Journal of Astronomical History and Heritage, 10(2), 115-121 (2007).

THE NORWEGIAN NAVAL OBSERVATORIES

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Abstract: Archival material has revealed milestones and new details in the history of the Norwegian Naval Observatories. We have identified several of the instrument types used at different epochs. Observational results have been extracted from handwritten sources and an extensive literature search. These allow determination of an approximate location of the first naval observatory building (1842) at Fredriksvern. No physical remains exist today. A second observatory was established in 1854 at the new main naval base in Horten. Its location is evident on military maps and photographs. We describe its development until the Naval Observatory buildings, including archives and instruments, were completely demolished during an allied air bomb raid on 23 February 1945. The first Director, C.T.H. Geelmuyden, maintained scientific standards at the Observatory between 1842 and 1870, and collaborated with university astronomers to investigate, develop, and employ time-transfer by telegraphy. Their purpose was accurate longitude determination between observatories in Norway and abroad. The Naval Observatory issued telegraphic time signals twice weekly to a national network of sites, and as such served as the first national time-service in Norway. Later the Naval Observatory focused on the particular needs of the Navy and developed into an internal navigational service.

Keywords: naval observatory, transit instrument, universal instrument, chronometer, sextant, time-service

1 INTRODUCTION

In 1817 a Naval Academy was established at Fredriksvern Naval Base in Norway. The cadets there were trained in the theory and practise of astronomical navigation following basic mathematical training in arithmetic, planar geometry, and spherical trigonometry and geometry. Annual cruises at sea allowed observational training and included computational tests to demonstrate that required skills in positioning were individually fulfilled by the cadets. On land the cadets exercised time-keeping and chronometer control. These topics occupied 10 hours in a weekly total of 46 hours of teaching. Most cadets needed 5-6 years to complete the Naval Academy training and pass the final exam; they were then appointed junior officers in the Norwegian Navy (Kvam, 1967).

Captain Søren Lorents Lous (Figure 1)[1] was the first lecturer in mathematics and navigation at the Naval Academy, and held this post from 1817 to 1841. On 19 November 1816 he attempted to determine the longitude of the Naval Academy by observing a solar eclipse, and in a letter to Professor Christopher Hansteen at the University of Oslo he described his effort throughout the month of November to determine local time whenever weather conditions permitted (Lous, 1816). He observed corresponding elevations of the Sun on either side of the local meridian to determine the acceleration and bias of his clocks. During the eclipse, clouds prevented observation of first contact, but Lous did observe the occultation of a large sunspot by the Moon before clouds prevented further observation. The total eclipse phase, which he estimated to last 49 seconds, was noted only from the darkness at the site. Three minutes later the skies cleared and the Sun remained visible until half its diameter had emerged from the eclipse. Then it remained overcast for the rest of the day. The following day Lous observed corresponding solar elevations in order to verify the clock bias. He derived a latitude of 58° 57′ N.

Hansteen (1816) remarked that clouds prevented observation of the solar eclipse elsewhere in Norway, and in Copenhagen, even though observers had been ready in Oslo, Bergen, Trondheim, and Kongsberg. Thus, no longitude differences could be determined.

Figure 1: Søren Lorents Lous (courtesy: Naval Museum).

The first successful determination of the geographical coordinates of Fredriksvern was made by Hansteen (1823) in July 1819, when he arrived by sailing ship from Oslo after a voyage of six days. Using the Naval Academy's sextant (Figure 2) he observed circum-meridian elevations of the Sun in the Academy gardens and found the latitude to be 58° 59′ 54.9″. The results from observing the upper and lower solar limb on 7 July 1819 were listed as 53.8″ and 56.0″, respectively, i.e. 54.9″ ± 1.6″ (rms). The drift and bias of his Arnold No. 132 pocket chronometer (Figure 3) was determined in Oslo before the voyage, and in Fredriksvern upon his arrival. The longitude difference between Oslo and Fredriksvern was found to be 2 minutes 41.6

seconds. However, the time determinations in Oslo suffered from lack of levelling control of the transit instrument because a thief had broken into the interim University Observatory at Akershus and had stolen the levelling device (see Pettersen, 2002). This incident and the long duration of the voyage suggest the presence of systematic effects in the result, which may be uncertain by several seconds.

