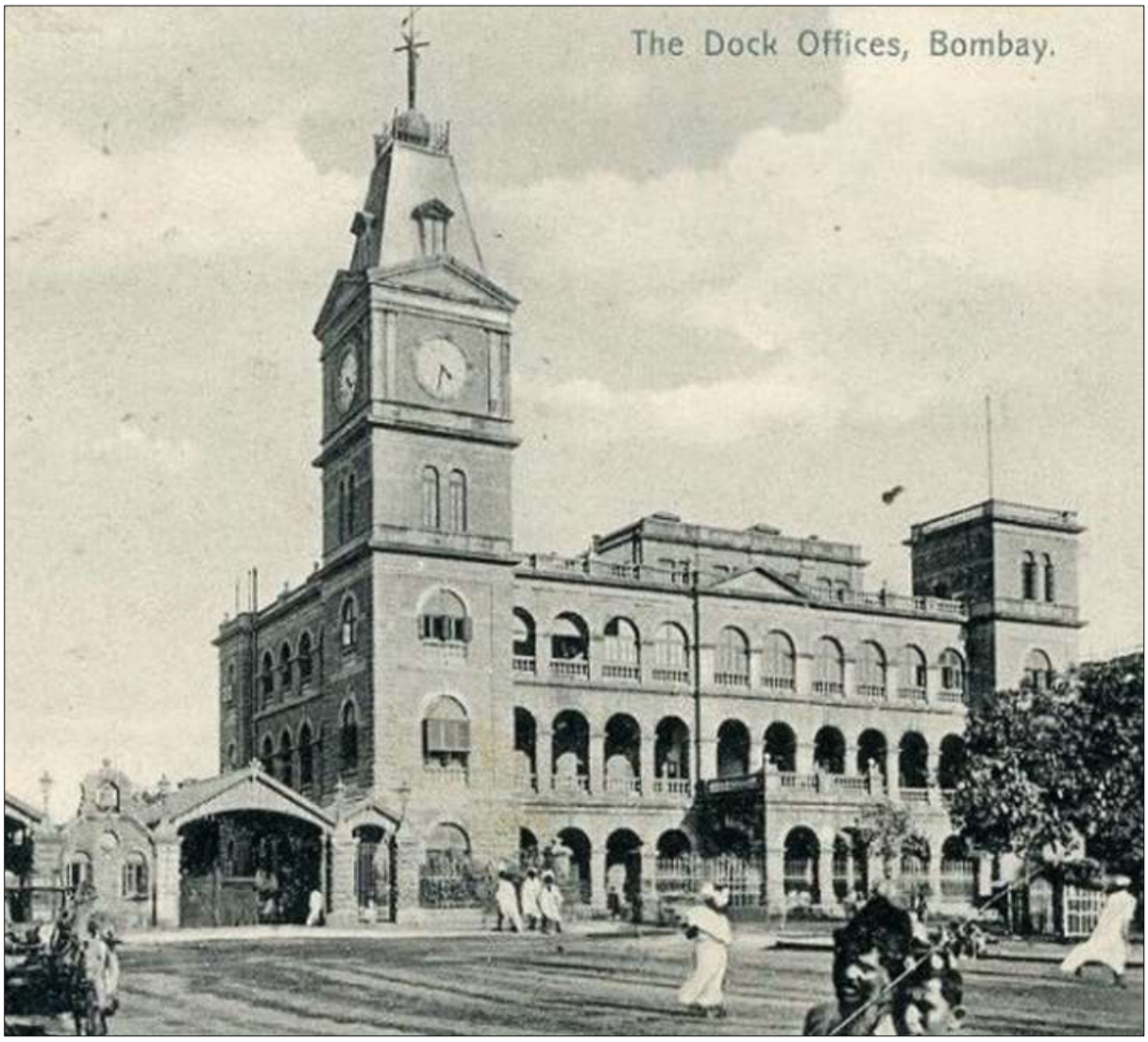


Figure 44: Bombay docks time ball (Klaus Hülse Collection).

8.1.4 Bombay: Docks

An additional time ball was erected at the Prince's and Victoria Docks and was operational in 1891 (The Time Ball, 1936). Figure 44 shows the Dock Offices at Bombay, with the time ball on top of the tower. It was a large ball with a diameter of 1.8m. The colour of the ball was not stated in Admiralty lists, but it was painted red in 1942 (Sailing Directions, 1942: 266). A prominent feature of the tower is the clock associated with the time ball. This clock was not electrically controlled from the Observatory (Time Ball, 1936) and was not recognised by the Admiralty as a time signal for mariners.

An accidental explosion in 1944 led to cessation of the Docks time ball service but remains of the apparatus still exist (Samant and Samant, 2016). The remains of the ball have red paint.

8.1.5 Madras: Early Signals

No direct evidence of a pre-1850s time ball at Madras, now Chennai, has been found. It was, however, under consideration and may have operated for a short period, even before the 1835 time ball at Calcutta. An intent to provide a time ball service appears to have been undermined by the desire of George Everest (1790–1866) to prioritise resource allocation to the Madras-based Great Trigonometrical Survey of India (Kinns, 2020c). A Madras time gun was certainly operating in 1841, whereby the precise time of firing was available to ships on the following day (Madras, 1841). A time ball at Madras, but not the time ball at Calcutta, was mentioned when a time ball was being considered for Edinburgh in 1846 (Kinns, 2011: 267). Bartky (1987) suggested "after 1839" and Howse (1997: 83) suggested "1840s" as dates of introduction of a time ball at Madras.

A Madras time ball and a telegraph connection from Madras Observatory to the Beach Office was established after August 1853, according to a notice in *The Journal of the Society of Arts* (Kenrick, 1853). John Henry Kenrick (1816–1895) was Secretary to the Madras Polytechnic Institution in 1854 (Dutt, 1854). He appears to have funded development of a time ball and telegraph link from his own resources, perhaps hoping for later recovery of his costs (see Kinns, 2021c). The following notice indicated that a Madras time ball was working in January 1854 (Elliott, 1855), but the service may have been suspended soon afterwards:

> At Madras, a time ball has been established over the Master-Attendant's office, in electrical connection with the observatory. The ball is hoisted up five minutes before one o'clock, and is dropped at one p.m., observatory mean time. The observatory is two miles and a quarter west of the Master-Attendant's flag-staff.

Kenrick proposed in July 1854 that the apparatus should be transferred to the Government of Madras. This proposal was considered in London, but the outcome is uncertain and any transfer is likely to have been delayed by political turmoil in India that led to creation of the India Office. The following extracts from a report covering the period from 1 May 1859 to 30 April 1860 show that a time ball was in use by 1859 but that it was initially unreliable and had to be rebuilt:

> The time ball, which was put on the centre of the sea customs house in 1858-59, has not worked satisfactorily, owing to the apparatus being defective. It is now under repair, and it is expected will soon mark the time more correctly than heretofore …
>
> The time ball has sustained severe damage from heavy gales to such an extent, that it was deemed advisable to construct a new one on a much more substantial principle …
>
> The correct time of the firing of the evening gun has been regularly published, and the time ball has also been in use; but till February its mechanism was very defective, and failures from this cause were frequent. In April the ball itself threatened to give way, and a new one has been constructed. No future difficulty in the matter is now anticipated. (East India, 1861: 71, 102, 110).

8.1.6 Madras, Signals after 1880

The Madras time ball had been replaced by a semaphore signal by 1880. It was replaced in turn by another time ball in 1917, but the service was not listed after 1932. Madras tended to favour the time gun at Fort St. George which was listed in 1915 and was still operating in 1947.

8.1.7 Karachi

The first notice of a time ball at Karachi, then spelled Kurrachee, was dated 3 August 1874 and published in the *Nautical Magazine* (Parker, 1875: 80). It did not, however, feature in the 1880 Admiralty list.

In 1898, a time ball was located on Merewether Pier, but there appear to have been concerns about its reliability. Figure 45 shows the Pier time ball in 1902. Another time ball at Manora point had been established, or reestablished, by 1904 as a daily service, excluding Sundays.

The Merewether Pier and Manora Point time balls had both been withdrawn by 1908 and replaced by a time ball on Baba Island.

There were several changes in the drop times, corresponding to the introduction of India standard time in place of local mean time.

8.1.8 Port Blair

A time ball was established at Port Blair in the Andaman Islands in 1919. It was still listed in 1947. The time ball was only dropped on Thursdays and Fridays and was considered to be unreliable.

8.1.9 Ceylon: Colombo

Colombo was the only port in Ceylon, now Sri Lanka, with a time signal in Admiralty lists. The first time ball at the Master Attendant's office had a small diameter of 3 feet (0.9m). The drop height was stated to be 40 feet (12m) in the 1880 Admiralty list. The first time ball was dropped at 1 pm local mean time on weekdays, 5h 19m 22s ahead of GMT.

By 1898, the ball had been replaced by a semaphore signal coloured red and white, apparently at the same location and same height as the time ball. It was operated using a clock that was regulated by telegraph from Madras Observatory. It was raised to about 45º, 5 minutes before the signal, then horizontal 2 minutes before the signal. Poor visibility and irregularity of the semaphore signal had been noted in the 1904 list with an additional note in 1908 that a local observatory in Colombo was being erected. In 1904, it was dropped every day at 4.15 pm Madras Standard time, which became India Standard time, 5½ hours ahead of GMT. It was also dropped at 8.15 am on weekdays. The same timings were given in the 1916 Admiralty list, with a continuing note that "… it was difficult to make out from the outer parts of the harbour."

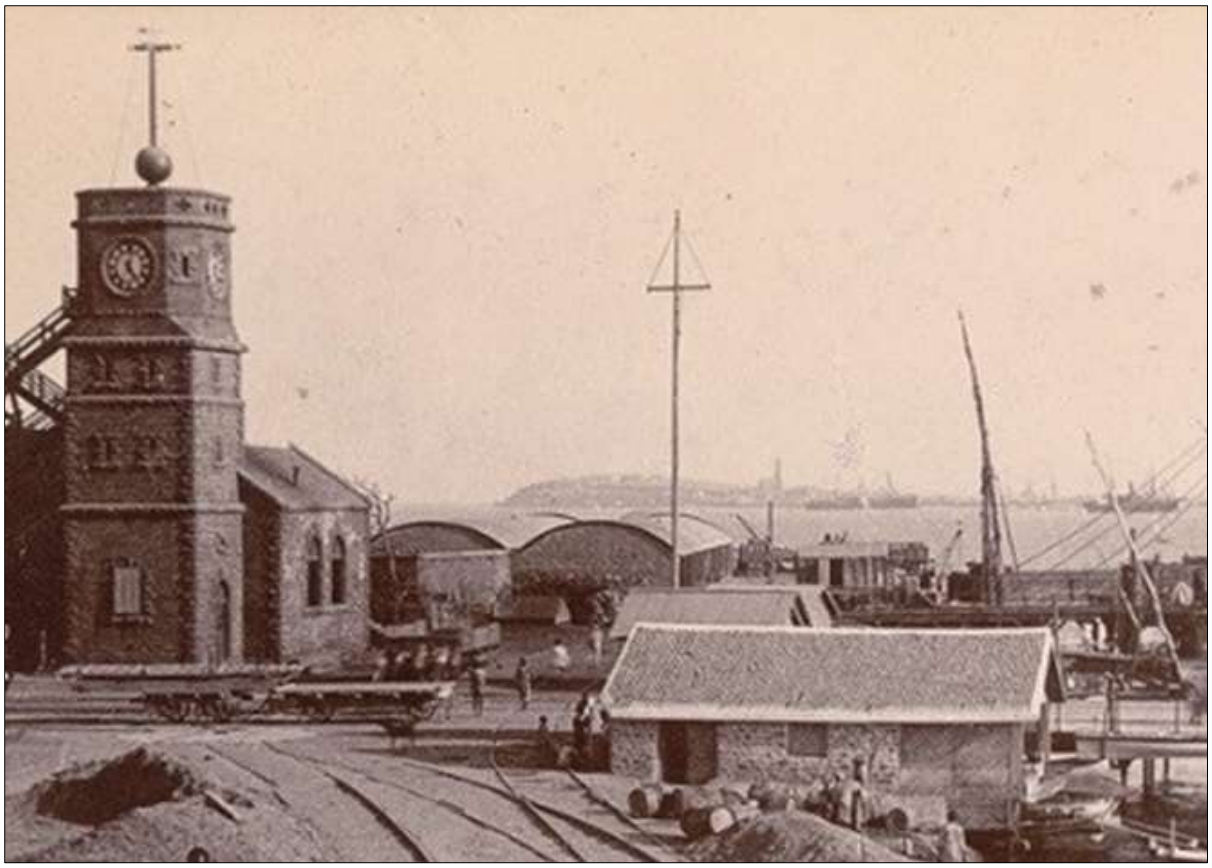


Figure 45: Karachi time ball at Merewether Pier (Klaus Hülse Collection).

The semaphore signal was in turn replaced by another time ball at the Master Attendant's office, which was controlled from Colombo Observatory. It had a diameter of 1.8m and a drop height of 4m at a higher elevation than the semaphore signal. The time ball is believed to have been erected in 1914 but not listed until 1917, so it may have been subject to trials over an extended period to establish its reliability. In 1917, the time ball was dropped a 9 am, 1 pm and 4 pm Standard Time on weekdays, with a drop at 9 am only on Sundays and public holidays. This was changed to 1 pm daily in 1918 but reverted to the earlier timings after 1919, which were retained until 1931. After that, the signal was made at 9 am only until at least 1939. The signal had been withdrawn by 1942.

8.2 Signals in China

The range of different time signals in China between 1880 and 1947 is listed in Table 10. There were no listed visual signals in China in 1880, but accurate time balls were established at Hong Kong and Shanghai in 1885. Later, time guns, a flag signal and lights were listed at the various locations shown in Map 10, which also includes those for Japan and Korea. Table 10 shows that most visual signals in China were still operating in 1939, but only the Shanghai time ball and the lights at Hong Kong and Macau remained in 1947. The time lights in China varied substantially in style and timing between locations.

8.2.1 Hong Kong

The need for a time ball and observatory at Hong Kong had been emphasised in November 1877:

> The Surveyor General's Report on the proposed Time-Ball for Hongkong, which appears in the *Gazette*, together with Admiral Ryder's letter, furnished much detailed information which tends to support the adoption of the proposal …
>
> … it would be necessary to build and organise a small Observatory, and to engage a competent professional person from England to take charge of it. A Transit, a Sidereal Clock, electric apparatus and wires, and the mechanism for dropping the ball would be the chief requisites. (Official reports, 1877).

William Dorberck (1852–1941) was appointed as Government Astronomer. His wider work as an astronomer has been described by Mackeown (2007). A description of the new observatory and its equipment was published in 1884 (The Hongkong Observatory, 1884). It included

Table 10: Signals in China.

Area	Location	1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
China	Amoy		Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	
					Flag	Flag	Flag	Flag	Flag	Flag	Flag	
	Chifu			black)	black)	black)	black)	black)	black)	black)	black)	
				Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	
	Dairen								Light	Light	Light	
	Hong Kong K		TB	TB								
	Hong Kong BH				(red)	(red)	(red)	(red)	(red)			
	Hong Kong							Light	Light	Light	Light	Light
	Macau										Light	Light
	Newchwang				TB							
	Shanghai		TB	TB	TB	TB	TB	TB	TB	TB	TB	TB
					Light	Light	Light	Light	Light	Light	Light	
	Swatau		TB	TB	TB	TB	TB	TB	TB	TB	TB	
			Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	
	Tsingtau			(black)	(black)	(black)						
						Gun	Gun	Gun	Gun	Gun	Gun	
Signal type totals		1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Time ball, including collapsible		0	3	5	6	5	4	4	4	3	3	1
Gun, including powder flash		0	2	3	3	4	4	4	4	4	4	0
Lights		0	0	0	1	1	1	2	3	3	4	2
Other: disc, drum, flag, etc.		0	0	0	1	1	1	1	1	1	1	0

Map 10: Signals in China, Japan, Korea and Asian Russia (Vladivostok) (map: Roger Kinns).

a brief description of the time ball and its operation:

> The mean-time clock, which is to discharge the time-ball automatically, is furnished with a magnetic apparatus for setting it to correct time without touching any part of the clock. The time-ball will be dropped at Tsim-sh'at-sui (*sic*.) point, opposite the harbour, about a mile from the Observatory. It is 6 feet in diameter. Opposite the mean-time clock is the sidereal standard clock …

The first time ball at Kaulung in Hong Kong was described as being near the police station and is shown in Figure 46. It began operation on 1 January 1885 and was moved to a more prominent location at the signal station in January

Figure 46: Hong Kong time ball before 1908 (Klaus Hülse Collection).

1908, as shown in Figure 47. The time ball was withdrawn in June 1933 (History of Hong Kong time service).

Time lights were added before 1920 and continued operation after the time ball had been withdrawn. Three lights were arranged vertically on the Observatory wireless mast at Kowloon. Their mode of operation is described below (1922 list):

> The lights are extinguished momentarily at even seconds excepting the 2nd, 28th, 50th 52nd and 54th seconds, of each minute, between 8h 56m 00s and 9h 00m 00s, Standard time.

The lights remained at the same location throughout. The sequence of flashes changed in detail, as shown in the Admiralty list entry for 1933.

> The lights are extinguished momentarily, every second from 20h 55m 00s to 21h 00m 00s Standard time except at the 28th, 54th, 55th, 56th, 57th, 58th and 59th seconds, of each minute (1933 list).

These lights are not mentioned in the History of the Hong Kong time service.

The time ball apparatus has been reconstructed and returned to its original site. It is a working arrangement. A display notice records that:

> The time ball served its function admirably from 1885 to 1907. On 7th December 1907 the time ball was moved to Signal Hill in Tsim Sha Tsui, ending the historic mission of the Time Ball Tower. The time ball on top of this Time Ball Tower has been reconstructed based on detailed studies of time ball towers in Greenwich, Lyttelton, New Zealand, and Sydney, Australia and on records of the Hong Kong Observatory.

Although the references are to time balls built by Maudslay, Sons & Field in 1833, 1855 and 1873 that used similar design principles, the supplier of the original Hong Kong apparatus has not been identified.

8.2.2 Shanghai

There was an inaccurate time ball at Shanghai by 1877: “Shanghai has a time-ball once a week, which, though better than nothing, is liable to serious error.” (Official reports, 1877). A new time ball was erected in 1884 at the

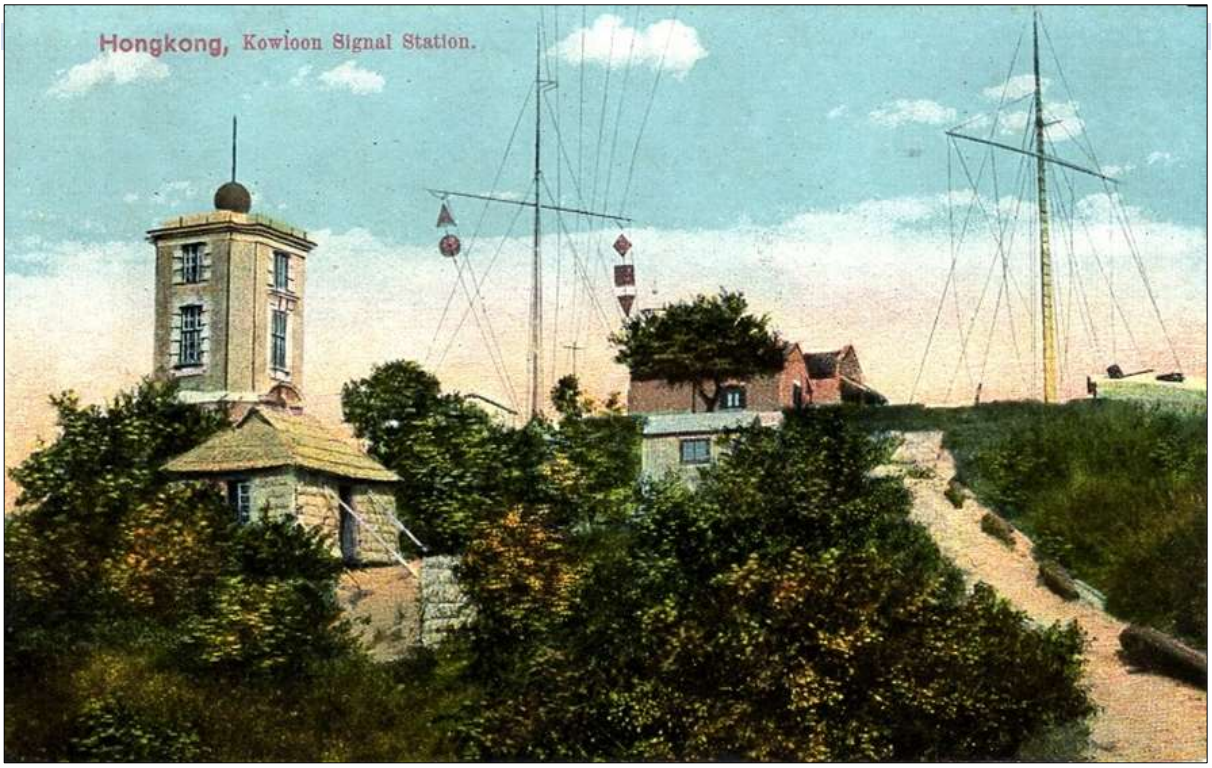


Figure 47: Hong Kong (Kowloon) time ball after 1908 (Klaus Hülse Collection).

French Concession. It was operated using electrical signals from the observatory at Zikawei (Siccawei) in SW Shanghai which was opened in September 1884. It has been described by Combridge (1989), who included a contemporary sketch that had been reproduced previously in *Nature* (Shanghai, 1885) and is shown in Figure 48. The drawing is not to scale, as the overall mast height was expected to be 90 feet (27m) with an unusually large ball diameter of 9 feet (2.7m) (Shanghai, 1884). The time ball at Shanghai outlived others in China but underwent various changes after its introduction. Its location continued to be given as the Semaphore at the French Concession in Admiralty lists. It was listed as having a diameter of 6 feet (1.8m) from 1908 onwards, with a drop of 21 feet (6.3m) from a height of 102 feet (35m) above ground. Figure 49 shows the support arrangement that existed before 1907. It was changed then from a mast to the concrete column shown in Figure 50. The tower has been restored, but the time ball no longer exists.

Shanghai had one of the first known time light signals, operational before 1911 and continuing until after 1939. Four white lights were arranged in the form of a diamond, also at the Semaphore location (1911 list). These were extinguished simultaneously every minute from 8.55 pm to 9.00 pm. Later lists included the statement “A short eclipse of 1 second is given 10 seconds before the signals to attract attention.”

8.2.3 Amoy

A gun had been introduced at Amoy before 1898. Admiralty lists from 1911 onwards indicated that a flag showing the international T code was hoisted to alert observers that the gun would be fired in 5 minutes. It was lowered when the gun was fired. The gun was, however, reported as unreliable. It was still operating in 1939.

8.2.4 Tsingtau

A time ball at Tsingtau was established by 1904 at the German Concession. The Tsingtau ball had a large diameter of 2.1m and a drop of 3m (1911 list). Its construction can be seen in Figure 51. A gun was added at Tsingtau and continued to operate after the time ball was withdrawn in 1915. It was reported to be inaccurate (1915 list).

8.2.5 Dairen

Time lights were introduced at Dairen in 1922 and replaced an earlier time ball, according to a published report from a visiting British ship which included the statement “This signal is reported to be very satisfactory.” (Notice, 1922). The arrangement of lights was not stated in Admiralty lists before at least 1927. The following description of an elaborate arrangement was

Figure 48: Shanghai time ball sketch (*Nature*, 1885).

Figure 49: Shanghai time ball before 1907 (Klaus Hülse Collection).

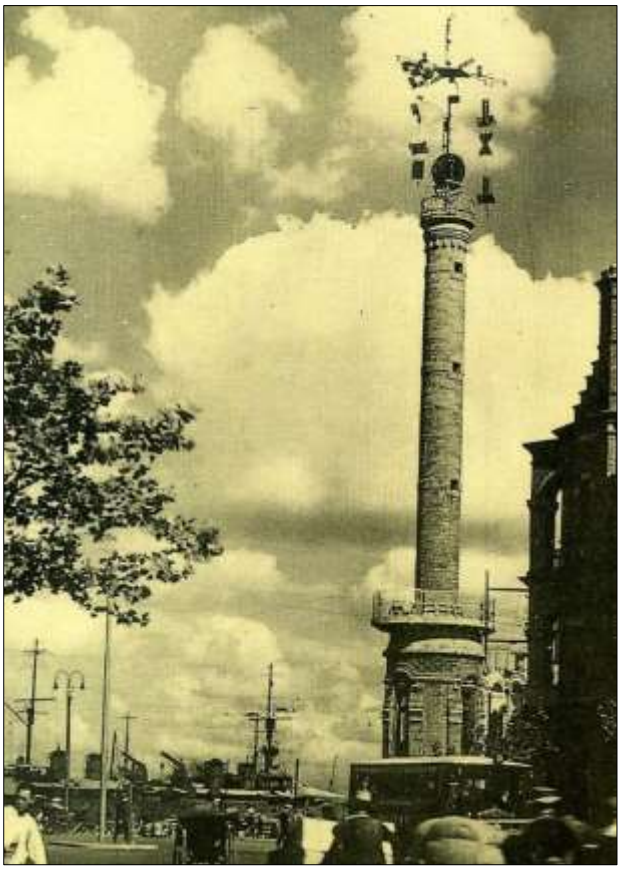


Figure 50 (left): Shanghai time ball after 1907 (Klaus Hülse Collection).
Figure 51 (right): Tsingtau time ball (Klaus Hülse Collection).

given in lists after 1930:

> The lights are shown in a spherical frame in 8 perpendicular rows of 10 lamps each. The lights are switched on at 20h 59m 00s and extinguished at 21h 00m 00s Standard time. They are switched on again one second later and extinguished at 21h 01m 00s and repeated at 21h 02m 00s.
>
> If the signal fails or is in error, three red horizontal lights are shown from Kwantung observatory …

The lights were located above the roof of a house on No. 2 pier.

8.2.6 Macau

The time lights at Macau were not listed by the Admiralty before 1934, but there is an indication in the 1939 list that they had been introduced as early as 1923. They were located at the Meteorological Observatory: “The lights are in the form of a triangle, and are switched on 4m 30s before the hour and extinguished at Noon and every 3 hours Standard time.” (1939 list).

8.2.7 Other locations in China

A time ball and gun at Swatau were operational before 1898 but the service was only provided on Saturdays “and is not to be depended on” (1922 list). By 1904 an additional time ball and gun had been established at Chifu, but “Stated not to be sufficiently accurate for comparing chronometers” (1922 list). A short-lived time ball at Newchwang was listed in 1911 but not in 1915 or later.

8.3 Signals in SE Asia

The time signals in SE Asia have been described previously, including images and signal details from various sources (Kinns, 2021a). Entries in Admiralty lists are shown in Table 11, and relevant locations are shown in Map 9. Burma, now Myanmar, was administered as part of India before 1947.

8.3.1 Burma

There is a mysterious photograph, taken in 1855, which shows a ball suspended from a yard arm on top of an ancient pagoda (see Kinns, 2021a). It has been stated to be a time ball, but no supporting evidence has been found and it may have served some other purpose. The first official time ball was gazetted in 1893 and listed originally as being on the tower of the Mayo Sailors’ Home, but this description was changed by 1911 to the tower of the Mayo Marine Institute when a time gun was also fired

Table 11: Signals in SE Asia.

Area	Location	1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Burma (now Myanmar)	Moulmein					Gun	Gun	Gun	Gun			
	Rangoon		TB	TB	TB	TB	TB	TB	TB			
					Gun	Gun	Gun	Gun	Gun	Gun	Gun	
										Light	Light	
Indonesia	Fourth Point	Discs										
	Tanjong Priok	Disc										
	: Tanjong Priok		Boards	Boards	Boards	Boards	Boards	Boards	Boards	Boards	Boards	
	Surabaya	Discs	Boards	Discs	Discs	Discs	Discs	Discs	Discs	Discs	Discs	
	Makassar						(black)	(black)	(black)	(black)	(black)	
Philippines	Kavite				TB	TB	TB	TB	TB	TB		
	Manila Obs.		(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)		
	Manila		Gun									
	Manila El				TB	TB	TB	TB	TB	TB		
Singapore	Fort Canning		TB	TB	TB	TB	TB	TB	TB	TB	TB	
									Gun			
	Pulo Brani		TB	(red)								
	Mount Faber Observatory				(red)	(red)	(red)	(red)	(red)	TB	TB	
										Light		
	Fullerton Build.									Lever D	Lever D	
Vietnam (was Cochin China)	Haiphong		TB									
	Saigon				TB	TB	TB	TB	TB	TB		
					Gun	Gun				Gun		
Signal type totals		1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Time ball, including collapsible		0	5	4	7	7	8	8	8	7	3	0
Gun, including powder flash		0	1	0	2	3	2	2	3	2	1	0
Lights		0	0	0	0	0	0	0	0	2	1	0
Other: disc, drum, flag, etc.		3	2	2	2	2	2	2	2	3	3	0

nearby.

Until at least 1922, the Rangoon gun was fired at noon Burma Standard time (5.30 am GMT) while the time ball was dropped at noon, Rangoon (local) mean time, 5 minutes 20 seconds later. This had changed by 1927 when the time ball was dropped and the gun fired at 1 pm Standard time, an hour later than before.

The Rangoon time ball was replaced by a simple time light in 1931, switched on 2 minutes before extinction at 1 pm, Burma standard time, when the gun was fired. The time gun at Rangoon was discontinued in 1939, but the light remained in use.

Another time gun had been introduced at Moulmein by 1915 but was not recommended for rating chronometers. It was fired initially at the same time as the Rangoon gun, but this had changed to 10 am in 1930. It was no longer listed by 1933.

8.3.2 Singapore

An extraordinarily wide range of time signals existed in Singapore (Kinns, 2021a). Two time balls were established in 1894 and appeared in the 1898 list. There had been a visit to Devonport, England in 1890 by Saxby & Farmer, who had been chosen as suppliers of the time ball apparatus for Singapore (Homes, 2009). An article published in 1892 gave details of the planned installations:

> The time ball apparatus consists of a steel mast, about 50 feet in height, duly supported by guys and an iron base. Projecting from the mast are two arms one above the other, about twenty two or three feet apart. Two strong wire ropes are stretched as guides to a time ball six feet in diameter and weighing 77 lbs.
>
> The ball is raised by a wire rope and then held in position by another single strand wire rope connected below with a magnet. When the standard clock makes connections, the ball is released by the single strand wire and falls 13ft. 6in. At that point in its fall, the main hauling rope brings into play a leaden check weight weighing 86lbs. and the last six feet of the fall is accomplished at a diminishing rate of speed, until the ball is brought up by spiral springs with a compressibility of 80 lbs. and an indiarubber cushion. (The proposed time balls, 1892).

One time ball was at Fort Canning and the other was at Pulo Brani. Each used a variant of the Devonport principle (Lewis, 1910), with the ball constrained by two guide wires. The red time ball at Pulo Brani was moved to Mount Faber in 1905. The time balls at Fort Canning and

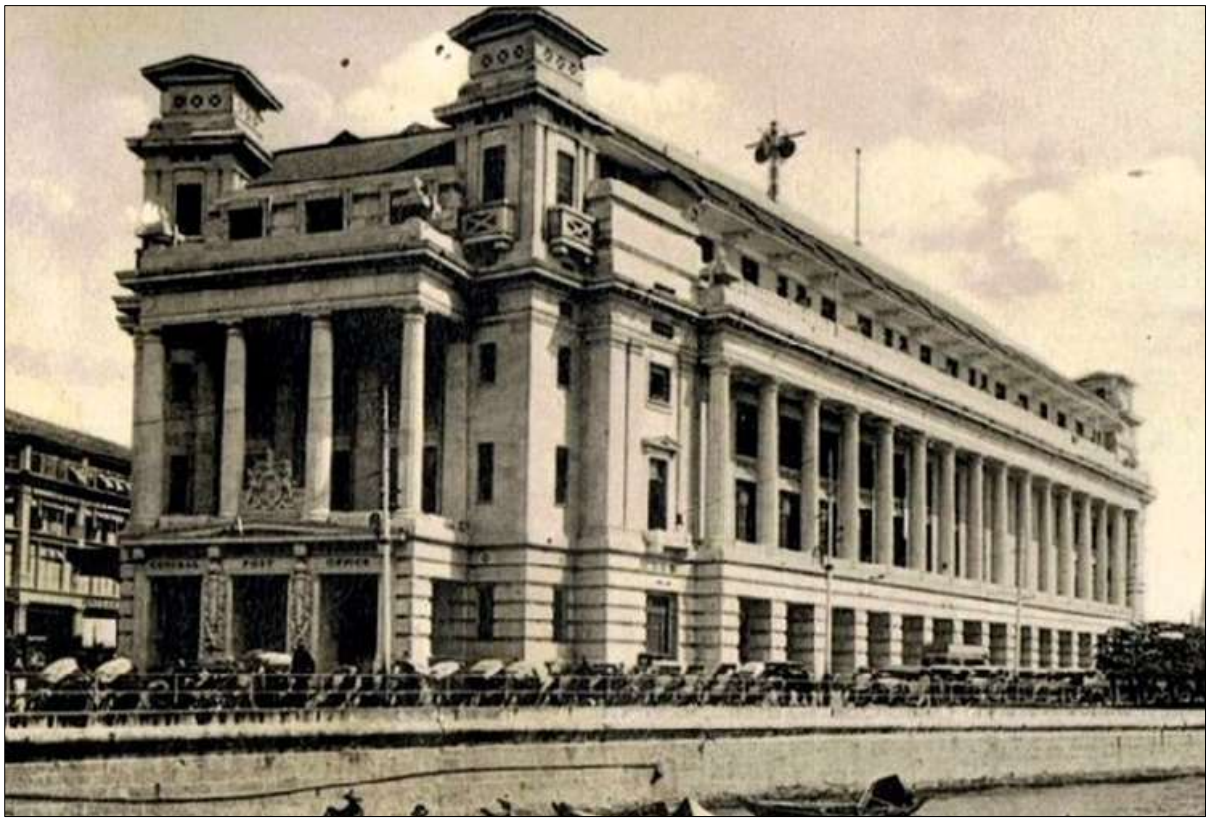


Figure 52: Singapore time signal on Fullerton building (Klaus Hülse Collection).

Mount Faber were still listed in 1939.

In 1930 another signal, designed locally, was installed on the Fullerton building (New Time Signal on Post Office, 1930). It used lever arms with discs at their ends on a mast above the roof. The arms were extended horizontally before dropping towards the mast as the time signal. The building and time signal arrangement is shown in Figure 52.

A complicated time light signal was added in 1931, using a defined sequence of flashes from three white lights arranged vertically. It was operated to give signals at 8 pm and 9 pm, local Standard time, when the lights were extinguished. It had been discontinued before 1939.

An electric bell was installed in an office on Tanjong Pragar wharf in 1905. It rang automatically at every hour of GMT and was included in the 1908 and 1911 lists. It is not included in Table 11 as it was not visible or audible to ships in harbour. Time bells had been installed at other locations by 1927 and three were mentioned in the 1930 list as being connected to the standard clock. A time gun at Fort Canning was used from before 1907 and was mentioned in pilot guides issued in the United States until at least 1932 but it was never included in Admiralty lists. It was fired at noon on weekdays and at 1 pm on Sundays.

It had been established that the time balls actually fell 0.7 seconds after the electrical time signal had been received from the standard clock, so it was decided to adjust the clock time to match. The principal time ball signals then gave a more exact time, but the bells rang slightly early.

8.3.3 Indonesia

The first time ball in SE Asia had been established on Java at Batavia, now Jakarta, in 1839 (Melvill and Smits, 1850). Another had been noted at Surabaya in 1878. Neither time ball was listed by the Admiralty in 1880. A time ball at Makassar was introduced in 1915 and withdrawn in 1939.

Discs rotating about horizontal axes, also described as flaps or boards, were preferred for Java, then a Dutch colony. Time discs were used at the Fourth Point on the Sunda Straight but had been discontinued by 1898. In 1880, a single disc was used at Tanjong Priok, later changed to 4 smaller discs at a different location after harbour development, as shown in Figure 53.

The time discs were similar in most respects to those used in the Netherlands, but the preparatory signals were different. At Tanjong

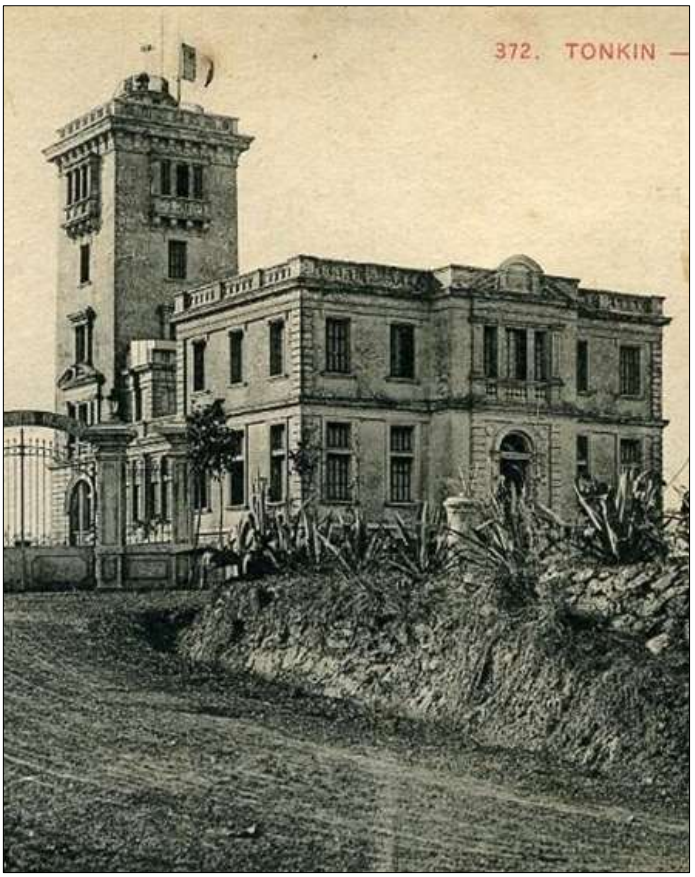


Figure 53 (left): Tanjong Priok time discs (Klaus Hülse Collection).
Figure 54 (right): Haiphong Observatory (Klaus Hülse Collection).

Priok and Surabaya the discs (or boards) were inclined at 45° five minutes before the signal and then placed in the vertical position two minutes before the signal, so there were two preparatory signals. In the Netherlands, the discs were placed vertically five minutes before the signal, so there was only one preparatory signal.

8.3.4 Vietnam

There have been two time balls in Vietnam (then Cochin China). A time ball at Haiphong (Phu Lien) is believed to have been established in 1886. It was on top of the observatory tower and used precise measurements of longitude that were made using undersea telegraphy (see Kinns, 2021a). It was listed in 1898, but not in 1904 or later. The Observatory building is shown in Figure 54.

The time ball at Saigon was positioned on the signal mast by the commercial harbour. It was installed in 1908 and used an open frame structure for the ball, as shown in Figure 55. In 1911 the ball was dropped at noon, Saigon mean time. In 1915 it was dropped first at noon Saigon mean time and then 6 minutes, 48.3 seconds later (5 am GMT). The drop times were

Figure 55: Saigon time ball (Klaus Hülse Collection).

Figure 56: Cavite time ball (Klaus Hülse Collection).

were changed in 1917 to 3 am and 3.05 am GMT. The time ball was still operating in 1937 but was then deemed to be for local use only (see Kinns, 2021a).

A time gun at Saigon was listed in 1911 as being fired at noon when the time ball was dropped but both the time ball and gun signals were described as unreliable. The gun was not listed between 1916 and 1930. It was listed again from 1933 to 1935 when it was fired at 10 am Standard time (3 am GMT), two hours earlier than before. Neither the time ball nor the time gun was listed in 1939.

8.3.5 The Philippines

Manila Observatory had been founded in 1865 by the Society of Jesus and introduced its time service in 1885, when the Philippines were administered as a Spanish colony (Manila Observatory, 2012). This period ended with the Spanish-American war in 1898, but the Observatory was undamaged and continued to develop its work and reputation under the control of the United States.

In 1898 a black time ball was listed with a time gun. The ball was dropped and the gun was fired at noon local mean time. The gun was stated to be insufficiently accurate for rating chronometers and was not listed by the Admiralty in 1904 or later.

In 1906, a second time ball was established at the Cavite Naval Station. This time ball was located on top of a water tower, shown in Figure 56. A third time ball was erected on the Semaphore Tower at Engineer Island after 1908. All three time balls were listed from 1911 to 1934. The Observatory and Engineer Island time balls were dropped at noon, local standard time, while the Cavite ball was dropped at 11 am. The original Observatory and its records were destroyed during World War II.

8.4 Signals in Japan

There were no listed time signals for Japan in 1880, although representatives of the Japanese Navy had visited Bidston Observatory, Liverpool to study the methods used by John Hartnup to rate chronometers (The Japanese Navy,

Table 12: Signals in Japan and Korea.

Area	Location	1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Japan	Hakodate			Flag	Flag	Flag	Flag	Flag	Flag	Flag	Flag	
	Kagosima					Gun	Gun	Gun	Gun	Gun	Gun	Gun
	Karafuto									Light	Light	
	Kobe		TB	(red)	(red)	(red)	(red)	(red)	(red)	(r, w)	(r, w)	
			Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	
												Light
	Kure			(red)								
	Moji				TB	(r, w)	(r, w)	(r, w)	(r, w)	(r, w)	(r, w)	
	Nagasaki				Flag							
					Gun	Gun	Gun	Gun		Gun		
					TB	(red)	(red)	(red)	(red)	(r, w)	(r, w)	
									Light	Light	Light	
	Niigatako								Whistle	Whislte	Whistle	Siren
	Osaka								(r, w)	(r, w)	(r, w)	
	Sasebo			(red)								
	Yokohama EH			(black)	(black)	(black)	(black)	(black)				
	Yokohama NB							TB				
	Yokohama HB								TB	(r, w)	(r, w)	(r, w)
Korea	Chemulpo				Gun	Gun	Gun	Gun	Gun	Gun	Gun	
Signal type totals		1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Time ball, including collapsible		0	1	4	4	4	4	5	5	5	5	1
Gun, including powder flash		0	1	1	3	4	4	4	3	4	3	1
Lights		0	0	0	0	0	0	0	1	2	2	1
Other: disc, drum, flag, etc.		0	0	1	2	1	1	1	2	2	2	1

1878). A time ball and gun at Kobe were the only signals listed in 1898. A range of different time signals appeared in later Admiralty lists, including time lights and a whistle, later replaced by a siren. Not all existed together. The range of different time signals in Japan is shown in Table 12. Their locations are shown in Map 10. Apart from the time lights, signals were made at noon.

8.4.1 Hakodate

A red and white flag signal was listed for Hakodate from 1904 to 1939. It was located on a flagstaff on the east side of the harbour. It was hoisted “on the dip” at 5 minutes before the signal, raised fully at 2 minutes before the signal and then dipped as the signal at noon Japanese standard time, 9 hours ahead of GMT.

8.4.2 Karafuto

Karafuto is at a remote northern location in Japan, at a latitude 24° N of Nagasaki. A simple T-shaped time light was introduced at the meteorological observatory in 1926. It was included in Admiralty lists from 1929 to 1934. It was illuminated for 5 minutes before extinction at 8 pm. No reference to a previous time signal at Karafuto has been found.