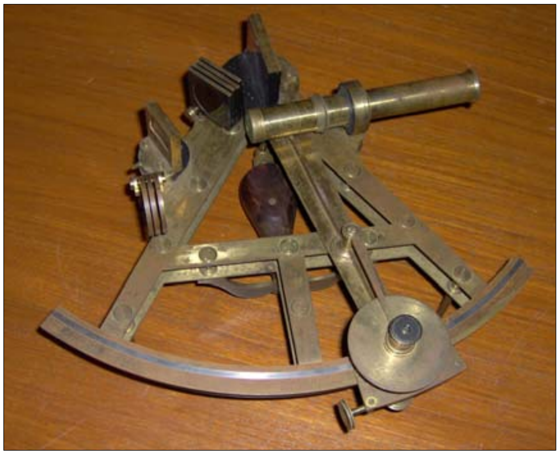

Figure 2: A Troughton sextant similar to the one used at the Naval Academy.

Figure 3: The Arnold No. 132 pocket chronometer, which is now in storage at the University of Oslo.

Another chronometer expedition took place in September 1824, involving a steamship (Hansteen, 1828a), and on this occasion the Arnold No. 132 pocket chronometer also was used. Hansteen (Figure 4) made observations in Oslo before the voyage, and Lous observed at Fredriksvern upon his arrival two days later. They derived a longitude difference between Oslo and Fredriksvern of 2 minutes 45.68 seconds.

To improve opportunities for travel, freight transport and postal deliveries the state operated the steamship *S.S. Constitutionen* between the capital, Christiania (now Oslo), and Kristiansand. It connected on a regular basis with the *S.S. Prinds Carl* in Fredriksvern, which then continued on to Gothenburg and Copenhagen. This allowed chronometer expeditions to Fredriksvern, as well as Gothenburg and Copenhagen, to be conducted more conveniently, and with a shorter travel time (Hansteen, 1828b). At this time, Hansteen was frequently corresponding with the Altona clockmaker Heinrich Johan Kessels in order to acquire chronometers for the University and the Geographical Survey of Norway. In 1826 he requested the first chronometer for the Norwegian Navy (Schulz, 1938), and was offered a Kessels No. 1257 for 200 Dutch ducats (Kessels, 1826a). This box chronometer (Figure 5) was made to run for 36 hours, but Kessels (1826b) recommended rewinding every 24 hours. It had a two-axis suspension for sea voyage, which could be locked for use on land. Hansteen accepted the offer on behalf of the Navy and the chronometer left Altona on 21 August 1826 on a ship bound for Oslo. It was promptly paid for and Kessels' receipt was in Hansteen's hands by 22 September (Kessels, 1826c). For a period of five months from 3 September 1826, Hansteen compared the Kessels No. 1257 chronometer with three other chronometers and with a pendulum clock made by Urban Jørgensen (Copenhagen). Local mean time was episodically determined by observations in the Observatory at Akershus. The Kessels No. 1257 chronometer showed a monthly acceleration of 1 second (Hansteen, 1827).

In May 1827 Hansteen (1828c) made repeated time observations in Oslo to determine the bias and drift of the Kessels chronometer. He then sent the box chronometer by *S.S. Constitutionen* to Fredriksvern, where it arrived the next day. Lous then made time observations with a Troughton sextant at Fredriksvern over the next four days. The longitude difference between Oslo and Fredriksvern was found to be 2 minutes 45.43 seconds. Recent GPS observations at the two locations produced geodetic longitudes (east of Greenwich) of 10° 44′ 28″ for Oslo and 10° 02′ 08″ for the Academy gardens, a difference of 42′ 20″, which corresponds to 2 minutes 49.3 seconds. The geodetic latitude of the Academy gardens is 58° 59′ 54″.

Figure 4: Christopher Hansteen, portrait from 1826.