8.4.3 Kobe

A time ball and time gun had been listed by 1898. In 1908 the ball was on a flagstaff near the Harbour Office. The gun was “On the West Camber”. The ball colour was not stated in 1898, but it was listed as red from 1904 to 1928 and then red with a white band between 1930 and 1939. These signals continued until after 1939. All listed time balls in Japan used the same colour combination from 1930 onwards.

The Kobe time light was not introduced until about 1941. It used a T-shaped array of lights that was illuminated for a short period before extinction as the signal at 9 pm. It was still listed in 1947 as the only remaining time light in Japan.

8.4.4 Moji

Moji had a time ball in 1911 with an unstated colour. It was then located “In Shimonoscki road, on the south side of the town.” It was repositioned to the summit of the Customs building in the late 1930s. It was red with a white band by 1915 and retained that colour throughout its listing until 1939.

8.4.5 Nagasaki

Flag and gun signals were introduced at Nagasaki before 1911. The red flag signal followed the procedure used at Hakodate. The gun was fired when the flag was dipped. The signals were stated to be inaccurate and a time ball was introduced during 1911, when the flag signal

Figure 57: Yokohama time ball (Klaus Hülse Collection).

was discontinued. The red framework ball was located on the “northern slope of Nabekamuri yama” (1919 list). It was moved to a different location close to the Observatory in 1923 and was painted red with a white band from 1930.

Electric lights were installed in 1923 near the new time ball. They differed from other installations worldwide in using three green lights at the vertices of a triangle. These were illuminated together 5 minutes before the signal, twice switched off briefly before being illuminated again and extinguished as the time signal at 9 pm.

8.4.6 Niigatako

A whistle was listed as the signal at Niigatako (Niigata) between 1924 and 1939, replaced by a siren in 1947. The whistle was on a white tower with a yellow dome near the harbour. The signal was made at noon and 8 pm. The following description shows how it operated

> The whistle commences a low note 20 seconds before the hour and ceases exactly at the hour. The blast is worked by compressed air. The time is obtained from a Standard clock corrected every other day by wireless by Niigata Observatory. Height of whistle 110 feet. (1933 list).

This, and the signal at Honolulu, were the only whistles listed by the Admiralty.

8.4.7 Osaka

A red and white time ball at Osaka was introduced in 1926 and listed until 1939. It was dropped electrically by Tokyo University from a yard arm at the administrative buildings.

8.4.8 Yokohama

Yokohama had three time balls, but not all existed together. The first, painted black, was on the Eastern Hatoba. A supplementary time ball was positioned on the north breakwater in 1920, but both were replaced by a new time ball near the Kanagawa Harbour Board building in 1924. It was positioned on a wireless mast, shown in Figure 57. Initially painted black, it

Table 13: Signals in Australia, New Zealand and Pacific Islands.

Country	Location	1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Australia	Newcastle	TB	TB	TB	TB	TB	TB	TB	TB	TB	TB	
	Sydney	TB	TB	TB	TB	TB	TB	TB	TB	TB	TB	TB
	Brisbane		(black)	(black)	(black)	(black)	(black)	(black)	(black)			
	Semaphore	TB	TB	TB	TB	TB	TB	TB	TB			
	Port Adelaide							TB	TB			
	Port Pirie SA						TB	TB	TB	TB		
	Hobart Tasmania	TB	TB	TB	TB	TB	TB	TB				
		Gun	Gun	Gun	Gun	Gun	Gun	Gun				
	Devonport Tas				TB	TB	TB	TB	TB			
	Williamstown	(black)	(black)	(black)	(b&r)	(b&r)	(b&r)	(b&r)				
	Geelong	TB	TB	TB					TB	TB		
					Flag	Flag						
	Queenscliff	Flag	Flag	Flag	Flag	Flag	Flag	Flag	Flag			
	Fremantle WA			(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	
									Gun	Gun	Gun	
New Zealand	Auckland HB			TB								
	Auckland FB						(w,r,g)	(w,r,g)	(w,r,g)	(w,r,g)		
	Wellington 1	(r&w)										
	Wellington 2		TB	TB								
	Wellington Obs					(w,r,g)	(w,r,g)	(w,r,g)	(w,r,g)	(w,r,g)		
	Lyttelton	TB	TB	TB	TB	TB	TB	TB	TB	TB		
	Port Chalmers		TB	TB								
Hawaii	Honolulu		Whistle	Whistle	Whistle	Whistle	Whistle	Whistle				
Signal type totals		1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Time ball, including collapsible		8	10	12	9	9	10	11	10	6	3	1
Gun, including powder flash		1	1	1	1	1	1	1	1	1	1	0
Lights		0	0	0	0	1	2	2	2	2	0	0
Other: disc, drum, flag, etc.		1	2	2	3	3	2	2	1	0	0	0

was painted red with a white band after 1930 and was still listed in 1947.

8.4.9 Other Time Signals in Japan

There were red time balls at Kure and Sasebo in 1904 and 1908 but neither was listed in 1898 or 1911. Both appear to have been short-lived.

Kagosima introduced a time gun in 1911 which was still listed in 1939 and 1947.

8.5 Signal in Korea

The only Korean signal was a time gun at Chemulpo on the western coast of the Korean Peninsula (see Map 9). It was listed between 1911 and 1939 as being located at the “Observatory on summit above town”.

9 SIGNALS IN AUSTRALIA, NEW ZEALAND AND THE PACIFIC ISLANDS

Time signals in Australia, New Zealand and the Pacific Islands are shown in Table 13 and Map 11.

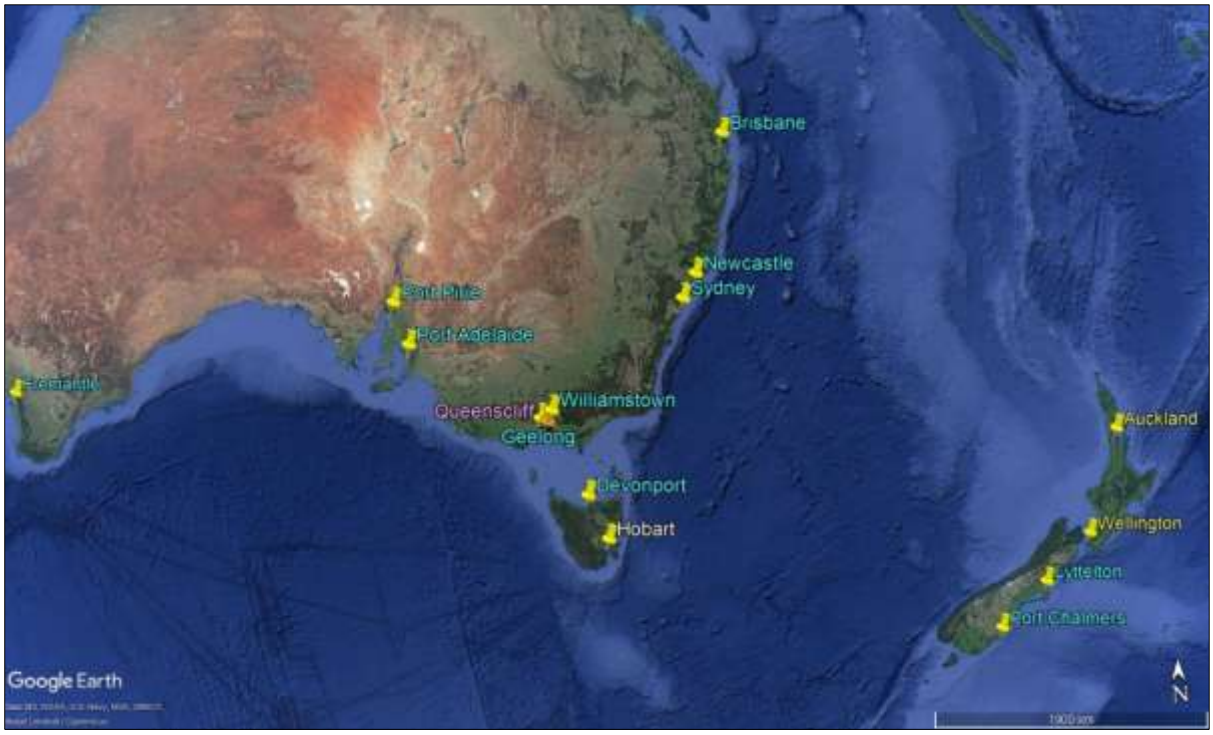
9.1 Signals in Australia

The first time balls in Australia had been introduced in the 1850s and many others had been introduced by the 1870s. Time balls at Sydney and Newcastle in New South Wales (NSW); Semaphore, near Adelaide in South Australia; Williamstown and Geelong in Victoria; Hobart in Tasmania were listed in 1880, together with a flag signal at Queenscliff in Victoria and a time gun at Hobart. Time balls at Brisbane in Queensland and Fremantle in Western Australia were added in 1894 and 1900. Three more: at Devonport in Tasmania, Port Pirie and Port Adelaide in South Australia were added in 1907, 1917 and 1920. A flag signal at Geelong was listed and then discontinued before a new time ball was installed there in 1922.

The time gun at Hobart was the only one in Australia listed by the Admiralty as a primary signal. A time gun at Fremantle was noted as a secondary signal. Many others had existed at various locations throughout Australia.

9.1.1 NSW: Sydney

The time balls at Sydney and Newcastle have been described in detail by Kinns and Abell (2009). The time ball apparatus for Sydney was manufactured by Maudslay, Sons & Field in 1855 and was operational in June 1858 after observatory completion (Pickett and Lomb,



Map 11: Signals in Australia and New Zealand (map: Roger Kinns).

2001). It was a development of the 1853 apparatus for Edinburgh and Deal which became operational in 1854 and 1855 respectively. Charles Todd (1826–1910) saw it under construction before he departed for Adelaide in 1855 and noted its similarity to the apparatus for Deal (Kinns and Abell, 2009). Details of the apparatus, including photographs of the mechanical components which show design development for Sydney, have been presented by Kinns (2009). Todd's subsequent responsibility for the time ball at Semaphore in Australia is described later.

The Sydney ball and mechanism were modified in the 1870s by Henry Russell (1836–1907), then the NSW Government Astronomer, but most of the original features were retained. Russell listed some of the modifications he had made in a letter to Sir Charles Todd in Adelaide, during an exchange about possible designs for Western Australia (Russell, 1899). The complete correspondence has been transcribed by Kinns and Abell (2009). Original wooden components were replaced with new parts made from metal. These included the ball, which had used a zinc skin on a wooden frame, the shaft and the external mast. The diameter of the cylinder used to provide the air spring had also been increased to accommodate the increased weight of the ball, shaft and piston. Later changes include provision of an electric motor to raise the ball to complement the windlass. The new ball made of Muntz metal had been painted black, but the colour was changed to yellow for the Millennium celebrations in 2000 and has been retained since. The apparatus remains in operation. Figure 58 shows the existing time ball and tower in Sydney.

It has been shown recently that the design for Sydney was also used for Lyttelton, New Zealand, in 1873 (Kinns, 2009). The 1873 apparatus for Lyttelton did not include Russell's changes and is effectively a manifestation of the original apparatus for Sydney.

9.1.2 NSW: Newcastle

The first time ball at Newcastle was introduced in 1871, as well as a time gun. A larger ball was installed in 1874. The early balls were made of wickerwork. The time ball on the clock tower at the Customs House was the third at Newcastle. The Russell modifications to the Sydney apparatus were included in the design of the new apparatus, which used a rack and pinion mechanism. The apparatus was made by Potter and Sons of Sydney in 1877 and was the first of its type to be made in New South Wales. The ball operated for the first time in February 1878.

The history of the Newcastle signals was included in a conservation plan for the third time ball at the Newcastle Customs House:

> The first time ball was erected on a mast 150 feet high at the rear of the Telegraph Office at the corner of Watt and Hunter Street. The ball was made of black painted

Figure 58: Sydney time ball in 2007 (author's photograph).

wickerwork and dropped at 1.00 pm each day. A signal gun was not provided by the government and there was general dissatisfaction with this state of affairs. Eventually the government agreed to provide a six pounder gun and necessary ammunition, which operated with the time ball from 1 May 1871. A larger, more conspicuous ball replaced the original time ball on 24 July 1874. This time ball operated until the existing time ball was erected at the top of the clock tower of the new Newcastle Customs House. The Customs House time ball first dropped on 21 February 1878. The time ball operated without major overhaul for 63 years and it was 94 years before the elements took their toll when, on 7 July 1972, an 85 mile per hour gale broke off the top portion of the mast. The time ball had been inoperative since 7 November 1941. The wreckage of the time ball was salvaged during late 1972 and early 1973. The ball was provided with a new inner steel framework and was re-erected in a fixed position on a shorter mast on 14 March 1973. The original weathervane was placed at the top of the mast. (McDonald, 2000).

The restored apparatus is believed to be operable, but is not presently in use after various changes of tower ownership. The photograph in Figure 59 was taken in 2008.

9.1.3 Queensland: Brisbane

The only Queensland time ball was at Brisbane. An unreliable early time ball was erected in the 1860s. It was replaced by a time gun which was not listed by the Admiralty in 1880 and ceased operation in 1891. A new time ball became operational in 1895 and was discontinued in 1930 (Observatory time ball, 1930; The time ball in Brisbane, 1894). It was listed by the Admiralty throughout that period and is known to have used the Devonport principle (Lewis, 1910). The black ball was installed "On top of the Signal tower, Wickham Terrace" (List, 1908) and had a diameter and drop height of 1.5m and 3.3m. It is shown in Figure 60.

Figure 59: Newcastle time ball in 2008 (author's photograph).

9.1.4 South Australia: Adelaide

The time ball at Semaphore near Port Adelaide was designed and commissioned by Charles Todd who had seen the Sydney apparatus under construction in London before his departure for Adelaide in 1855. His post at Greenwich had given him responsibility for the time balls at Greenwich and Deal (Abell and Kinns, 2010; Bateman et al, 2014; Kinns and Abell, 2009). Todd saw the need for an Adelaide time ball service from the time of his appointment and would have been able to exploit his earlier experience with Maudslay mechanisms. He is best-known for his work on the overland telegraph between Darwin and Adelaide that transformed international communications with Australian cities in 1872 (Taylor, 1980; Thompson, 1999).

Todd developed a design that used electrical triggering in 1867 and presented a working model in January 1869, but he was still unable to obtain necessary funding. It was only after completion in 1872 of the telegraph link between Adelaide and London, which caused a further increase in shipping movements, that a time ball service was provided at last. The Semaphore apparatus is likely to have been a development of Todd's 1867 design and was manufactured locally. The Semaphore mechanism, which became operational on 2 August 1875, differed considerably from that at Sydney, reverting to a chain hoist as in the original 1833 Greenwich mechanism. This would have been cheaper and easier to manufacture than the Sydney rack and pinion arrangement. The reported cost of the mechanism and ball was

Figure 60: Brisbane time ball (Klaus Hülse Collection).

Figure 61: Semaphore time ball (courtesy: State Library of South Australia, B2408).

less than half that for Sydney. Unusually, an array of vertical segments was used to simulate a sphere from a distance. The tower at Semaphore was restored in 2007 using a modern apparatus to raise and lower the ball (Kinns and Abell, 2009). The original and restored arrangements are shown in Figures 61 and 62.

By 1920, the time ball at Semaphore had been obscured from shipping by new buildings and a supplementary time ball was installed at the Adelaide Harbour Board Office in Port Adelaide. It is shown in Figure 63. Both time balls were discontinued in 1932.

9.1.5 South Australia: Port Pirie

Another time ball was erected at Port Pirie in 1917 and continued after those for Adelaide had been withdrawn in 1934. It was positioned on the Harbour Master's residence.

9.1.6 Tasmania: Hobart

Discussion at the Royal Society in Hobart in 1865 and acoustic experiments in 1868 led to a combined time ball and time gun service at Battery Point in Hobart from March 1875 (Kinns, 2011a). Complaints from residents led to relocation of the gun a month later. It was then fired from Queen's Battery in the Domain for half a century. The change of location in 1875 had not

Figure 62: Semaphore time ball tower in 2006 (photograph: Marion Kinns).

Figure 63: Port Adelaide time ball (Klaus Hülse Collection).

been recognised in the 1880 Admiralty list but was corrected later. The drop of the ball at Battery Point was always the master signal; the gun was fired when the ball was seen to drop.

A large house called Lenna, now a hotel, was erected in the 1870s after the time ball had been introduced. The building features in almost all known photographs that show the time ball. An example is shown in Figure 64. This and other images are described by Kinns (2011a).

The time ball service had a remarkable history, having been provided initially by Francis Abbott (1799–1883), a private citizen, using his own transit telescope. Abbott had been deported as a convict from England to Tasmania in 1845 before gaining his freedom and establishing himself as a respected citizen (Orchiston, 1992). Ill-health forced his retirement in 1880 and the time service was provided until 1886 by his son Charles. Responsibility for it was then transferred to Hobart Observatory, but there were ongoing concerns about signal accuracy and the extent of manual intervention required to drop the ball. These led to independent enquiries into time service provision in 1894 and 1908 (see Kinns, 2010). During February 1910, the source of the telegraph signal was changed from Hobart to Melbourne Observatory, but the service was still unreliable and there was pressure to re-equip Hobart. Finally, automatic dropping of the time ball by telegraph from Melbourne was introduced in November 1910. The time ball service ended in February 1927.

The time gun had probably ceased to operate by the end of 1923, but there were sometimes long gaps in the time gun service before that date.

9.1.7 Tasmania: Devonport

A lesser-known time ball was installed at Devonport on the northern coast of Tasmania in 1907. Devonport was the usual destination of ferries operating between Melbourne and Tasmania. The time ball near the Post Office was withdrawn in 1928.

9.1.8 Victoria: Port Phillip

Port Phillip is the large bay that shields Melbourne from Bass Strait. Queenscliff is located at the narrow entrance to the bay and Geelong is at its western extremity. The principal time signal was established at Williamstown, close to Melbourne near the mouth of the River Yarra. Signals at Williamstown, Queenscliff and Geelong were all regulated by Melbourne Observatory from 1863.

The earliest time ball in Australia was established at Gillibrand Point, Williamstown, in 1853 by Robert Ellery (1827–1908), later Government Astronomer in Melbourne. His intention to erect a time ball was published in May 1853 (Ellery, 1853). Part of the first notice, issued on 30 July 1853, is reproduced below:

> Commanders of vessels are requested to take notice that, for the purpose of enabling them to rate their chronometers, a time ball, painted black, will be dropped daily (Sun-

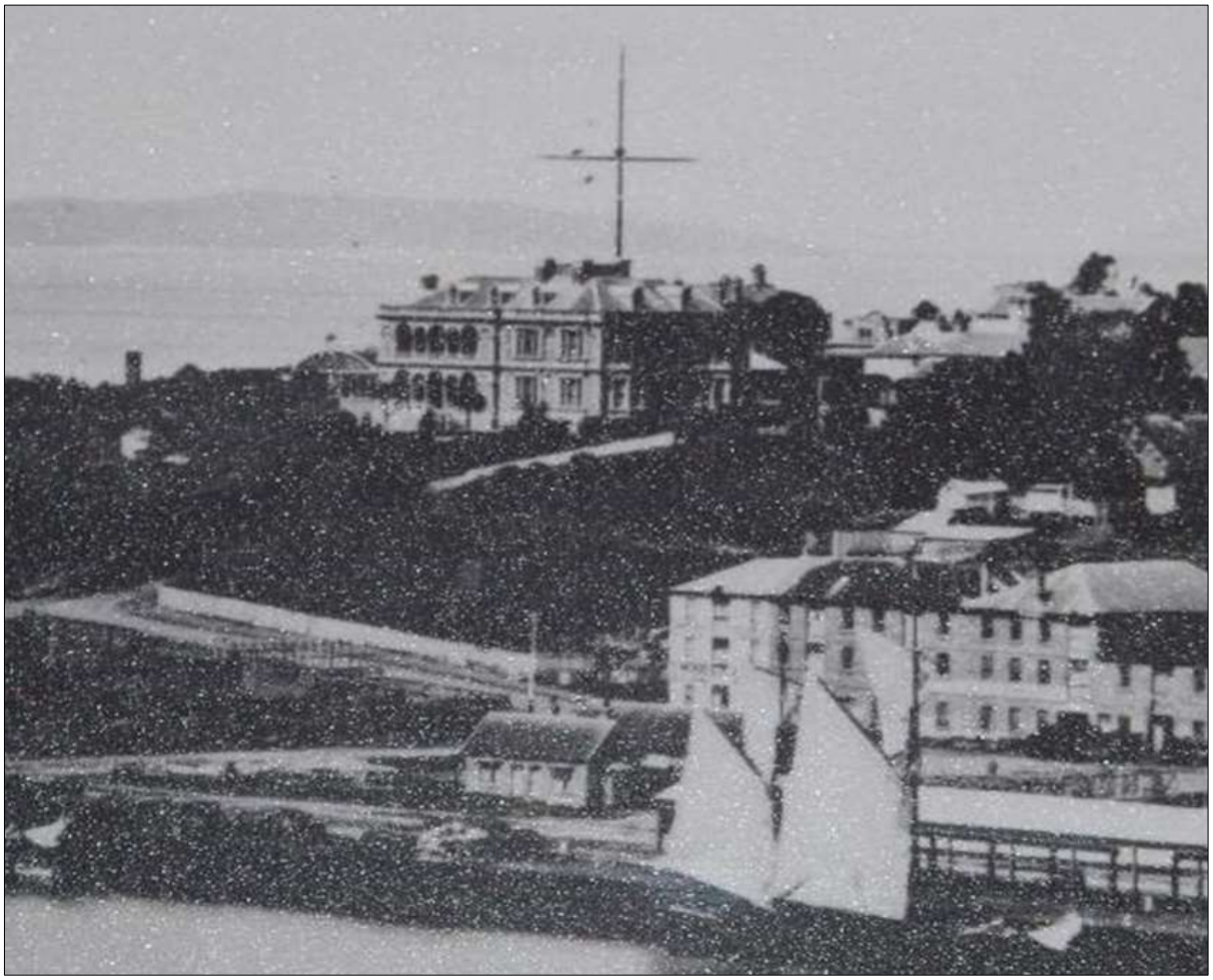


Figure 64: Hobart time ball in 1908 (courtesy: Martin George).