Lous continued to work with small field instruments throughout his tenure at the Naval Academy. No documents reveal the acquisition of any larger instruments for scientific use. A doubling of the Naval budget from 6.5% to 14.5% of the national budget in 1836 (see Einang et al., 1934: 285) allowed a series of new box chronometers to be acquired. An archival note (Preus 1928) lists the acquisition of four new Kessels chronometers: No.1333 in 1835, No.1349 in 1837, No.1372 in 1839 and No.1391 in 1841. According to an archival card at the Norwegian Naval Museum, a Dent No.2067 box chronometer (Figure 6) was acquired in 1839, but in 1847 Hansteen remarked that it was a recent acquisition (see Hansteen and Fearnley, 1849: 56). The two-year periodicity of the acquisition program suggests that the Dent chronometer may have been acquired in 1843. A box chronometer by Kessels with suspension was then priced at 240 Dutch ducats (Hagerup, 1840). The chronometer investment program thus represented a considerable financial outlay, and led to the establishment of the Navy's *Instrument and Chart Collection* in 1835.

When C.T.H. Geelmuyden (Figure 7)[2] succeeded Lous as Naval Academy lecturer in 1841, plans were immediately prepared to expand the Instrument and Chart Collection with a Naval Observatory equipped with permanent instrumentation. In addition to its educational function, its role would include the accurate control of Navy chronometers.

Figure 5: The Kessels No. 1257 box chronometer (courtesy: Naval Museum).

Figure 6: The Dent No. 2067 box chronometer (courtesy: Naval Museum).

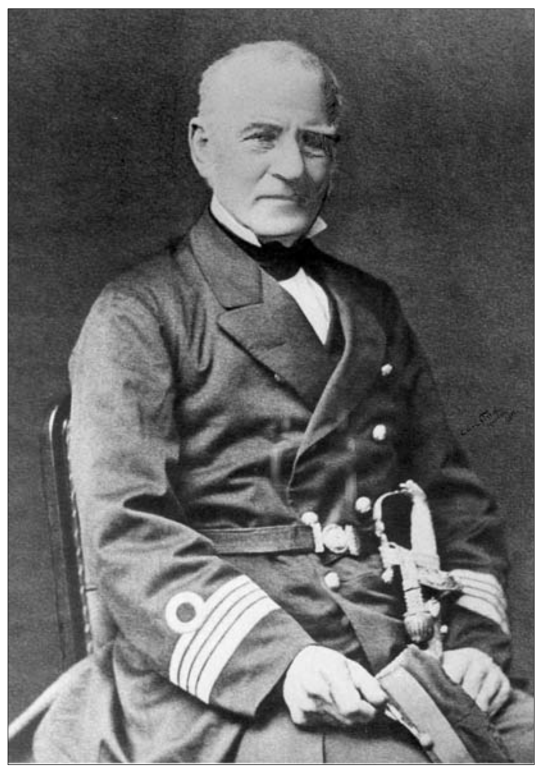

Figure 7: Christian Torber Hegge Geelmuyden (courtesy: Naval Museum).

2 THE NAVAL OBSERVATORY IN FREDRIKSVERN 1842-1864

The Norwegian Naval Observatory was set up in 1842 on the campus of the main naval base, which was then located at Fredriksvern (Oppegaard, 1928). It was equipped with a transit instrument and two pendulum clocks. No vestige of this facility remains today.

The transit instrument has a peculiar history. It was ordered from A. & G. Repsold by Hansteen (1838) for the Geographical Survey of Norway (which he directed), and was intended as a field instrument for mountaintop stations; thus it had to be small and transportable. During a visit to continental Europe in the summer of 1839 Hansteen discussed the details directly with Repsold in his workshop in Hamburg (Hansteen, 1839). Four years later he had still not received it (Hansteen, 1842), but Repsold (1842a) responded that it was almost ready for shipment to Norway. During this time priority at the Repsold workshops had been given to several large and complex instruments for the observatories at Pulkovo, Königsberg, and Oslo (see Repsold, 1914; 1927). The transit instrument left Hamburg at the end of November 1842 (Repsold, 1842b; 1842c) and arrived in Oslo two months later (Hansteen, 1843), delayed by transport irregularities between Germany and Norway caused by winter conditions. It was promptly paid for, and Repsold (1843) acknowledged this with a signed receipt.

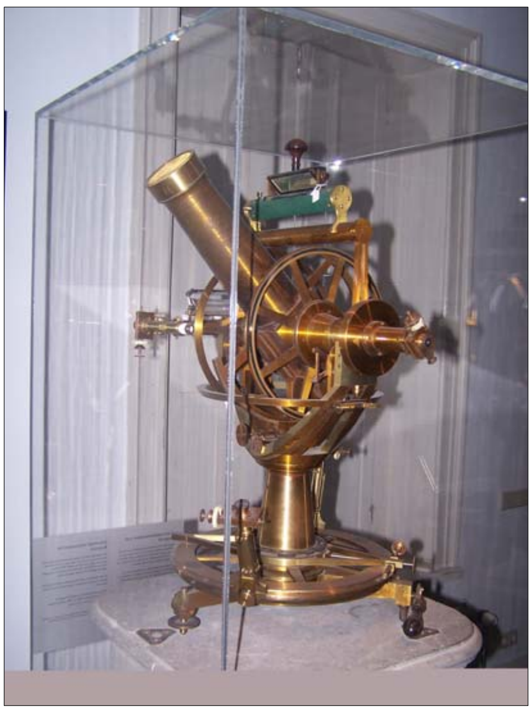

Figure 8: The Repsold universal instrument at the Utrecht Observatory (courtesy: Dr Roland Wittje).

The peculiarity is that this transit instrument was never included in the instrument inventories of the Geographical Survey of Norway, and the receipt is not in their Archives. I suggest that Hansteen offered the instrument to the Naval Observatory and that it was paid for by the Navy. A key motivation for Hansteen was the involvement of Geelmuyden, who was the driving force behind the setting up of the Naval Observatory at Fredriksvern. Geelmuyden's academic skills had impresssed Hansteen, who had good reason to expect that the young lieutenant would develop a scientific career and become a useful future collaborator. In addition to his Professorship at the University, Hansteen lectured in advanced mathematics, mechanics, astronomy and navigation at the Military College in Oslo between 1826 and 1849, and upon entering the College in 1839 Geelmuyden had attracted attention by requesting permission to skip the first year and enter directly into the senior class (Oppegaard 1928). He was given an individual mathematics exam by Hansteen and passed it brilliantly. When he was appointment lecturer at the Naval Academy in 1841, Geelmuyden promptly wrote a textbook on navigation which was to remain a standard for the next fifty years. A transit instrument in Geelmuyden's hands thus seemed an excellent investment for the future. Unfortunately, no photographs or drawings exist of this instrument, and no information of its dimensions have survived. Presumably it was destroyed in the 1945 bombing raid (see below).

Once the Naval Observatory was set up, Geelmuyden (1850) attempted to determine its longitude by observing the end of a partial solar eclipse on 6 May 1845. He used a refractor ('Seefernrohr') by Utzschneider & Fraunhofer (e.g. 1816), for which he improvised a tripod. Unfortunately the telescope did not focus sharply, and Geelmuyden considered the result erroneous by several seconds. At the University Observatory in Oslo the start of the eclipse was observed, but the end was missed due to clouds (Hansteen 1847), so no longitude difference emerged from this effort.

In 1850 Geelmuyden organised a chronometer expedition with Dent No. 2067 between the Naval Observatory and the University Observatory in Oslo. The latter institution had been established by Hansteen in 1833 and was located 5.5 seconds west of its interim predecessor at Akershus (Hansteen and Fearnley 1849; Pettersen 2002), which was the datum reference point prior to 1830. The longitude difference was found to be 2 minutes 40.55 seconds (Hansteen 1853), while previous chronometer expeditions conducted in 1824 and 1827 had yielded a value of 2 minutes 45.56 seconds between the Academy gardens and the Observatory at Akershus. Thus the Academy gardens were 2 minutes 40.1 $\pm$ 0.2 seconds west of the University Observatory. The Naval Observatory and the Academy gardens were almost on the same meridian. The resulting longitude of the Naval Observatory is 10° 03′ 14.2″ east Greenwich. By comparison, its geodetic longitude was derived to be 10° 02′ 01″ east Greenwich using a GPS observation in the Academy gardens.