> days excepted), from the top of the flagstaff at Gellibrand's Point, at the instant of one o'clock mean solar time there, corresponding to 9h 41m 8s Greenwich time …
>
> Assigned position of the time ball, lat. 37d 52m 42s S., long. 144d 55m 28s E. (Ferguson, 1853).

Another time ball in Melbourne was introduced at the same time:

> A ball (painted red) will be dropped from a gaff attached to the top of the flagstaff daily (Sundays excepted) at one o'clock mean solar time. (Public Notice, 1853).

The drop times of both balls were published regularly in the *Melbourne Argus*. These early time balls are thought to have been made of wickerwork. Admiralty list entries from 1880 did not include time signals in the City of Melbourne, which would not have been visible to ships in harbour.

Ellery (1855) described his early work at Williamstown Observatory in a paper published in *Monthly Notices of the Royal Astronomical Society*. Initially, the time service was maintained at Williamstown using a small transit telescope, two chronometers and an astronomical clock. Ellery sought to improve the accuracy of time signals by purchasing new instruments. In March 1854 a new Telegraph Office was opened there and the time ball was transferred to a mast on the roof. The time ball had been moved to the top of the Old Lighthouse by 1862. This remained its location until the service was withdrawn in September 1926.

Williamstown had a deteriorating environment during the 1850s. In 1860 the Government appointed a Board of Visitors to oversee Ellery's astronomical work at Williamstown Observatory and Georg Neumayer's magnetic and meteorological researches at Flagstaff Observatory. The Board recommended that the observatories should be merged at a new site in Melbourne (Williamstown Observatory, 2022). This led to the establishment of Melbourne Observatory next to the Botanic Garden in 1863 (Melbourne Observatory, 2022). A gun for signalling time to Melbourne citizens was introduced in Melbourne in 1865.

The entries for Williamstown all stated that the ball was on the staff of the Old Lighthouse,

68 feet above ground, and that the drop was 11 feet (3.3m). The ball was listed as having a diameter of 5 feet (1.5m) in 1898. The ball was still black in 1908, but the lower half of the ball was red from 1911 onwards. It was an accurate signal, the ball being dropped electrically from Melbourne Observatory. It was stated in Admiralty lists that errors of more than ⅓ second would be posted in the following day's newspapers. The Williamstown tower and apparatus were restored in 2009 as a famous landmark and the ball can now be operated with a slow descent. The tower and ball are shown in Figure 65.

Figure 65: Williamstown time ball in 2011 (author's photograph).

A flag time signal was used at Queenscliff Signal Station for the whole of the period from 1880 to at least 1928. The flag "was dipped in coincidence with the time ball signal."

Another time ball was established at the Telegraph Office in Geelong in 1862. It was listed in 1880 and 1898 but had been replaced by a flag signal before 1908. There had been an intent to install a time ball on the Geelong Post Office tower (Geelong time ball, 1907), but the flag signal was still listed in 1916. This too was discontinued and a new time ball was eventually installed at the end of Moorabool Pier in 1921 or 1922. It was still listed in 1934. A replica time ball has been installed at the original Telegraph Station site and was operated for the first time in 2006. It is shown in Figure 66.

9.1.9 Western Australia: Fremantle

A time ball was introduced at Fremantle in 1900, after William Cooke (1863–1947) had been appointed Government Astronomer in Western Australia. He had previously worked with Sir Charles Todd in Adelaide who advised him on selection of a time ball design (Kinns and Abell, 2009). It was listed until at least 1922 as a black ball having a diameter of 5 feet and a drop height of 10 feet on the flagstaff at Arthur Head, dropped by electricity from Perth Observatory. By 1927, its indicated location had been changed to "Tower of Harbour Trust Office, Cliff Street" with almost identical latitude and longitude. The same entry was retained up to 1939 but was removed from the 1940 list.

A display at the time ball site (Fremantle, 2018) indicates that the time ball had been moved from its original location to the base of the then recently decommissioned lighthouse at Arthur Head in 1903. This is the location shown in Figure 67. The Federal Government reclaimed land at Arthur Head and required the time ball to be moved again. The tower of the Harbour Trust Office was the chosen site, but the move appears to have taken place before 1910. Also, the time ball and gun signal had been withdrawn before 1938. It appears that the Admiralty lists may not have been updated promptly.

It was also noted in Admiralty lists from 1927 that on weekdays a gun was fired when the ball was seen to drop. This gun was never included as a primary signal and was not mentioned at all in 1922 or earlier lists. Press announcements on display at Fremantle show that a time gun was first fired in October 1902, much earlier than its first mention in Admiralty lists. It also appears that gelignite was exploded in place of firing a cannon in later years (Fremantle, 2018). The modern arrangement in Fremantle includes a cannon and a representative ball dropped from a yard arm.

9.2 Signals in New Zealand

Signals in the Admiralty lists are summarised in Table 13. There were no visual signals after 1937. Various designs of time ball apparatus were used in New Zealand, some procured overseas and some made locally. The time lights were designed and built in New Zealand.

9.2.1 Wellington

The Wellington time ball was supplied by Sandys & Co in London (Maclear, 1863b; 1863c; see

Figure 66: The Geelong time ball, after restoration at its original site (https://www.workingheritage.com.au/places/geelong-telegraph-station).

Kinns, 2017a) and was operational at its first location in 1864. It was kept in store during a long period of harbour development and re-erected with a new ball at its second location in 1888 (Kinns, 2017a). The original ball had been destroyed and was replaced by a copy of the Lyttleton ball. Figures 68 and 69 show the time ball at its first and second locations. The time ball had an unusually large drop height for a system using a rack and pinion hoisting arrangement and a slotted mast. It burned down in 1909 and was replaced by time lights at the Dominion Observatory in 1912.

The lowest green lamp in a vertical array was illuminated first, the middle red lamp second and the upper white light last, at nominated intervals. This gave three preparatory signals, reduced to two when calibration using star transits were not available to give maximum accuracy. Extinction of all three was the time signal, repeated at least once. The timings changed over the years and the light signals were withdrawn in 1937 (Kinns, 2017b). Figure 70 is an early photograph of the installation.

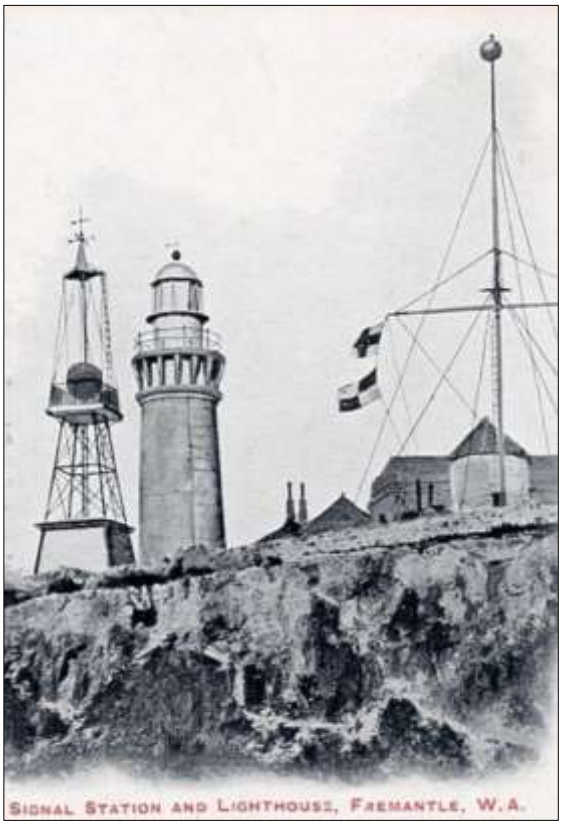


Figure 67: Fremantle time ball (Klaus Hülse Collection).

9.2.2 Auckland

The official time balls at Auckland had a chequered history and were never a success,

Figure 68: Wellington time ball at first location (Alexander Turnbull Library, H.N. Murray Collection, Ref: PAColl-0824-1).

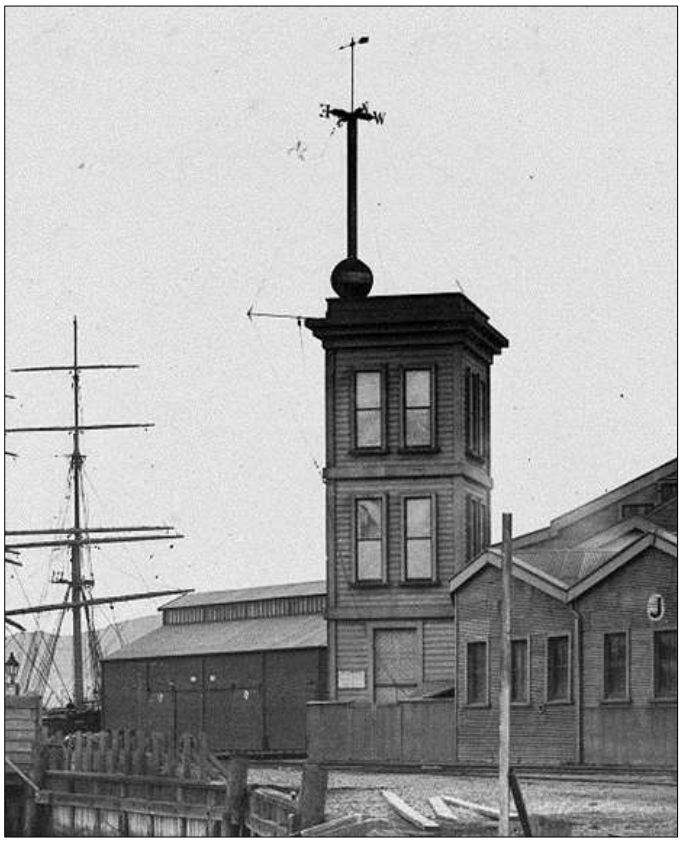


Figure 69 (left): Wellington time ball at second location after 1888 (Wellington City Archives 2012/2:6725).
Figure 70 (right): Wellington time lights in 1913 (Wellington City Council Archives, 2005/24-13-23, Dominion Observatory, photograph: W.F. Tibbutt).

for a combination of technical and management reasons (Kinns, 2017a). There had been an early time ball of unknown veracity as early as 1864 and various proposals to erect an official ball were published in the local press (*ibid.*). One was eventually erected on the Harbour

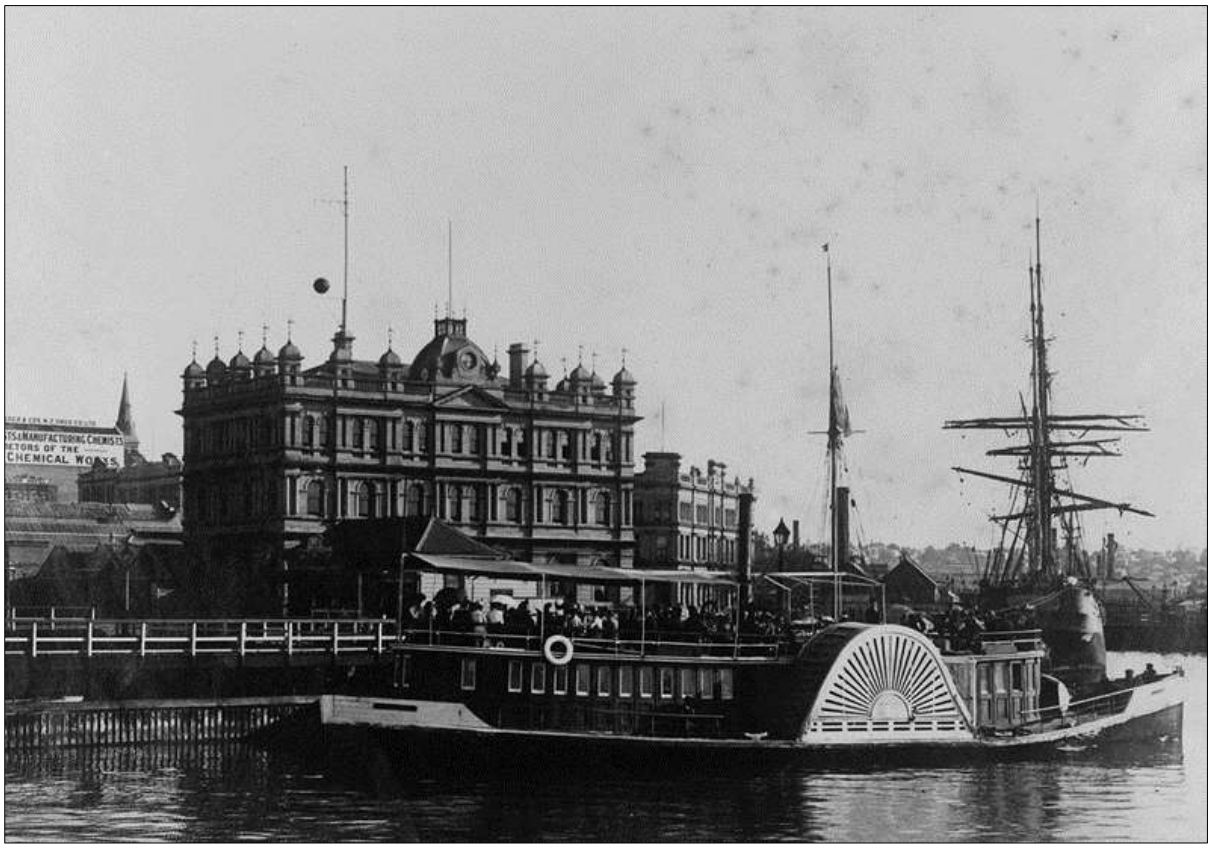


Figure 71: Auckland time ball on the Harbour Board Building in 1901 (Auckland Libraries Heritage Collections, 4-2938).

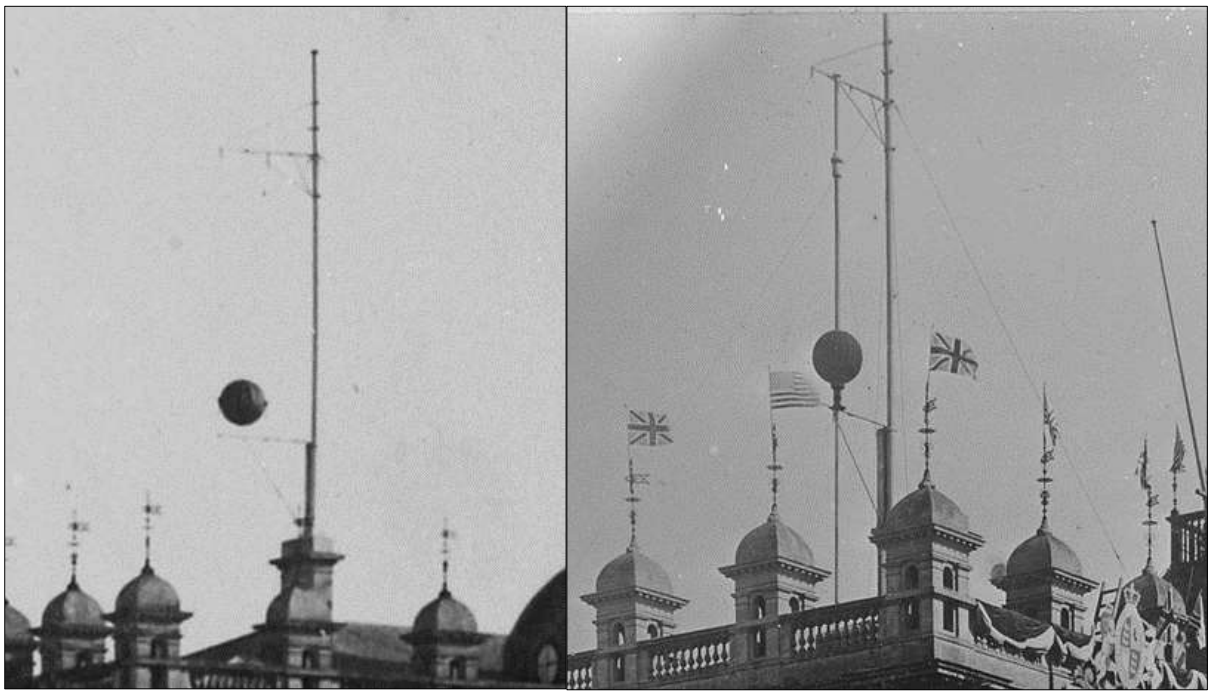


Figure 72: Auckland time ball on Harbour building in 1901 and after 1904 (Auckland Libraries Heritage Collections, 4-2938 and 4-889).

Board Building in 1901, as shown in Figure 71, but it soon acquired a reputation for poor reliability and the service was suspended in 1902. The external arrangement was altered from a ball that dropped between two guide wires to a ball sliding on a mast, as shown in Figure 72. The second photograph was taken in 1908, when the United States fleet visited Auckland

Figure 73: Auckland time ball on the Ferry Building in 1913 (Auckland Libraries Heritage Collections, 1-W1555).

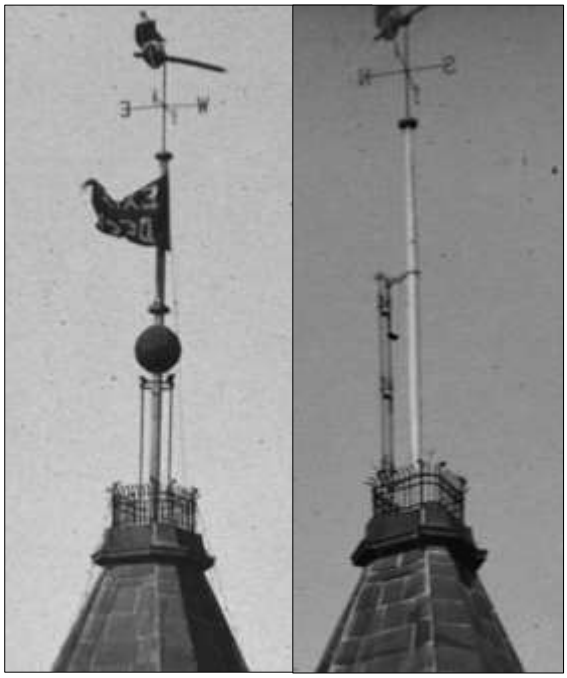


Figure 74: Auckland time ball in 1913 (left) and time lights (right) in 1915 (Auckland Libraries Heritage Collections, 1-W1555 and 1-W1321).

so the ball remained in place for several years. It featured optimistically in the 1904 Admiralty list but the service had been suspended again by the end of that year. It was never re-established on the Harbour Board building as an operational time ball.

Another time ball was installed on the then new Ferry Building in 1912, as shown in Figure 73. It too was the victim of technical and management problems and was only operational for a short period in 1915. It was replaced by time lights at the same location, as shown in Figure 74 (Kinns, 2017b). These remained in service until 1937, along with the time lights at Wellington, as the last visual time signals in New Zealand.

9.2.3 Lyttelton

The time ball system at Lyttelton, near Christchurch (Figure 75), was supplied from London by Siemens Brothers, but the mechanical apparatus had been made by the nearby firm of Maudslay, Sons & Field in 1873 as a replica of the apparatus the firm had made for Sydney Ob-

Figure 75: Lyttelton time ball station before 2011 (https://nzhistory.govt.nz/media/photo/lyttelton-timeball-station).

servatory in 1855. This was the 1873 system that was long thought to have been made for the Cape of Good Hope and was the only time ball apparatus ever supplied by Siemens (Kinns, 2009). The original drawing of the apparatus, supplied by Siemens Brothers in London, is shown in Figure 76. The time ball was regulated by telegraph from Wellington and the service was withdrawn in 1934. The apparatus was restored to working order in the 1970s and the time ball station was an iconic landmark, but the building collapsed during the major 2011 earthquake that (along with the 2010 earthquake) devastated Christchurch and the original apparatus was severely damaged. As much as possible of the original apparatus was saved from the debris. The ball itself has been restored and is now dropped using a modern electrical arrangement within a reconstructed tower.

Figure 75 shows the time ball tower at Lyttelton, as it was before the 2010 and 2011 earthquakes. The ball was then painted black with a red band. The ball was the original supplied from England, but its colour is likely to have been changed on more than one occasion. It is now red with a white band after restoration.

9.2.4 Port Chalmers

The arrangement at Port Chalmers is thought to have been made locally and was operated from 1 June 1867 as a daily service, excluding Sundays, using local observatory facilities (Customs Entries, 1867). The service had been withdrawn by 1878 and was not included in the 1880 Admiralty list (Kinns, 2017a). It was re-established in 1882 at the same location and regulated from Wellington as a weekly service. Figure 9.20 shows the arrangement in 1905. It was finally withdrawn in 1909. The design was different to others in New Zealand (see Kinns, 2017a). A replica arrangement, externally similar to the original, is now operating using a modern electrical system.