The latitude of the Naval Observatory was listed by Hansteen (1852; 1853) as 58° 59′ 33.9″, obtained by combining unpublished observations by Geelmuyden and Hansteen's results from July 1819, transferred from the Academy gardens to the Naval Observatory. This locates the Naval Observatory 650 meters south of the Academy gardens. A search in the area revealed no physical remains of the Observatory.

The total solar eclipse on 28 July 1851 offered opportunities for further longitude observations. Geelmuyden (1850; 1851) was on duty on the corvette *Ellida* that summer (Einang et al., 1934), while his deputies, Knud Geelmuyden Smith and Hans Iver Andreas Hiorth, observed from the Naval Observatory. They were accompanied by several foreign visitors (e.g. John Couch Adams (1852) from Cambridge University), who observed the eclipse from locations near the Observatory building. The Naval Observatory results are discussed by Hansteen (1852; 1853).

A new Naval Observatory was established in Horten in 1854. A remark by Geelmuyden (1857) reveals that the first observatory at Fredriksvern continued to be used for chronometer control as late as 1857. The Naval Academy was transferred to Horten in 1864, and it is likely that all activity ceased at the Naval Observatory at Fredriksvern on this occasion.

3 THE NAVAL OBSERVATORY IN HORTEN 1854-1945

A major new naval base had been under development in Horten for several decades when the Naval Observatory was transferred there in 1854. A two-story brick building for the Instrument and Chart Collection was set up south-east of the outer perimeter of the base citadel. The collections of navigation instruments and naval charts were housed on the ground floor, while an observation room occupied the top floor. The Repsold transit instrument was transferred from Fredriksvern to Horten, and in 1858 a new pendulum clock was acquired (Geelmuyden, 1858).

In 1860 wear and tear justified a replacement for the transit instrument, and Geelmuyden sought the advice of the new Director of the University Observatory in Oslo, Carl Fredrik Fearnley (1860a). He ended up ordering a large universal instrument from Repsold (Fearnley 1861a), and Repsold (1861a; 1861b) responded by offering a copy of the one he was making for the observatory in Utrecht (Figure 8). This was accepted by Geelmuyden (Fearnley, 1861b), and the instrument left Hamburg on the *S.S. Sanct Olaf* on 29 August 1863, bound for Oslo (Repsold, 1863). At the Naval Observatory a small octagonal building with a rotating roof was set up in 1864 to house the new instrument. This same year the Naval Academy was transferred from Fredriksvern to Horten, and the Observatory was used for educational purposes. In 1876 an administrative reorganisation changed the name of the unit from the Instrument and Chart Collection to the Navigation Services of the Navy (Einang et al., 1934: 225). The two Observatory buildings were connected in 1878 by a one-story east wing to the original observatory, adding a magnetic observing room and offices (Karl-Johansværns Ingeniør-Detachement, 1882). The Observatory buildings remained the home of the navigation services until the entire naval base (then occupied by the German Navy) was destroyed in an allied bombing raid on 23 February 1945. By that time, the astronomical time-service had been surpassed by more modern technology.

In 1856 the national geodetic survey had reached Horten. The garrison church had been consecrated the previous year, and the church spire was thus available as a surveyor's datum point. Using the geodetic coordinates determined for the church (Næser, 1856) and my own GPS observations of the official national reference point at the time, I have derived coordinates in a modern reference frame (ϕ = 59° 25′ 34.2″ and λ = 10°29′ 22″ east of Greenwich). These compare well with GPS observations made at the church (φ = 59° 25′ 37″ and λ = 10° 29′ 23″). Photogrammetric measurements on historical military maps of the naval base locate the Naval Observatory 142m north of the church and 280m west of it. The derived geodetic coordinates are thus 59° 25′ (39-42)″ north and 10° 29′ 04″ east of Greenwich for the location of the transit instrument. GPS observations at the site yielded φ = 59° 25′ 41″ north and λ = 10° 29′ 06″ east Greenwich. The University Observatory in Oslo has a geodetic longitude (as measured repeatedly by GPS) of 10° 43′ 05″. This yields a geodetic longitude difference of 13′ 59″ (arc) = 55.9 time seconds between Oslo and Horten.