9.3 Signals in the Pacific Islands

Some Pacific islands provided telegraph time signals that could be accessed upon going

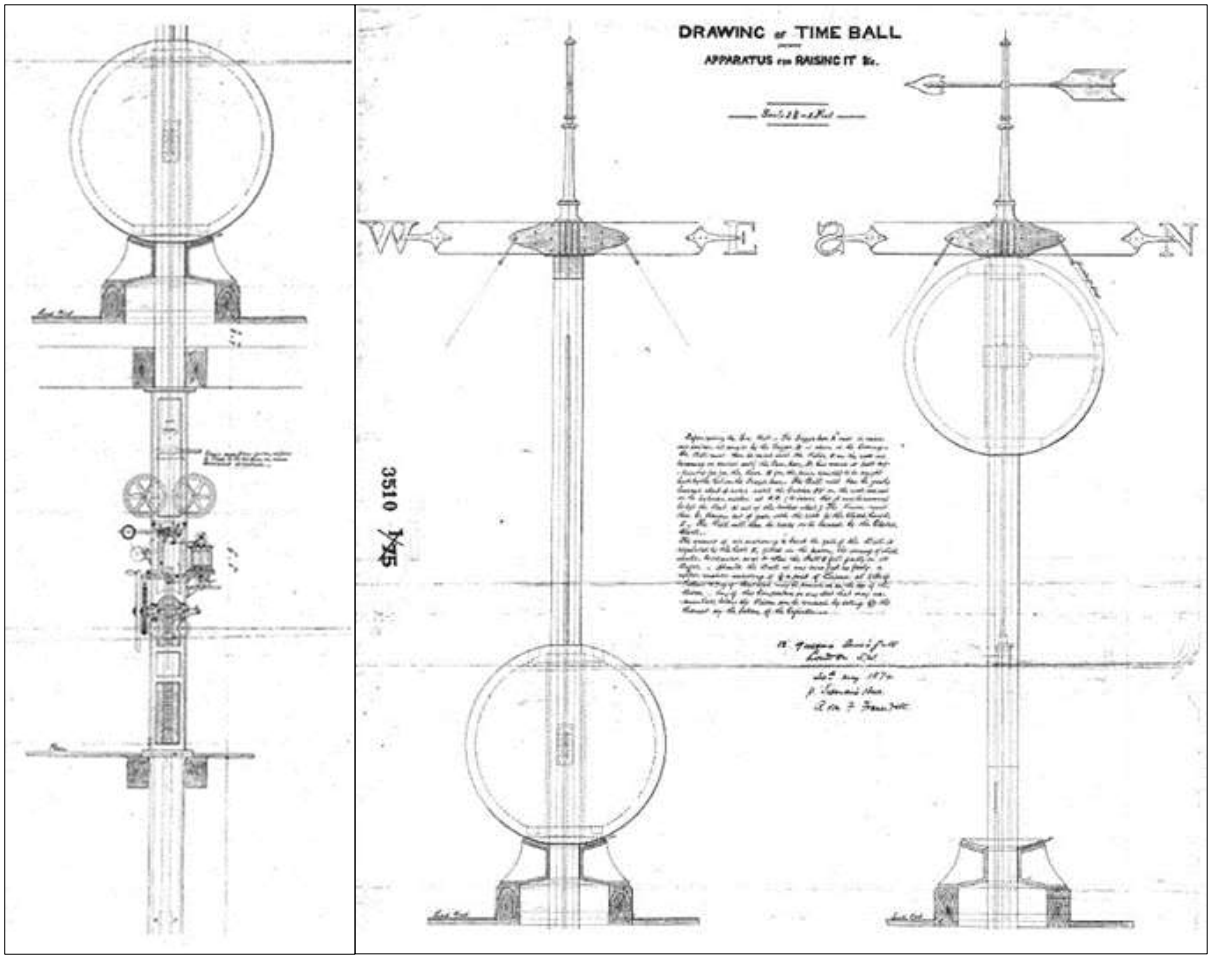


Figure 76: 1874 drawing of Lyttelton time ball apparatus (Wellington Harbour Board Archive, Drawing Office No. 3510).

Figure 77: Port Chalmers time ball in 1905 (Ref: 1/1-002534-G. Alexander Turnbull Library, Wellington).

ashore. These were included in Admiralty lists. One example was at Suva, in the Fiji Islands, established in 1912. Another was at Yap in the Caroline Islands.

There was a whistle at Honolulu from before 1898 to after 1922 which was located on a steam mill near the harbour. The whistle exhaust may have been visible to ships. The time for a sound signal to reach the harbour was only about 2.5 seconds, so the propagation correction time would have been known accurately. There were no listed time balls.

10 SIGNALS IN NORTH AMERICA

Table 14 shows how visual time signals in the USA and Canada evolved between 1880 and 1947. Time ball colours have been included when stated in Admiralty lists. Their locations are shown in Map 12. Time lights were never listed for North America and time guns were only listed for Canada and Newfoundland.

The number of time balls in the USA and Canada reached a maximum of 24 in the 1908 and 1911 lists. It had fallen to 9 in the 1939 list and to only one at New York in 1947.

Table 14: Signals in North America.

Area	Location	1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Great Lakes	Duluth			(red)	(red)	(red)						
	Sault St. Marie			(black)	(black)	(black)						
	Chicago				(red)	(red)						
	Cleveland				(black)	(black)						
	Buffalo			(black)	(black)	(black)						
USA (East Coast)	Boston	(copper)		(black)	(black)	(black)	(black)	(black)	(black)			
	Newport RI		(black)	(black)	(black)	(black)						
	Woods Hole		(black)									
	New York	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)
	Philadelphia			TB	TB	(black)	(black)	(black)				
	Baltimore		(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)		
	Washington	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	
	Newport News				(black)	(black)	(black)					
	Norfolk			(black)	(black)	(black)	(black)	(black)	(black)	(black)		
	Savannah		(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)		
	Key West				(black)	(black)	TB	TB	TB	TB		
USA, (Gulf of Mexico)	New Orleans		(black)	(black)	(black)							
	Galveston			TB	TB	TB	TB	TB				
USA (West Coast)	San Francisco		TB	TB	TB	TB	TB	TB	TB	TB	TB	
	Mare Island		(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	
	Portland				TB	(r, w.)	(r, w.)	(r, w.)	(r, w.)	(r, w.)	(r, w.)	
Newfoundland	St. John's	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun
Canada	Saint John	(b, g.)	(b, g.)	(b, g.)	(b, g.)	(b, g.)	(b, g.)	(b, g.)	(b, g.)	(b, g.)	(b, g.)	
	Quebec	(black)	(black)	(black)	(black)	TB	TB	TB	TB	TB	TB	
	Montreal	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	(black)	
	Halifax				(black)	(black)	(black)	(black)	(black)	(black)	(black)	
			Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun
	Vancouver			Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun
	Victoria						TB	TB	TB	TB	TB	
												Gun
Signal type totals		1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Time ball, including collapsible		6	12	18	24	23	18	17	15	14	10	1
Gun, including powder flash		1	2	3	3	3	3	3	3	3	3	4
Lights		0	0	0	0	0	0	0	0	0	0	0
Other: disc, drum, flag, etc.		0	0	0	0	0	0	0	0	0	0	0

10.1 Signals in the United States

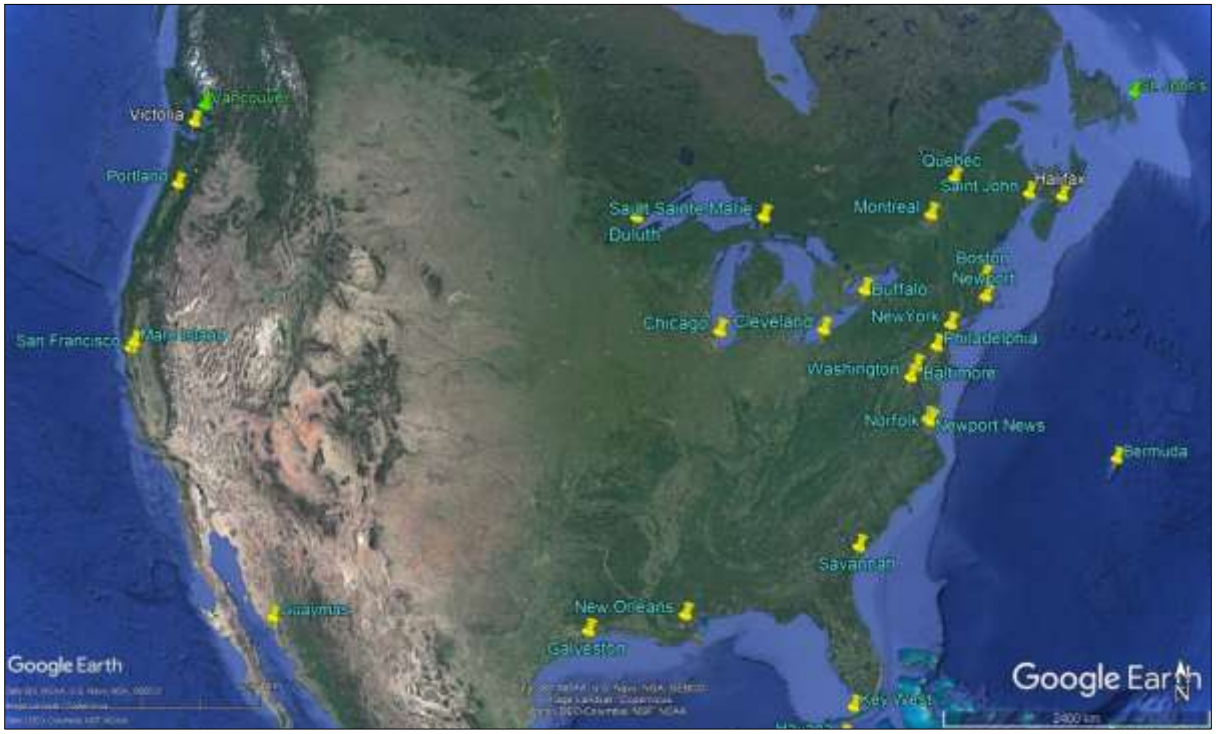
A comprehensive discussion of time signals in the USA has been presented by Bartky (1983), who included images of the many different time balls that used to exist around the coasts of the United States. Many of the images in Bartky's paper are included in the collection assembled by Hülse (2022) and are reproduced in this paper.

Wauchope had proposed the use of time balls for rating chronometers in the USA in his 1830s correspondence, but the required infrastructure for accurate measurement and distribution of time with such a large coastline took a long time to develop. Time balls at Washington DC, New York City, and Boston were the only entries for the USA in the 1880 Admiralty list, although many other time balls had been erected for public use across the USA by that time. The history of these three time balls will be considered later in more detail. The history of the Washington time ball, the first to be introduced in North America, has been described by Bartky and Dick (1982). The 1981 and 1982 papers by Bartky and Dick have been reprinted in Dick (2020).

10.1.1 Time Balls for Chronometer Rating in the USA

Two time balls for rating chronometers in the USA were identified in an 1877 report prepared for the Secretary of the Navy (Rodgers, 1877). These were at Washington DC and New York City. The author of the report was Rear Admiral John Rodgers (1812–1882), who was Superintendent of the Naval Observatory from 1877 to 1882 (Dick, 2003: 168).

The time ball at New York became operational in September 1877. It was anticipated prematurely that another at Baltimore would



Map 12: Signals in North America, Mexico and Bermuda (map: Roger Kinns).

soon be erected. The failure rate of the time-ball signal at Deal in England, which was dropped by direct telegraph signal from Greenwich, was also noted. Extracts from the report for 1877 are shown below:

> In September arrangements were perfected for dropping a time-ball in New York City at exact New York noon; and on the 10th of that month the ball was dropped from the chronometer room for the first time. It has been dropped at New York mean noon daily, except Sundays, to the present time, without a single failure.
>
> It may be of interest to remark that the time-ball at Deal, England, which is dropped by signal from the Royal Observatory at Greenwich, is subject to about fifteen failures annually …
>
> This New York time-ball is already used … in rating the ship's chronometers.
>
> The Baltimore Board of Trade contemplates the establishment of a similar time-ball at Baltimore, to be dropped at Washington mean noon daily, except Sundays; and it is to be hoped that similar time-balls may be established gradually at various other ports. (Rodgers, 1877).

The corresponding report for 1878 (Rodgers, 1878) stated that there had been eight failures of the New York time ball drop since its introduction in September 1877, for a variety of reasons. The Baltimore time ball was not mentioned in the 1878 report.

Time balls for marine chronometer calibration were adopted enthusiastically after 1880. Bartky (1983) described how time was disseminated by telegraph around the United States, initially using observations from different observatories but later using telegraph signals from Washington, DC throughout the Nation. By 1888, time balls at Woods Hole, Massachusetts; Newport, Rhode Island; New York City; Philadelphia, Baltimore; Hampton Roads; Savannah; and New Orleans were regulated by telegraph signals from Washington (Dick, 2003: 189). Bartky (1983) included a chart showing approximate dates of operation. Time ball apparatus was changed and moved between buildings in various American cities. These changes are not shown in Table 14. Dick (2003: 46) noted that 19 time balls were dropped using telegraph signals at principal ports in 1905. Many had been introduced in the early years of the twentieth century. The Admiralty lists for 1908 and 1911 included 20 time balls in the USA, while only 9 had been listed in 1898 and 16 in 1904.

Ironically, the best-known time ball of them all, dropped slowly at Times Square in New York to announce the arrival of each New Year since 1908, with the exception of 1942 and 1943, had nothing to do with chronometer rating.

Most, but not all, time balls in the USA had small diameters and light weights relative to

most of those used in the British Isles, where a diameter of 1.5m had been preferred after visibility trials at Greenwich that preceded erection of the 1833 time ball. Many had diameters of 1.2m, but some were much smaller. Even the Washington time ball had a diameter of less than 0.9m.

The following summary concerning the first time signals in Washington is derived primarily from the authoritative history of the Naval Observatory in *Sky and Ocean Joined* (Dick, 2003). The Observatory was the home of the first visual time signal in the United States in 1845, but the signal was not promoted initially as a means for rating chronometers.

10.1.2 Washington, DC

The Depot of Charts and Instruments had been founded in 1830. Its functions included selection and calibration of chronometers for the US Navy, using a transit telescope to rate chronometers and to check rate stability before issue to ships. There was no provision for visual time signals that could be seen outside the Depot. The organisation developed into the Naval Observatory which became operational in 1844. Matthew Fontaine Maury (1806–1873) was Superintendent from 1844 to 1861 (Dick, 2003: 60). The Observatory was located initially at Foggy Bottom in Washington close to the Potomac River. It was relocated in 1893.

Secretary of the Navy John Mason (1799–1859) wrote to Lt. Maury, on 10 December 1844 "You will be pleased to devise some signal by which the mean time may be made known every day to the inhabitants of the city of Washington." Maury responded quickly by ordering a flagstaff, stays, halyards and a black ball with a diameter of 3 feet (0.9m) from the Navy agent in Washington (Dick, 2003: 85). The time ball service was announced in the *Daily National Intelligence* on 2 January 1845, but the nature of the ball and its dropping arrangements appear to have been subject to subsequent experimental development (Dick, 2003: 85). In February 1845 Maury (1845) wrote to the New York agent for Charles Goodyear, the inventor of vulcanised rubber:

> Be pleased to make and send … four air tight balls of Gumelastic Composition capable of being inflated into spheres. They are wanted for signal balls … Let two of the balls be at least 4 feet in diameter when inflated one of 3 feet and one of 18 inches …

These balls may have been for various purposes, not necessarily for signalling time. A letter in May 1845 to another supplier in New York included the statement "What will you charge for that copper ball? I may want it for a time ball."

The ball was dropped at noon each day, except Sunday, above the dome of the 9.6-inch refractor at the Observatory's original site and served as the first public time service in the USA. The early arrangement is shown in Figure 78 (Anonymous, 1846; Bartky, 1983; Dick, 2003). It was a far cry from the sophisticated 1833 arrangement at Greenwich, England.

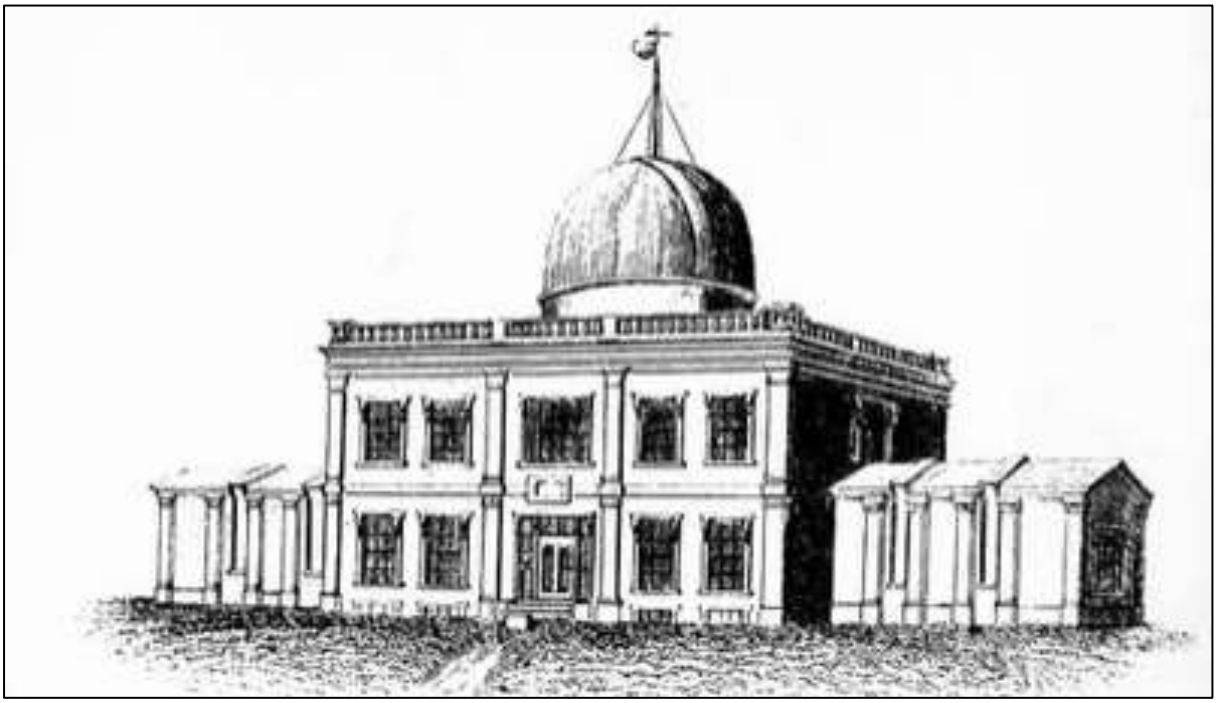


Figure 78: The first time ball at the Naval observatory in Washington (after Bartky, 1983).

The Washington time balls were of light construction (Dick, 2003: 154; from Gilliss, 1863):

> In 1863, the supply of time balls having been exhausted, Gilliss ordered three others to be constructed. As in the past, they were constructed of hoops of hickory three feet in diameter, covered with canvas painted black, and fitted with a loop at each extremity of diameter, the latter undoubtedly for attachment to the flagstaff atop the Observatory dome.

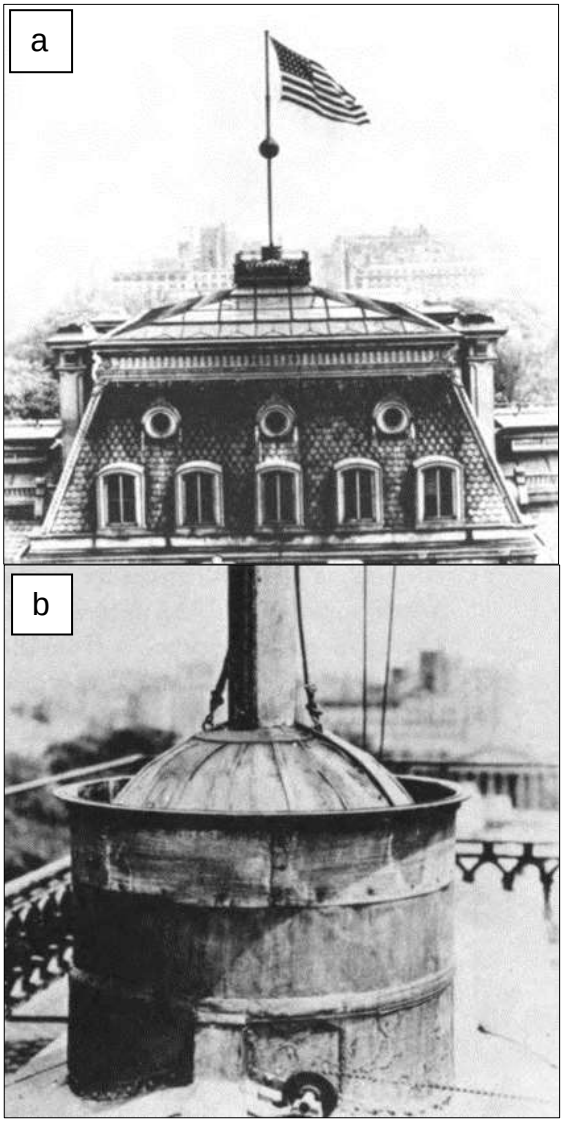


Figure 79: Washington time ball on the Executive Office building (after Bartky, 1983).

James Melville Gilliss (1811–1865) succeeded Maury as Superintendent in 1861 and saw the Observatory through the Civil War (Dick, 2003: 45).

The time ball was dropped manually until some time in the 1850s (Dick, 2003: 186). It may have been operated like a flag signal for at least part of that period, using halyards to lower the ball. It was subsequently dropped by a clock observer who pressed a key to release electromagnetic triggers. This was changed to automatic operation in 1879. Halyards were used for hoisting the ball throughout its existence, rather than a mechanism for pushing the ball up a slotted mast. According to the 1880 Admiralty list, the black ball had a diameter of only 2 feet 8 inches (0.8m) and a drop height of 12 feet (3.6m). It was 162 feet above high water and 68 feet above ground, located at the "Marine Observatory" with latitude and longitude 38° 53′ 39″ N, 77° 3′ 6″ W. It was dropped at noon local time, 5h 8m 12.4s behind GMT.

The time ball was relocated in 1885 to the nearby State, Navy and War building where it would be more visible (Dick, 2003). However, automatic ball release was discontinued. The Naval Observatory itself was relocated further north to Massachusetts Avenue in 1893 but the time ball remained at its 1885 location. The time ball description had changed significantly in the 1898 Admiralty list when its location was given, misleadingly, as the "Naval Observatory". The Observatory was the source of the signal but was not the time ball location in 1898. The stated time ball latitude was unchanged from 1880 but the longitude had increased slightly to 77° 3′ 8″ W. There were significant changes to other parameters after 1880. The ball diameter was changed slightly to 2 feet 10 inches but the drop height had more than doubled to 25 feet by 1898, while the heights above high water and ground had been increased to 205 feet and 157 feet respectively. The drop time was then 5h GMT or 23h 51m 47.5s local time, based on zero hours at noon. These details were repeated until at least 1911. The principal change after that was in the description of the building, rather than the time ball location. It was given as the State, Navy and War building in Admiralty lists after 1915. There were some minor changes to the principal dimensions after 1919. In the 1922 list the drop height was reduced to 21 feet, while the heights above high water and ground had been reduced to 197 feet and 150 feet respectively. The ball diameter was then given as 2 feet 7 inches. These parameters were still the same in lists up to 1946. Dick indicated that the Washington ball was dropped until 1936 (Dick, 2003: 468), so such late Admiralty list entries are surprising. It had been deleted from the 1947 list.

Figure 79a shows the time ball at its location on the State, Navy and War building, specifically the Executive Office building. Figure 79b shows the lowered time ball in a tub with the halyards used for hoisting the ball (Bartky, 1983). A new time ball at the U.S. Naval

Observatory was erected in 1999 for the Millennium celebrations (Dick, 2020: Figure 26.5).

10.1.3 East Coast Time Balls

Time balls on the East Coast extended from Boston in the north to Key West in Florida. A time ball at Woods Hole, Massachusetts was listed in 1898 but not in 1904 or later. There was no time ball at Hampton Roads in Admiralty lists: they referred instead to an accessible regulated chromometer. The Admiralty lists for 1908, 1911 and 1915 included 10 east coast time balls, many at naval dockyards. These were at: Boston, Newport RI, New York, Philadelphia, Baltimore, Washington DC, Newport News, Norfolk, Savannah and Key West. The time balls at Newport RI and Newport News were no longer listed in 1922. The time ball at Philadelphia had been delisted by 1928.

The black time ball at Newport RI had an unusually large diameter of 6 feet (1.8m) and a 24 feet drop height after it was moved from the machine shop to a wireless mast (Notice, 1911). Its diameter and drop height were given as 3.5 feet and 16 feet in Admiralty lists up to 1911, which had been prepared in the previous year. The revised parameters were listed after 1911. The Newport time ball service was discontinued in 1918 when the wireless mast was removed (Notice 1918).

Another time ball had been established at Hampton Roads (Bartky, 1983) but this was not listed by the Admiralty in 1898 or later. The service was "suspended temporarily" because the apparatus was out of order in 1896 (Notice, 1896) so there may have been longer term reliability problems.

Those at New York and Boston will be discussed in more detail. The east coast time balls remaining in the 1939 Admiralty list were at New York and Washington.

10.1.4 New York

The first time ball in New York City was on the Custom-house at 55 Wall Street, which had been built in 1842. It had been operated using a telegraph signal from the "Dudley Observatory, at Albany" (The Electric Time Service, 1878). It was stated to have been in operation twenty years before 1878, so its approximate year of introduction was 1858. Bartky (1983) gave its date of introduction as 1859/1861. It is shown in Figure 80. This time ball was for public use rather than chronometer rating.

A new time ball in New York was erected in 1877 for chronometer rating (Rodgers, 1877; 1878). The 1880 Admiralty list described its location as "Staff on tower of Western Union

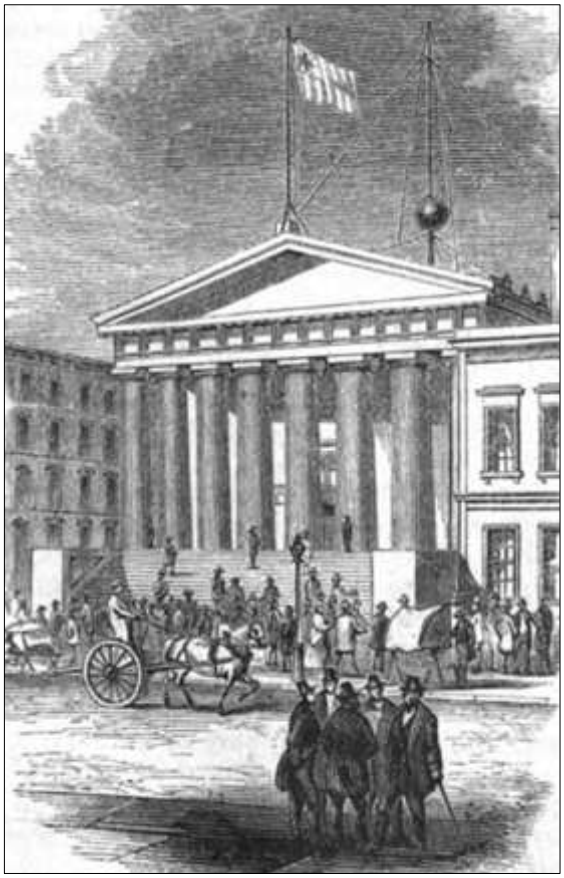


Figure 80: New York time ball at the Custom-house (The electric time ball, 1878).

Telegraph Office." Its diameter was 3.5 feet (1.05m). Lists up to 1911 gave similar details and specified that the ball was black with a drop of 25 feet (7.5m). This is consistent with the description "It was to be made of copper-wire netting painted black, and 3.5 feet in diameter." (Dick, 2003: 186). The alternative design shown in Figure 81 used ten segments at 36° intervals

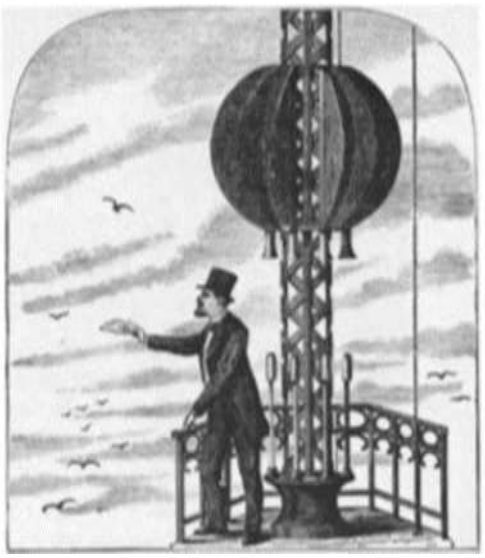


Figure 81: New York time ball design (The electric time ball, 1878).

around a vertical axis to simulate a spherical ball. It was published in *Scientific American* (Bartky, 1983; Electric time ball, 1878), but may have been just an illustrative arrangement.

The Western Union announced in 1914 that their office building at 195 Broadway was to be demolished and that "No provision has been made for a time-ball service …" at their new location at 15 Dey Street (Notice, 1914). It had been replaced by a time ball at the "Seaman's Church Institute" in 1913, about 1.6km away. This was described as a black ball with a diameter of 4 feet (1.2m) and a drop of 16 feet (4.8m) in Admiralty lists from 1915 to 1947. These time balls were entirely separate from the Times Square arrangement that has welcomed the New Year since 1908.

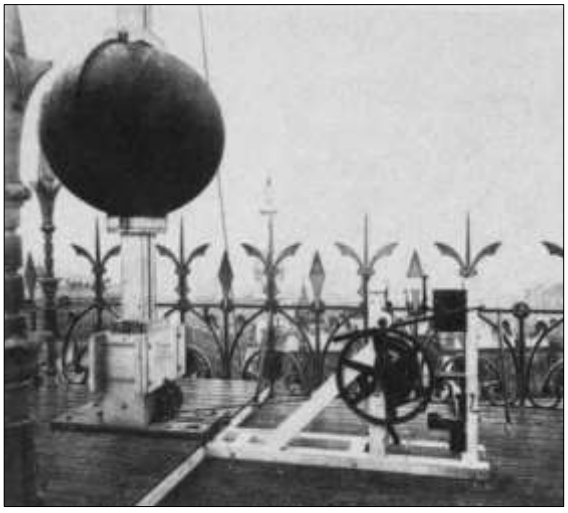


Figure 82: Boston time ball (Bartky, 1983).

10.1.5 Boston

The Boston Time-Ball became operational in May 1878 on top of the Equitable building (Lumbricht, 2015). The ball was made of rolled plate copper and had a diameter of 4 feet (1.2m). It was an unusually heavy time ball and weighed 180kg (Bartky, 1983). It had a drop height of 4.8m. A friction brake mechanism was used to stop the ball. Figure 82 shows the ball in its rest position. The time signal to release the ball was relayed from the standard clock at Harvard College Observatory in Cambridge by telegraph wire to the ball location (Lumbricht, 2015). These details are consistent with the 1880 Admiralty list which gave the time ball as "located on a mast on a building near the Harbour Signal Office."

There was no Admiralty list entry in 1898, so the original ball appears to have ceased operation by that time. A new time ball was erected in 1902 on the roof of the Ames building, then the highest building in Boston (*ibid.*). A black time ball with the same 1.2m diameter as the 1878 ball was listed by the Admiralty between 1904 and 1932. It was removed from the 1933 Admiralty list and was never reinstated.

10.1.6 Gulf of Mexico

A time ball at New Orleans was listed from 1898 to 1911. Another at Galveston, Texas was introduced in 1901 (Notice, 1901) and was listed from 1904 to 1922.

10.1.7 West Coast: Mare Island, California

There were no visual time signals for the Pacific coast of North America in the 1880 Admiralty list. The Naval Observatory at the Mare Island naval shipyard, north of San Francisco, distributed time to locations on the Pacific coast from 1884 (Bartky, 1983; Dick, 2003: 192–193). Time balls were soon established at Mare Island and San Francisco. A new longitude determination by telegraph in 1908 showed that there was a small error in Mare Island time, corresponding to a longitude error of about 5 arc-seconds.

In 1898, the latitude and longitude of the Mare Island time ball were given as 38° 5′ 53″ N., 122° 16′ 16″ W. The black ball had a diameter of 0.9m and a drop height of 4.5m. In 1908, the coordinates had been adjusted to 38° 5′ 57″ N, 122° 16′ 6″ W. There was a further small adjustment in longitude to 122° 16′ 9″ W by 1922, but no changes thereafter.

10.1.8 West Coast: San Francisco, California

A time ball on Telegraph Hill was established in 1885. It had a diameter of 0.9m and a drop height of 4.5m, as at Mare Island. The location was changed to the Ferry Building (Notice, 1898). The Ferry building time ball mast was bent in the 1906 San Francisco earthquake (Bartky, 1987). The time ball was moved to its final location on the Fairmount Hotel building in 1911. The three locations are shown in Figure 83. Their respective coordinates were given in Admiralty lists as: 37° 48′ 5″ N, 122° 24′ 20″ W; 37° 47′ 38″ N, 122° 23′ 38″ W; 37° 47′ 27″ N, 122° 24′ 36″ W. The same diameter and drop height were used throughout. The Mare Island and San Francisco time balls were still listed in 1939 but had been withdrawn by 1947.

10.1.9 West Coast: Portland, Oregon

The time ball at the Portland Custom House was listed from 1908 until 1939. It had a typical diameter of 1.2m but it was noted as deep red with a white band in lists from 1911 onwards. As

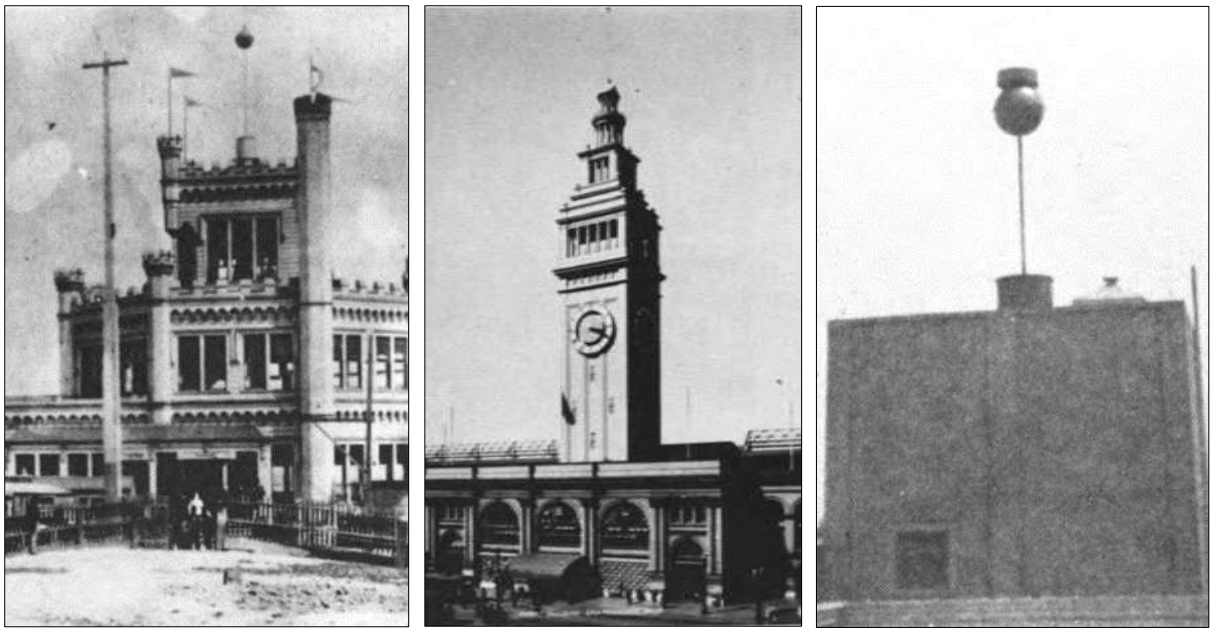


Figure 83: San Francisco time balls: Telegraph Hill; Ferry Building; Fairmont Hotel (Bartky, 1983).

at other West Coast locations, it was dropped by the Mare Island Observatory at noon, standard time of the 120th meridian, 8 hours behind GMT. Its latitude and longitude were 45° 31′ 39″ N, 122° 40′ 44″ W.

10.1.10 Great Lakes

The Admiralty list for 1908 included five time balls on the Great Lakes. These were at Duluth, Minnesota and Sault St. Marie on Lake Superior; Chicago, Illinois on Lake Michigan; Cleveland, Ohio and Buffalo, New York on Lake Erie. They were also included in the 1911 and 1915 lists and all apart from Chicago and Cleveland had appeared in the 1904 list. The time balls at Duluth and Chicago were painted red but the others were black. Their diameters varied between 0.9m at Sault St. Marie to 1.3m at Chicago and Cleveland. They were all deleted in Admiralty lists from 1916 onwards. Bartky (1983) indicated that some of the Great Lakes signals may have continued at some locations into the 1920s. Table 14 is otherwise consistent with Bartky's findings from independent sources in the USA.

10.2 Signals in Newfoundland and Canada

10.2.1 Newfoundland

The only signal in Newfoundland, now a province of Canada, was the 32-pounder time gun on Signal Hill at St. John's. This was listed throughout the period from 1880 to 1947. The 1880 list included the comment "No preliminary signal is given." Lists from 1898 onwards included the unusually strong statement "The signal has been reported to be useless for rating chronometers."

10.2.2 Eastern Canada: Quebec City

The first visual time signal in Canada was erected on the Citadel in Quebec City in 1852 or soon afterwards. It was implemented by Edward David Ashe (1814–1895). His distinguished early career in the British Royal Navy and his subsequent work as an astronomer in Canada have been described by Jarrell (1975; 1990). He was invalided out of the Navy after a shipboard accident in 1849 and was offered the directorship of a proposed new observatory in Quebec. He arrived in Quebec in 1850 to supervise development of the observatory, using instruments supplied from Greenwich. The exact date of time ball introduction is uncertain but the apparatus was procured from Messrs Forrester in Liverpool, England (Airy, 1871) and shipped to Quebec. It was erected in July 1852, soon after its delayed arrival (Jarrell, 1988). The following notes are on display at the restored Ball House, which includes a static representation of the time ball arrangement.

> In 1857, the exact longitude of Quebec City was determined by linking it to the longitude of Harvard based on an exchange of astronomical clock beats using the telegraph network rather than the signals of star transits … the longitudes of Montréal, Toronto and Kingston were determined based on the longitude of Quebec City.
>
> Ball House was the most accurate source of time available to navigators for a number of years … During the navigation season from May 13th to November 29th the time ball was used every day except Sunday. It was raised to the half-way point at

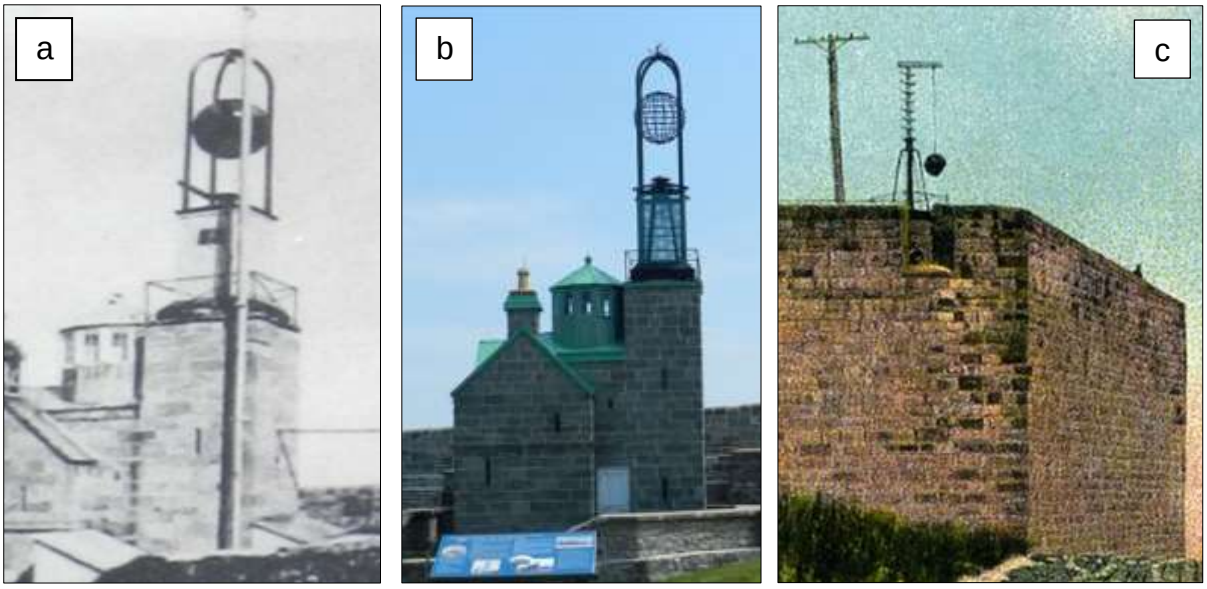


Figure 84: Quebec Citadel time balls: a) 1870 photograph (Ball House, 2007); b) modern restored arrangement at the Ball House; c) arrangement using a yard-arm (Klaus Hülse Collection).

> 12:45 p.m., was at the top by 12:55 p.m., and was dropped at 1:00 p.m. local time.
>
> In 1874, the Citadel's observatory and its instruments were moved to a new building located in Bonner pasture on the Plains of Abraham. The time ball remained at the Citadel and was converted to run on electricity.

Ashe had erected an equatorial telescope at the Plains site in 1865 but other instruments, including the transit telescope, were retained at the original site until 1874, when additional buildings had been completed (Jarrell, 1975).

The 1880 Admiralty list included the following details, which are consistent with the above notes after the observatory relocation. It is, however, possible that the time ball arrangement had been changed in 1874 (see later):

> At the Citadel, 1,370 yards from the Observatory.
> 355 feet above high water.
> 46 feet above ground.
> (Drop 8 feet)
>
> Ball dropped (by electricity from the Observatory) at 1h 0m 0s Quebec mean time.

The latitude and longitude of the time ball were given as 46° 48′ 23″ N, 71° 12′ 17″ W. Quebec mean time at noon corresponded to 4h 44m 50.3s GMT in 1880.

The 1898 list included the same details about the location, except that the ball was dropped at 6h 0m 0s GMT, or 1h 15m 11.0s local mean time. Quebec mean time had been changed to 5 hours behind Greenwich by 1898. There had been a local mean time adjustment of 1.3 seconds at some time after 1880, or a longitude correction of 18 arc-seconds. The following details about preparatory signals were included in the 1898 list, and are consistent with the Ball House display:

> Ball hoisted half way up as preparatory 15 minutes before signal.
> Ball hoisted close up 5 minutes before.
> Ball dropped (by electricity from the Observatory) at 1h 00m 00s mean time for 75° W. long., or 5h 00m 00s from the meridian of Greenwich.
> [*Note*. – Signal not made on Sundays.]

The above details were repeated until the signal was withdrawn, apart from the change to civil time based on zero hours at midnight in 1925. By 1908, the stated longitude of the "Signal Station" had been adjusted to 71° 12′ 35″ W: the local mean time was then consistent with the stated longitude of the signal. It became common after the introduction of time zones to indicate the latitude and longitude of the signal location to the nearest arc-minute: the precise time of the signal was the critical parameter.

There is a mystery about the time ball installation itself. An 1870 photograph is shown in Figure 84a (Ball House, 2007). The arrangement then used a caged ball, which was later used at several other locations in eastern Canada. The modern static arrangement at the restored Ball House includes a representation of this original design (Figure 84b) but the associated display also shows another design, where an uncaged ball was dropped from a yard-arm (Figure 84c). This design may have been introduced after instruments had been relocated in 1874. All the Admiralty lists from 1880 onwards included the same time ball parameters.