Horten and Oslo were connected by a telegraph line on 23 June 1855, and in November of that year Fearnley (Figure 9) and Geelmuyden began testing the line for a transfer of time signals. Astronomical observations of meridian transits of stars established local sidereal time as recorded on the Observatory's pendulum clocks. Time was then transferred to chronometers, which were carried to the local telegraph office. In Horten the telegraph office was located in barrack A on the naval base (Hansen, 1993). The observers received exclusive access to the telegraph line at midnight on predetermined dates, and exchanged time signals according to an agreed upon scheme. Several attempts were made to determine the longitude difference between the Naval Observatory and the University Observatory, but were thwarted by broken lines, noisy signals and other operational difficulties. Repeated tests in 1855 and 1858 revealed variable time delays and changing observational precision.

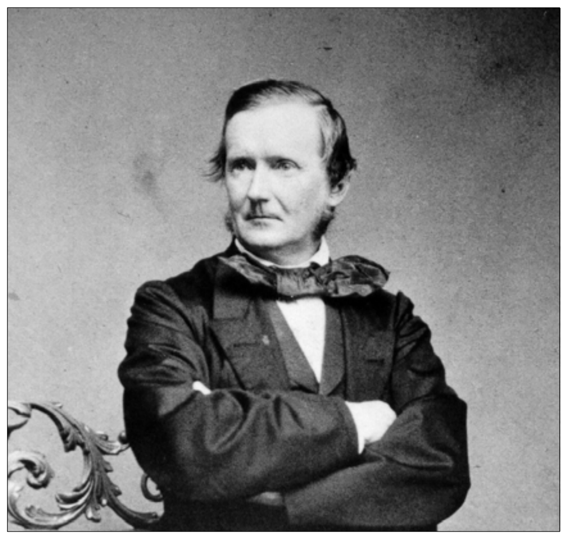

Figure 9: Carl Fredrik Fearnley.

By 1859 the telegraph system had expanded to include other major cities in Norway, and the operational reliability had improved. A project was carried out between March and July 1859 to exchange telegraphic time signals between three observatories in the country (Pettersen, 2006). Repeated experiments between Oslo and Horten yielded a longitude difference of 54.0 seconds (Fearnley, 1860b). My re-analysis of the data from twelve different days gave a value of 53.9 ± 0.5 seconds. The astronomical longitude of the University Observatory, 10° 43′ 22.5″ east of Greenwich (cf. Hansteen and Fearnley, 1849; Fearnley et al., 1890; Lous, 1926), thus implies that the Naval Observatory in Horten was located at 10° 29′ 52.5″ east of Greenwich. The latitude was listed by Fearnley (1860b) as 59° 25′ 55″ north.

The numerical differences between the astronomical (Φ, Λ) and geodetic (φ, λ) coordinates for the Naval Observatory are about 15″ in the meridian and about

45″ along the parallel. The astronomical value is larger than the geodetic. The deflection of the vertical at an observation site some 20 km to the southwest (on the Tønsberg baseline) is $\xi = \Phi - \varphi = -3.9''$ in the meridian and $\eta = (\Lambda - \lambda) \cos \varphi = 12.6''$ in the prime vertical. For the University Observatory (about 55 km to the northeast) these parameters are $\xi = \Phi - \varphi = -3.3''$ and $\eta = (\Lambda - \lambda) \cos \varphi = 8.8''$. It appears that the errors of both astronomical coordinates may be 10″ or more for the Naval Observatory.