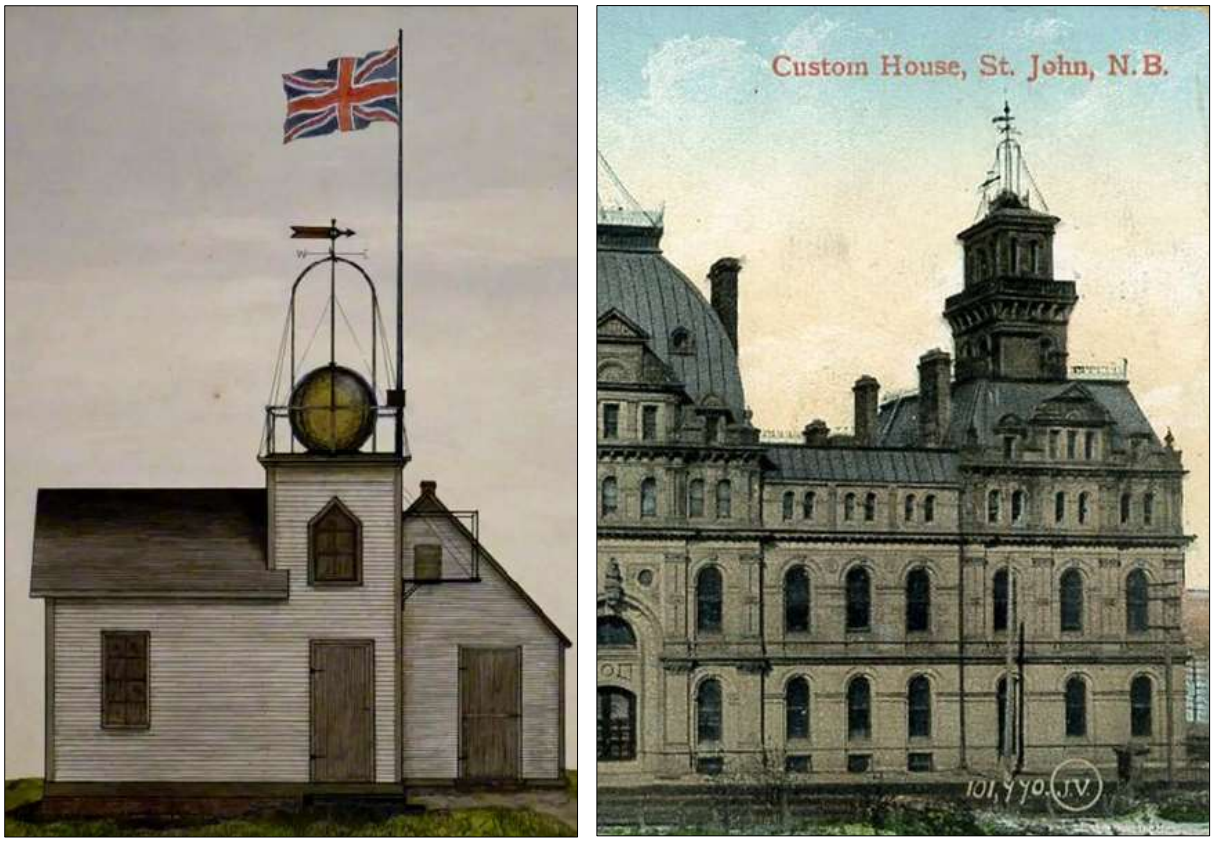


Figure 85: Saint John, NB time balls (Klaus Hülse Collection).

10.2.3 Eastern Canada: Other Locations

The first astronomical observatory in Canada was established at Fredericton, New Brunswick in 1851, thanks largely to the persistence of William Brydone Jack (1817–1886) who was a Professor at King's College, Fredericton, and an amateur astronomer (Kennedy, 1982). Jack and colleagues determined the longitude of Fredericton in 1854 by exchanging clock signals and star transit timings with Harvard College Observatory in Cambridge, Massachusetts, using a telegraph link. The Harvard longitude had been determined by exchange of numerous chronometers with Greenwich, there being no transatlantic telegraph cable at that time. This in turn allowed Ashe to re-determine the longitude of Quebec which was the meridian reference for other locations in British North America. It was almost two decades before a time ball was established at Saint John, New Brunswick. The time ball at Montreal followed in the 1860s, but a time ball at Halifax, Nova Scotia was not listed until the twentieth century.

Several time balls in eastern Canada used a caged arrangement so the time ball could be operated in harsh winter conditions (Bartky, 1983).

In 1880, time balls were listed at Saint John, New Brunswick and at Montreal, as well at Quebec City. The Saint John time ball was distinguished by its gold band, the others being black. It had been established at Fort Howe in 1870 and later moved to the Customs House, continuing with the caged arrangement, as shown in Figure 85. Another black time ball, also caged, was first listed for Halifax, Nova Scotia in 1908. It had been erected in 1904 (Brooks, 2022). Figure 86 shows the arrangement at Halifax. These time balls in eastern provinces were still listed in 1939 but not in 1947.

A time gun at Halifax was listed between 1898 and 1947. A description of its operation was published in 1891 which also included a short history of earlier signals at Halifax which had not been included in the 1880 Admiralty list and appear to have been of dubious accuracy:

> At Halifax, Nova Scotia, a signal gun is fired from the citadel each day at noon and at 2.30 p.m. Twenty years ago the gunner in charge regulated his watch at a famous jewelry establishment. A flag signal system was subsequently adopted, and that in turn was succeeded by a time ball signal system. The interference with the signals by fogs made a new and more reliable arrangement necessary. A cable has been laid from a clock-maker's establishment to the citadel, and is connected with a clock which automatically fires the gun.

Figure 86: Halifax Citadel time ball (Klaus Hülse Collection).

This was clearly an improvement on earlier arrangements, but the 1898 Admiralty list included the following statement:

> Gun fired at noon mean time of the 60th meridian. [Note: This gun is fired for local purposes only, and is not to be depended upon for rating chronometers.]

There was no mention of the gun in the 1908 Admiralty list which included the time ball for the first time, while the 1911 to 1922 lists included the statement "A gun is fired by hand" when the ball dropped at 1 pm. This had been changed by 1926, when the gun was "Fired electrically from St. John's (sic), New Brunswick." It was still operating in 1947 when the time ball was no longer in service.

Figure 87: Montreal time ball (Klaus Hülse Collection).

The black time ball at Montreal was dropped by electricity from Montreal Observatory and was located on the tower of the Harbour Commissioner's building, shown in Figure 87. The Observatory at McGill University was operational by 1863 and a time ball was introduced before 1870 (Bignell, 1962). A larger transit telescope was acquired 1n 1879. As at Quebec, the ball had a drop of 2.4m. The comment "Signal may always be relied upon within half a second." was repeated in all Admiralty lists from 1880 to 1937. The time ball was only operated during the navigation season when the St Lawrence seaway was free of ice. Clearly, the signal was highly regarded for its accuracy.

10.2.4 Western Canada

A time ball on the Pacific coast was established at Victoria on Vancouver Island in 1916. This time ball was operated by "The superintendent of the Meteorological Observatory at Gonzales Heights" throughout its life. It was positioned on the Belmont building.

A time gun at Vancouver, British Columbia was first listed in 1904. It was "fired electrically from McGill College, Montreal, at 9 am Standard time" and located at Brockton point. It was still listed in 1947. Another gun at Victoria was listed in 1947, but not in 1939 or earlier. It was located at Work Point barracks.

11 SIGNALS IN THE WEST INDIES, CENTRAL AND SOUTH AMERICA

Signals in the West Indies, Central and South America were few in number, but many were unusual and several were deemed unreliable. Those listed from 1880 onwards are shown in Table 15 and Maps 13 and 14.

11.1 The West Indies and Bermuda

11.1.1 US Virgin Islands

A flag time signal had been provided at St. Croix and St. Thomas, now in the US Virgin Islands, by distinguished amateur astronomer Andrew Lang during the 1840s (Spencer Jones, 2020). Lang developed a well-equipped observatory at St Croix and made an accurate determination of its longitude which needed a correction of only 17 seconds of arc (1.1 seconds of time) when telegraphic determinations were made by the US Hydrographic Office in the 1870s. No signal in the Virgin Islands was included in Admiralty lists from 1880.

Table 15: Signals in the West Indies, Central and South America.

Area	Location	1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Bermuda	Ireland Island	TB	TB	TB								
West Indies	Havana NO		(black)	(black)								
	Havana Obs.				TB	TB	TB	TB	TB	TB	TB	
	Havana MC				Sema.							
						TB	TB	TB	TB	TB	TB	
	Barbados				TB							
	St. Lucia		TB	TB	TB							
	Curaçao GS	Flag	Flag	Flag	Gun	Gun	Gun	Gun	Gun	Gun	Gun	
	Curaçao FN				Flag	Flag	Flag	Flag	Flag	Flag	Flag	
	Trinidad		TB	TB	TB							
Central America	Balboa						TB	TB	TB			
	Guaymas										TB	
South America	Argentina Buenos Aires		Drum	Drum	Drum	Drum						
							Light	Light	Light			
	Argentina La Plata		(red)	(red)	(red)							
						Light	Light	Light	Light	Light	Light	
	Brazil Rio de Janeiro	Drum	Drum	Drum	Drum	Drum	Drum					
								Light	LIght	Light	LIght	
	Brazil Ilha Fiscal							Flash	Flash	Flash	Flash	Flash
								Flag	Flag	Flag	Flag	Flag
	Chile Coquimbo				Cone	Cone						
					Gun	Gun						
	Chile Valparaiso		TB	TB	TB	TB	TB	TB	TB			
					Gun	Gun	Gun	Gun	Gun	Gun	Gun	Gun
	Georgetown	(red)	(red)	(red)	(red)	(red)	(red)	(red)	(red)	(red)	(red)	
	Peru, Callao								TB	TB	TB	TB
	Suriname Paramaribo		Discs	Diiscs								
		Flag			Flag	Flag						
						Gun						
	Uruguay MV					(r, g)	(r, g)	(r, g)	(r, g)	(r, g)	(r, g)	
Signal type totals		1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Time ball, including collapsible		2	7	7	7	5	6	6	6	5	6	1
Gun, including powder flash		0	0	0	3	4	2	3	3	3	3	2
Lights		0	0	0	0	1	2	3	3	2	2	0
Other: disc, drum, flag, etc.		3	3	4	6	5	2	2	2	2	2	1

11.1.2 British Colonies

A time ball at the Ireland Island dockyard in the British colony of Bermuda was listed from 1880 to 1904. The dockyard is shown in Figure 88 but the photograph may have been taken after the time ball service had been discontinued. The ball was listed as having a diameter of only 0.5m with a drop of 9m. It was positioned on the western jetty in front of the main dockyard building. The signal was made on Saturdays only.

Time balls were in use at Port of Spain, Trinidad and Castries, St. Lucia before 1898. A time ball at Bridgetown, Barbados was also listed in 1911. These three in British colonies were not listed in 1915 or later. The time balls at Port of Spain and Castries were described respectively as “Signal reported of no value for rating chronometers” and as “Signal reported unreliable and as being dropped for local purposes” in 1908 and 1911. The short-lived signal at Bridgetown was dropped from a flagstaff at “Rickett’s Battery”. The 1911 Admiralty list contained the following qualification for Bridgetown:

> The time ball will be dropped at any arranged time, on application to Mr. Bailey, watchmaker; chronometers may also be compared at his shop. Neither method is recommended, as their accuracy is doubtful.

Early withdrawal of signals with such limited performance is unsurprising.

There had also been a time ball in Jamaica during some of the period between 1880 and 1898. It was withdrawn in 1894:

> The dropping of the Time Ball at noon daily at the flagstaff in the dock yard, Port Royal has been discontinued by order of the Admiralty. (Notice, 1894).

Map 13: Signals in the West Indies and northern South America (map: Roger Kinns).

Figure 88: Bermuda, Ireland Island Dockyard (Klaus Hülse Collection).

Map 14: Signals in southern South America (map: Roger Kinns).

11.1.3 Curaçao

A flag signal on the guard ship in Santa Anna Harbour, in the Dutch colony of Curaçao, was listed in 1880. The flag signal was changed to a gun before 1908 and the flag signal was provided at Fort Nassau as the secondary signal. The flag was hauled down when the gun fired. The gun and flag were still listed in 1939.

11.1.4 Havana

Cuba had been a Spanish colony until the Spanish–American War in 1898. It was then under US military rule before gaining independence in 1902. Havana had a more extended provision of time signals than other locations in the West Indies.

There was a black time ball with a diameter of 0.9m on the flagstaff of the Naval Commandant's office by 1898. It was dropped at noon, local mean time, and was also included in the 1908 list. It had been replaced by a similar time ball at the National Observatory by 1910, also dropped at noon, local mean time. A semaphore signal at Moro Castle was dropped by hand. The 1911 list included the statement "signals reported unreliable, 1910" and the comment "Local mean time is kept throughout Cuba. Havana mean time has been adopted for meteorological and railway services only." The semaphore signal was replaced by a secondary time ball, also dropped by hand, before 1915. The 1910 comment about reliability was withdrawn. In 1939, the National Observatory and Moro Castle time balls were still operated at noon, local mean time, corresponding to 17h 29m 23.5s GMT.

11.2 Signals in Central America

A time ball at Balboa was listed between 1919 and 1928. There was also a short-lived time ball at Guaymas in Mexico that was listed in 1939. Otherwise, telegraph signals were available at Panama for shore access.

11.3 Signals in South America

11.3.1 Argentina: Port La Plata

A small red time ball with a diameter of 2 feet (0.6m) at Port La Plata was listed between 1898 and 1911. It was replaced by time lights on 15 March 1911 (Notice, 1911). These lights were switched on 3 minutes before noon GMT and extinguished at noon GMT without flashing. The time lights at La Plata were still listed in 1939.

11.3.2 Argentina: Buenos Aires

A large red cylindrical drum with a diameter of 1.8m and length of 2.4m was listed for Buenos Aires between 1898 and 1915. It was discontinued on 20 September 1915 and replaced by time lights. These lights were operated in a different sequence to Port La Plata: they were switched on 2 minutes before 10 pm Cordoba mean time (4h 16m 48.2s behind GMT) then flashed on and off in a defined sequence before extinction at 10 pm (Notice, 1916). The time of

Figure 89: Valparaiso time ball replica (https://www.armada.cl/noticias-navales/proyecto-patrimonial-time-ball-de-valparaiso-es-entregado-a-la-armada).

the Buenos Aires signal was changed to 9.30 pm Standard time (4 hours behind GMT) after the introduction of new time zones. The signal had been withdrawn by 1931.

11.3.3 Brazil: Rio de Janeiro

Brazil used a red cylindrical drum at Rio de Janeiro from before 1880 to 1920, when it was replaced by a time light. The cylinder was inflated before the signal and had large dimensions: its diameter and drop height were 1.8m and 2m respectively.

11.3.4 Brazil: Fiscal Island

A combined flag and magnesium flash signal was provided on Fiscal Island in Guanabara Bay from 1921. This signal was still extant in 1947.

11.3.5 Brazil: Bahia

An unusually short-lived time ball service was provided in Brazil at Salvador in the state of Bahia, close to the historic Fort San Marcello do Mar. It was announced in 1906 and withdrawn in the following year (Notice, 1907). It never appeared in Admiralty lists.

11.3.6 Chile: Valparaiso

Chile used a time gun and a time ball at Valparaiso, but neither was listed in 1880. The time ball was listed in 1898. The gun at Fort Bueras was added in the 1904 list. The 4 feet (1.2m) diameter ball was located on a mast in front of the Naval School and at an elevation of 90m above high water. It had a drop height of 7m and remained at the same location throughout. The ball was dropped and the gun was fired at noon, local mean time, 4h 46m 34s behind GMT, until the time ball was withdrawn.

The time ball service had to be suspended because of a devastating earthquake in 1906. The 1908 list included the comment “Time ball suspended; gun is still fired, but is unreliable. Buildings were destroyed by an earthquake in 1906”. Both signals were included in the 1911 list. The time ball had been discontinued by 1933, but the gun was still listed in 1947. It was still fired at noon, by then changed to 4 hours behind GMT.

There is a modern working replica of the time ball at Valparaiso which is shown in Figure 89. It was erected in 2015 and is now located on top of the Naval School building.

11.3.7 Chile: Coquimbo

A combined cone and gun signal in Chile was listed for Coquimbo between 1911 and 1917. A black cone was raised on the mizzen mast of the training ship *Abto* in Coquimbo Bay. A gun was fired when “the ball” dropped at noon, local time. The “signal adopted” was always described as a black cone in Admiralty list, but “addi-

Table 16: Signals in the Atlantic Islands.

Area	Location	1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Azores	Horta						Light	Light	Light	Light	Light	
	Ponta Delgada					Light	Light	Light	Light	Light	Light	
	Terceira								Light	Light	Light	
Cape Verde Islands	St Vincent PO							Flag	TB+Dia	TB+Dia	TB+Dia	
	St Vincent SB								Gun	Gun	Gun	
	St Vincent Fort							(black)	(black)	(black)	(black)	
St Helena	St Helena TO	TB	TB	TB								
	St Helena LH	TB	TB	TB								
Signal type totals		1880	1898	1904	1911	1915	1919	1922	1928	1934	1939	1947
Time ball, including collapsible		2	2	2	0	0	0	1	2	2	2	0
Gun, including powder flash		0	0	0	0	0	0	0	1	1	1	0
Lights		0	0	0	0	1	2	2	3	3	3	0
Other: disc, drum, flag, etc.		0	0	0	0	0	0	1	0	0	0	0

tional details" in the same lists included the statement "Ball hoisted half-way …" The same ambiguity has been noted at other locations. The signal was withdrawn permanently in 1917, when it was described as a time ball (Notice, 1917).

11.3.8 Peru

A time ball was established at Callao in 1924. It was located on "Mast of the "Union" near the La Punta Naval School", 85 feet above sea level and had a very large drop height of 75 feet (23m). It was dropped using a wireless signal from Washington at noon Standard time, 5 hours behind GMT, and was still operational in 1947.

11.3.9 Uruguay

Uruguay used a 0.9m diameter red time ball with a horizontal gilt band at Montevideo from 1912. It had a drop height of 3m. Unusually, a flag was hoisted 10 minutes before the signal while the ball was raised 5 minutes later, giving two preparatory signals. The flag was dropped at the same time as the ball. The time ball was still listed in 1939.

11.3.10 Guyana and Suriname

The northernmost signals in South America were in British Guiana (now Guyana) and Dutch Guiana or Surinam (now Suriname), both on the Atlantic coast.

A red time ball at Demerara (Georgetown) in British Guiana was listed from 1880 to 1939. It was on a flagstaff near the General Post Office in Georgetown and was dropped on Wednesdays and Saturdays only.

Suriname (Surinam) used a variety of visual time signals at Paramaribo. A flag signal was listed by the Admiralty in 1880 and again between 1911 and 1916. A disc signal had been used for part of the intervening period and was listed between 1898 and 1908. The disc or flag were both hoisted on the main yard of the Paramaribo guard ship. The disc was described as black and white with a diameter of 1 foot 4 inches and a length of 3 feet. It was hoisted half-way up 5 minutes before the signal and close-up 3 minutes before the signal, so it was not the rotating disc signal favoured elsewhere in the Netherlands and Dutch colonies. It might have been an unusually shaped object that was dropped like a time ball. It was actually described as a time ball in 1912:

> The Netherlands Government has given notice that the time ball at Paramaribo, Dutch Guiana, is unreliable and should not be used for the comparison of chronometers. (Notice, 1912).

The latitude and longitude of the signal were the same in the 1912 notice as for the disc and flag in the Admiralty lists. A gun was also listed at Fort Zelandia in 1915 and 1916 but not in 1917 or later.

12 SIGNALS IN THE ATLANTIC ISLANDS

Table 16 shows visual signals in the Atlantic Islands that were listed between 1880 and 1947. Their locations are shown in Maps 5 and 7. Bermuda and the West Indies have been considered in the Americas section. One of the earliest time balls was established on St Helena in 1834 by the British East India Company. Time balls there continued into the twentieth century. Another had existed on Ascension up to at least 1865, but never appeared in Admiralty lists from 1880.

Most islands under jurisdiction by Spain and Portugal offered telegraph time signals that could be accessed for chronometer calibration. These were listed by the Admiralty but required shore access. Electric light signals were introduced from 1914 in the Azores. Time balls were introduced in the Cape Verde Islands in the 1920s but were never used in Madeira or

Tenerife.

12.1 Ascension

The extraordinary history and administration of Ascension are described in detail by Hart-Davis (2016). Like St Helena, it was initially uninhabited when it was discovered by the Portuguese in 1502. Unlike St Helena, there was then no vegetation on the volcanic island, which was introduced later to provide victualling for ships. From 1815 to 1922, Ascension was run as a naval shore establishment with a detachment of marines. Facilities for time determination were probably limited to sextants, chronometers and almanacs carried by naval vessels stationed there. Despite those limitations, there was a time ball service.

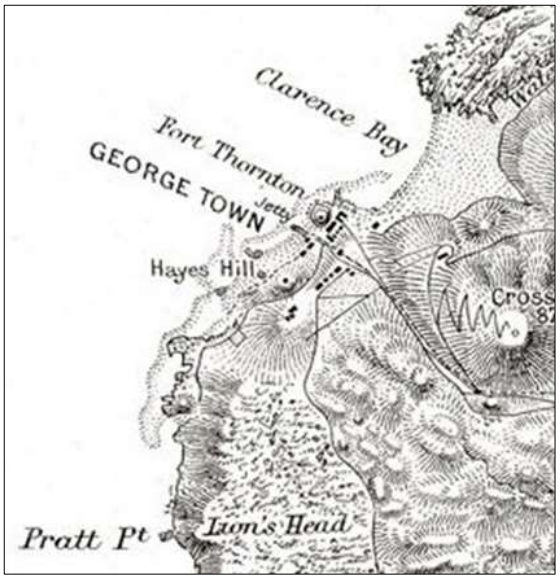


Figure 90: Detail from map of Ascension (Science History Images ID: 2BE1090).

A notice concerning a time ball at Ascension was published in *The Nautical Magazine* (Time Signal Ball, 1860) and is transcribed below:

> *Time Signal Ball at Ascension.* — In order that vessels calling at Ascension may readily find the errors and rates of their chronometers, a Time Ball is dropped daily (Sundays excepted) from a flagstaff at the Master's cottage, precisely at one o'clock of Greenwich mean time. The Master's cottage is to the southward of Hayes Hill …

Another, much shorter, notice was published in 1865, but the drop times had changed: "The Time Ball is now dropped from a staff on Hayes Hill at 8h. a.m. and 1h. p.m. mean time at Ascension." (The Time Ball, 1865). Both notices pointed out its proximity to Hayes Hill. Figure 90 is a detail from a map of Ascension published in 1876. Hayes Hill is very close to George Town on the western side of the island.

The Ascension garrison was subject to continued budgetary pressures and the time ball service had probably been discontinued by 1870, with the advent of the Suez Canal and the decline of sailing ships. David Gill (later Director of the Cape Observatory) and his wife had stayed there for several months in 1877 to observe the Opposition of Mars, but they brought their own equipment and set up a temporary observatory.

12.2 St Helena

The following notes about the general history of St Helena have been derived primarily from the excellent Island website (Saint Helena, 2021). St Helena is believed to have been discovered by the Portuguese in May 1502. It was then uninhabited, but with an abundance of trees and fresh water. The island became an important rendezvous point and source of food for ships returning from Asia to Europe. It was occupied by the Dutch and the British at different times. The Emperor Napoleon was confined on the island from October 1815 until his death in May 1821. He was buried in St. Helena but exhumed in 1840, when his remains were transferred to Paris.

St Helena became a British Crown Colony in April 1834, having been administered for long periods by the British East India Company. The Ladder Hill Observatory and time signals had already been established by the East India Company. St Helena played an important role in the interception of slave ships by the Royal Navy, with a fleet operating between the Cape of Good Hope and St Helena. The latter half of the nineteenth century saw the advent of steamships not reliant on trade winds and diversion of trade from routes via the Cape of Good Hope to routes via the Suez Canal. The number of ships calling at the island fell from 1,100 in 1855 to only 288 in 1889 (see Kinns, 2021c).

12.2.1 Ladder Hill Observatory

The Ladder Hill observatory was commissioned in the 1820s. It was directed by Lieutenant Manuel Johnson (1805–1859) of the St Helena Artillery. He received the Gold Medal of the Royal Astronomical Society for his work in cataloguing stars of the Southern Hemisphere between November 1829 and April 1833 (Warner, 1981). He left St Helena in 1833 and became a distinguished astronomer at Oxford.

The observatory was closed on 29 February 1836

> … due to its uselessness and immense annual cost of £300, the Crown Commissioners reporting that they had been unable to learn its establishment had been attended

> with any important result to science. (Saint Helena, 2021).

That was a remarkable assertion, given Johnson's achievements. Most of the instruments were sent to Canada, although the clocks were retained. The building was then used as a mess hall for the fort and the Ladder Hill Observatory was never re-established.

Early navigation guides for the South Atlantic included the following note about rockets in the entry relating to St Helena:

> The practice of discharging rockets for rating the chronometers of vessels touching here has also been discontinued and a time ball has been substituted. (Findlay, 1867).

12.2.2 The First Time Ball at St Helena

An editorial concerning the St Helena time ball has been noted previously (Editorial, 1835). The parts of that editorial relating specifically to St Helena are reproduced below:

> We shall now extract from the remarks of H.M.S Thalia, Captain R.Wauchope, his account of the St. Helena Time-ball, on the arrival of that ship there in December last [1834]:–"On our arrival at St. Helena, after an eighteen days' passage from Prince's Island, we found my chronometer-signal established there. The ball drops at mean noon, St. Helena time, for the benefit of the inhabitants; and at one P.M. mean time at Greenwich, for the advantage of the shipping. The ball is hoisted half-mast high five minutes before the time, and at one minute before to the mast-head.

The article went on describe the apparatus, using the engraving reproduced in Figure 91. The description of the apparatus was unsatisfactory, but an arrangement of ropes, pulleys and weights appears to have been used to arrest the ball's descent. The arrangement differed markedly from that used at Greenwich. The Observatory ball appears to have had a small diameter of about 0.8m (Kinns, 2021c). It was dropped twice daily.

The notice issued by the Observatory to announce the service was dated 21 January 1834. Parts of the notice are transcribed below:

> To prevent mistakes, a *White Ball*, hoisted upon a Staff over the Observatory, will denote the time, agreeably to the following instructions:–
>
> The ball will be hoisted half mast at *five* minutes, and close up at *two* minutes before *twelve o'clock*.
>
> At the instant of the *Mean Time*, at noon of St. Helena, the ball will drop from the top of the Staff, when the gun will be fired at High Knoll.
>
> The signal will be repeated at *one o'clock*, at the instant of *Greenwich mean time*, for the benefit of the shipping …
>
> Ships concealed from a view of the Observatory, will attend to the Repeating Ball at Ladder Hill, and in neither case is any allowance to be made for loss of time, since the astronomer will make the calculation of the few tenths required.

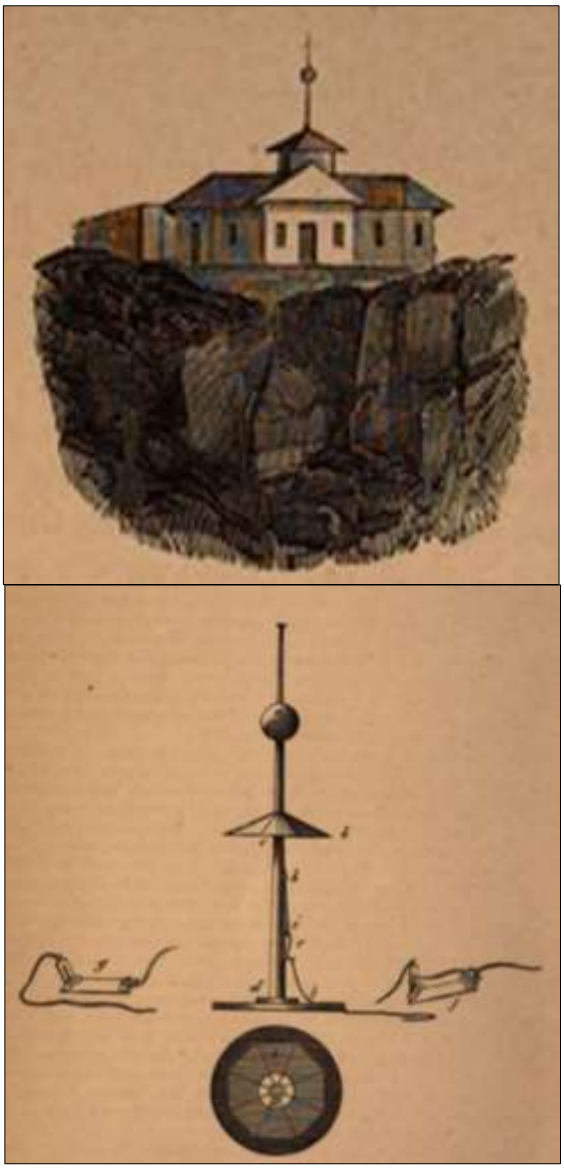


Figure 91 (top): Ladder Hill Observatory, and (bottom) the St Helena time ball (after *Nautical Magazine, 1835*).

It included the observation that the astronomer would allow for the delay of a fraction of a second in releasing the ball and that this applied both to the Observatory time ball and the repeater ball on Ladder Hill. Firing of the gun was not automatic, but it was controlled by the Observatory.

12.2.3 Continuation after 1836

A letter published in *The Nautical Magazine* confirmed that the time ball service continued after

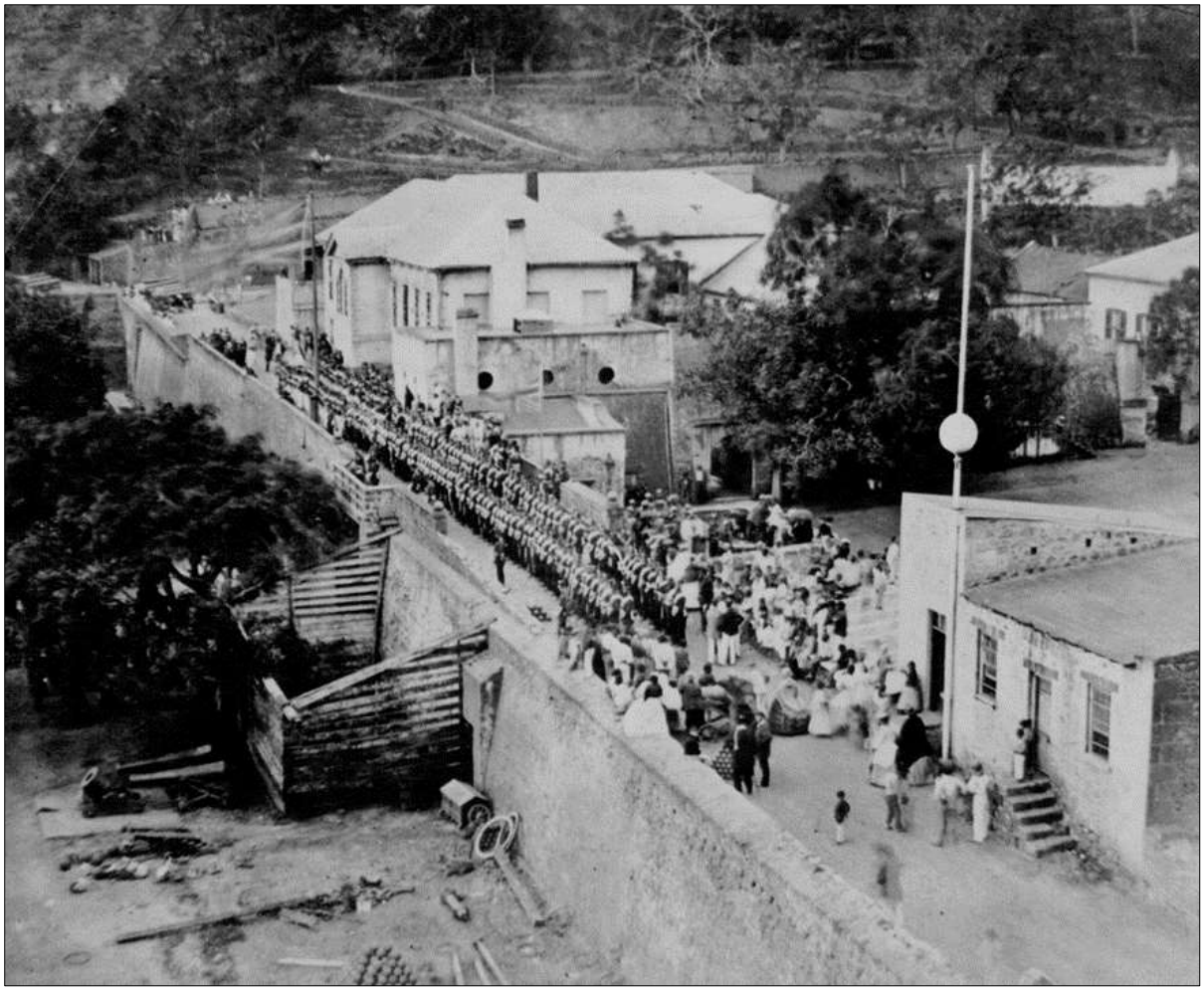


Figure 92: St Helena time ball at Port Office in 1866 (photograph by John C. Lilley, St Helena Museum).

closure of the Ladder Hill Observatory (Liddell, 1837). The Observatory time ball had been removed and the original repeater ball was not mentioned, but the repeater ball on Ladder Hill was included in later Admiralty notices. The principal time ball was now located in Jamestown itself:

> It gave me also great pleasure to observe, that, although General Middlemore had brought out instructions to shut up the beautiful little observatory, and send home the valuable instruments so munificently provided by the East India Company, the admirable system of dropping a ball for regulating chronometers was still kept up as efficiently as ever. The ball has been removed from the hill to the town, and is now in charge of the master-attendant, Mr. Gulliver, late master of H.M.S. Thalia, whose attention to it is unremitting. It is dropped at two stated times every day, and oftener, if requested by any commander.

The photograph in Figure 92 shows the lower level time ball on a tall mast. It was taken on Queen Victoria's birthday in 1866. Like the original ball, it was painted white. There are no known photographs of the repeater ball on Ladder Hill, but a drawing of the rear of the observatory was made by Durand Brager in 1840, the artist who was present for the exhumation of Napoleon. Figure 93 shows the central part of the drawing, including a flagstaff which may have been used for dropping the repeater ball.

There was a fee of 5 shillings for provision of the time ball service in April 1859 (Russell, 1859). This fee was noted by Findlay (1867) and was still extant in 1888 (notice in St. Helena Museum). It appears to have been accepted without complaint.

12.2.4 Admiralty List Entries

The St Helena time balls were listed in 1880, with a final entry in 1904. They had been removed from the 1908 list. The Admiralty lists noted that "Ladder Hill Observatory" time was used in St Helena. Its latitude and longitude are likely to have been measured by Johnson before 1833 when extensive instruments were available. The same description of the two time balls was used throughout. These are repro-

Figure 93: St Helena mast on Ladder Hill (from drawimg by Brager, 1840).

duced below.

> Time Office west side of the lines, James Town Valley. 74 feet above high water, 40 feet above ground (Drop 13 feet.)
>
> Yard arm of the flag staff on Ladder Hill. 653 feet above high water. 45 feet above ground (Drop 40 feet.)

The latitude and longitude of the principal ball were given as 15° 55′ 0″ S., 5° 42′ 30″ W. in 1880. Those for the repeater ball were not stated. By 1898, the principal ball location had been adjusted to 15° 55′ 20″ S., 5° 42′ 25″ W. (approximate), with the location of the repeater ball given as 15° 55′ 17″ S., 5° 42′ 42″ W. It has been shown recently that the longitude in use up to 1990 was in error by 732 m (Saint Helena, 2021).

12.3 The Azores

Clocks were available for chronometer calibration in the Azores at Punta Delgada by 1904 and at Horta by 1908, regulated from Lisbon and Hamburg respectively. These signals could not be seen from ships in harbour so are not included in Table 16. Time lights were introduced at three locations in the Azores during the 1920s. The first was at Ponta Delgada in 1914, followed by another at Horta in 1915 and a third at Terceira in 1923. All were still listed in 1939, but not in 1947.

Telegraph office signals were available at Tenerife and Madeira by 1911.

12.4 Cape Verde Islands

A telegraph signal at the Telegraph Office at Port Grande on São Vicente (St. Vincent) Island was first listed by the Admiralty in 1911. Visual signals were first listed in 1922. A telegraph signal from Greenwich was still noted, together with a blue flag at the “Captain of the port’s office” and a time ball at the “fort on Monte Videa”. New signals were introduced at Porto Grande in February 1922, after the list had been published (Notices, 1922: 510). These were a time ball, a repeater signal with a diamond shape and a gun. All were at 10 am local time, corresponding to noon at Greenwich. The gun was fired on three days only. The complete notice is transcribed below.

> CAPE VERDE ISLANDS— São Vicente Island-—Porto Grande Visual time signal—Information.—Since February 9, 1922, the time signal at Porto Grande has been made in the following manner from the signal mast of the meteorological station located in the building of the captain of the port:
>
> The ball (sphere) is hoisted at half mast at 9h 55m; mastheaded at 9h 58m, and dropped at 10h a. m., the time corresponding to that of the 30° meridian of longitude west of Greenwich.
>
> This signal is repeated from the semaphore mast at the fort with a black diamond-shape. The dropping of the diamond-shape is accompanied by the firing of a gun at the saluting battery on Mondays, Wednesdays, and Fridays. Approximate position of Porto Grande: latitude 16° 53′ N., longitude 24°

59′ W.

Subsequent Admiralty lists included the comment that the sphere was hauled down, rather than dropped. The sphere is shown as a time ball in Table 16.

The time ball and flagstaff signals were still in use in 1942, but the time gun had been discontinued (Sailing Directions, 1942: 273). No signal was listed in 1947.

13 CONCLUDING REMARKS

The aims of this paper have been to provide a fresh perspective concerning evolution of time signals for mariners and to provide a framework for future research. Much detail has had to be omitted and only illustrative images of time signals have been included. The extensive collection of postcards and other images of time signals by Klaus Hülse provides a valuable complement to this paper and is available online.

Admiralty lists contain details of latitude and longitude that have been used to create maps of signals. Tabulation of signals has shown clearly how certain types of signals were favoured by some countries. Time balls were used widely and were always the dominant signal type after 1880. They took many different forms that have been described for selected locations. Many time balls used an open frame construction rather than a skin over a hidden frame. They were usually dropped at noon or 1 pm, but France preferred 10 am with a repeat drop two minutes later. Other variations have been identified. Although time balls were proposed initially for calibration and particularly rating of marine chronometers, they were also established at inland locations for domestic use and many were accurate signals controlled by electric telegraph. They are outside the scope of the present study.

Time ball familiarity is likely to have inhibited development of other devices that might have offered improvements in efficiency and reduced costs, although collapsible objects and semaphore signals were used at a small number of locations. Time discs or flaps were favoured in the Netherlands and Dutch colonies in Indonesia. The hauling down of a flag was used as the time signal at a few locations, following Wauchope's original 1824 suggestion to the Admiralty that led eventually to the time ball.

It is striking how electric time lights were never listed in the British Isles or North America. They were favoured by Portugal and the earliest known introduction of electric time lights as a principal signal was in 1909 at Lorenzo Marques in Mozambique. They were also used widely in northern Europe, China and Japan. A unique arrangement of coloured time lights was used in New Zealand. Some time lights replaced time balls while others offered a complementary or alternative service.

Time guns were usually regarded by the Admiralty as secondary signals, with the repeated qualification that it was the flash of the gun, not sound that propagated slowly, that should be used as the accurate time signal. Nevertheless, the use of maps to show propagation times in average environmental conditions was promoted by time gun enthusiasts. Time guns for mariners were never listed for the United States but were favoured by Canada.

13.1 Future Research

Several little-known or forgotten visual time signals have been found in the Admiralty lists, many of them short-lived. Examples are two time balls in the British Isles at Immingham Dock and Rosyth and two in Australia at Port Pirie in South Australia and Devonport in Tasmania. Others were at Massawa in Eritrea, Makassar in Indonesia and Guaymas in Mexico. There was a time gun in Djibouti and another was introduced at Durazzo in Albania as late as 1939. The signals in Asia and South America were often innovative and merit deeper investigation, as do those in many European countries. The present work has identified where signals were located but collaborative work with authors in different countries will be needed to establish how they were designed and operated.

Mistakes have occurred in published notices and these have been resolved as far as possible, but there may be others that have yet to be identified. Dates of signal withdrawal are often more difficult to establish than dates of introduction. There is some evidence that Admiralty lists, relying on accurate information from port authorities, included signals after they had ceased to be in commission.

There will be differences of opinion about signals that were not included in Admiralty lists but were noted in pilot guides and almanacs issued by different authorities. Their value depended on accuracy and reliability as well as location. Further work is needed to establish their design criteria.

There are sometimes unexplained inconsistencies between descriptions in Admiralty lists and what were believed to be photographs of time signals. Two examples are the time balls at Gibraltar and Rangoon. There are also cases where dimensions such as time ball elevations and drop heights have been given incorrectly in published lists, possibly because

changes to a signal arrangement had not been notified. This applied to the Alfred Docks signal in Cape Town, for example.

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This paper has been inspired by Wayne Orchiston and draws extensively on studies of time signals in particular countries that have been published in the *Journal of Astronomical History and Heritage*. It has developed with the help of many people. Paul Fuller has an extraordinary knowledge of British time signals and has also found many notices about worldwide time signals that clarify Admiralty lists. Douglas Bateman has an exceptional understanding of how the time ball signal at Greenwich evolved to the present day.

Images have been obtained from various sources. Many general images, often of buildings or ships, have been cropped to emphasise time signals. The collection of images formed by Klaus Hülse continues to provide a valuable record. Staff at the National Library of Scotland in Edinburgh have helped me to access Admiralty lists under the constraints of the Covid-19 pandemic and my overseas contacts have always been supportive. I thank them all.

A new book by the author about the history of visual time signals worldwide is planned to include a more complete record, with guest chapters by expert authors.

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Admiralty list of lights and time signals. Issued in nine parts. Printed for the Hydrographic Office, Admiralty, by Wyman and Sons Ltd., London, 1912–1920.

I. British islands;
II. Eastern shores of the North Sea and in the White Sea;
III. Baltic Sea;
IV. Western coasts of Europe and Africa (from Dunkerque to the Cape of Good Hope) including Azores, Madeira, Canary, Cape Verde islands;
V. The Mediterranean, Black, Azov, and Red Seas;
VI. South Africa, East Indies, China, Japan, Australia, Tasmania and New Zealand;
VII. South America, western coasts of North America, Pacific Islands, &c.;
VIII. Eastern coasts of North and Central America (from Labrador to the River Amazon) including Bermuda and the islands of the West Indies;Western side of the Atlantic Ocean, United States of America, Gulf of Mexico, West Indies, and the northern coasts of South America to Cape Orange.

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Admiralty list of lights, fog signals and visual time signals. Issued in twelve parts. Published for the Hydrographic Office, Admiralty, by HM Stationery Office, London, 1929–1971.

I. British islands;
II. North and Arctic Seas except the British Isles;
III. Baltic Sea, with Kattegat, Belts and Sound;
IV. Eastern sides of north and south Atlantic Ocean, south of Dunkerque;
V. Mediterranean, Black, and Red Seas;
VI. Indian and west Pacific Oceans;
VII. Western side of south Atlantic Ocean and eastern Pacific Ocean;
VIII. Western side of north Atlantic Ocean (Canada, Newfoundland and Labrador);

IX. Western side of the Atlantic Ocean, United States of America, Gulf of Mexico, West Indies, and the northern coasts of South America to Cape Orange;
X. Indian and south Pacific Oceans;
XI. North and Arctic Seas except the British Isles;
XII. Arctic Ocean (varies).

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