In Bergen an observatory was established in 1855 (Pettersen, 2005), and it was equipped with a transit instrument by Repsold (f.l. = 60 cm), a pendulum clock with Mercury compensator by C. Höeg obtained from Bergen, and pocket chronometers derived from Altona. Johan Julius Åstrand was appointed City Astronomer on 1 July 1857, just weeks before the local telegraph office opened. In 1857 he used lunar distances to derive a longitude of 5° 18′ 00″ east of Greenwich. In 1859 Åstrand (1859) observed on six days in May and June and exchanged telegraphic time signals with Geelmuyden in Horten. Åstrand was concerned about the accuracy of the time transfer since the walking distance between the Observatory and the telegraph office in Bergen was considerable. He determined Bergen to be 20m 46.1s west of Horten, with an uncertainty of 2s, i.e. at longitude 5° 18′ 21″ (± 30″) east of Greenwich.

At the Naval Observatory in Horten time determinations were made routinely for chronometer control. Each Sunday a cadet transferred time from the Observatory's pendulum clock to a box chronometer, and the latter was carried to the Telegraph Office. Starting in November 1855, telegraphic time signals were issued every Sunday for the next thirteen years. In 1858 signals were transmitted also on Wednesdays. Telegraph offices in local communities across the country were thus updated continually and so could show correct time. This service continued until it was taken over by the University Observatory in Oslo in 1869. Geelmuyden had announced that he would leave the Naval Observatory the following year in order to accept the Directorship of the Technical School in Trondheim.

4 CONCLUDING REMARKS

The Naval Observatory in Fredriksvern was established as a calibration facility for the collection of chronometers acquired by the Navy between 1835 and 1845. The improved accuracy of navigation at sea put the safety of naval ships far ahead of commercial shipping at the time. The navigational skills and experience of naval officers, with six years of basic training at the Naval Academy, made them attractive also as teachers and examiners in the public nautical schools.

The Naval Observatory in Horten initiated the use of telegraphy for time transfer in Norway, and developed the first national time-service by issuing weekly telegraphic time signals to other coastal cities during C.T.H. Geelmuyden's Directorship. His personal interest in modern technology was a driving force. Unfortunately, his successors did not continue his collaborative and national approach, and so the Naval Observatory developed into an internal navigation service for the Navy.

5 NOTES

1. Søren Lorents Lous was born in Copenhagen on 29 June 1785, where his father (and grandfather before him) was Director of Navigation. He attended the Naval Academy in Copenhagen and began a military career in the Danish-Norwegian Navy. He was transferred to the main naval base in Norway (Fredriksvern) in 1812, and married in that same year. When Denmark handed Norway to Sweden in 1814 following the Napoleonic wars, Lous remained in Norway and became a Captain (and later a Commander) in the Norwegian Navy. When the Norwegian Naval Academy was established at Fredriksvern in 1817, he was appointed to lecture in mathematics and navigation. He held this position until 1841, when he was appointed head of military enrolment and chief of the pilot service in Bergen. He retired in 1857 and died in Bergen on 14 January 1865 (Anon., 1872).
2. Christian Torber Hegge Geelmuyden was born in Trondheim on 16 October 1816. He passed through the Naval Academy (1837) and the Military College (1840) in record time with remarkable academic success, and was sent to Sweden to study iron production and cannon design. In 1841 he was appointed lecturer of mathematics and navigation at the Naval Academy in Fredriksvern. He wrote a textbook on navigation which was used for more than fifty years. In 1842 he established the Naval Observatory. He also married that same year, and one and a half years later became father to a future university professor of astronomy. A decade later he transferred to the naval base in Horten, which replaced Fredriksvern as the main naval station. He also transferred the Naval Observatory to Horten, and founded a technical school in 1855 (which he directed until 1870). For some years he then directed a new technical school in Trondheim before returning to Horten as commander of the naval base. He died in Horten on 13 May 1885. He was a member of science academies in Oslo, Stockholm and Trondheim.

6 ACKNOWLEDGEMENTS

It is a pleasure to thank staff members of archives and libraries for access to original source material, notably Solveig Berg at the Astronomy Library of the University of Oslo and Helge Rønnes of the Norwegian Naval Museum, Horten. Photographs and portraits from the collections of the Naval Museum were kindly made available by Helge Rønnes.

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UO = Original in the astronomy archives, University of Oslo.

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