The Bicentenary of the Nautical Almanac

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(*Superintendent of the Nautical Almanac*)

(Text of a talk given at the Ordinary Meeting on 1966 December 9)

On the ninth day of February 1765, Nevil Maskelyne, fifth Astronomer Royal, presented to the Board of Longitude his suggestion for the calculation and publication of a 'Nautical Ephemeris', designed to make possible the determination of longitude at sea by means of the method of lunar distances. The Commissioners of Longitude resolved 'that Application should be made to Parliament . . . for power to give a Reward to persons to compile a Nautical Ephemeris and for Authority to print the same'. The application was duly approved and the first edition of *The Nautical Almanac and Astronomical Ephemeris* was prepared for the year 1767 and published in 1766. At the same time Maskelyne also published his *Tables Requisite to be Used with the Astronomical and Nautical Ephemeris* to serve as a handbook for use with the Almanac.

Although the motivation behind the publication was almost entirely navigational, the Almanac (as its full title indicates) also contained what are now known as 'the fundamental ephemerides of the Sun, Moon, planets and stars' to the highest precision. At that time, as will be seen, they were barely adequate for the purpose of navigation; but, with the advancing progress of astronomical observation and theory, the increasing precision outstripped that required for navigation. Even so it was not until 1914 that the two distinct functions of *The Nautical Almanac* were recognized by the publication of separate almanacs, one for navigators and one for astronomers. The position was ultimately clarified only in 1960 when the titles of the two publications were changed to the appropriate parts of the original title: *The Nautical Almanac* is specially designed for the use of marine navigators; and *The Astronomical Ephemeris* has no navigational use. There are now also *The Air Almanac* for the use of air navigators, and *The Star Almanac* for the use of land surveyors—a total of some 1700 pages annually as compared with the original, much smaller, 165 pages. It is better to make no comment on matters of productivity and efficiency, bearing in mind that astronomy now provides a very minor aid to navigation!

PREFACE.

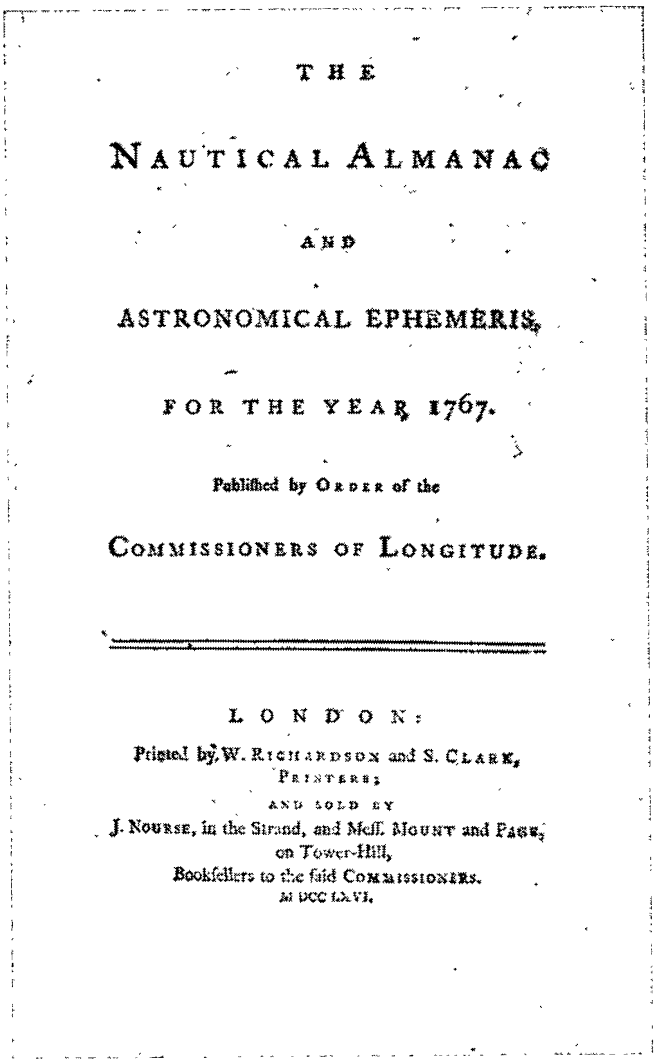
THE Commiſſioners of Longitude, in purſuance of the Powers veſted in them by a late Act of Parliament, preſent the Publick with the NAUTICAL ALMANAC and ASTRONOMICAL EPHEMERIS for the Year 1767, to be continued annually; a Work which muſt greatly contribute to the Improvement of Aſtronomy, Geography, and Navigation. This EPHEMERIS contains every Thing eſſential to general Uſe that is to be found in any Ephemeris hitherto publiſhed, with many other uſeful and intereſting Particulars never yet offered to the Publick in any Work of this Kind. The Tables of the Moon had been brought by the late Profeſſor MAYER of Gottingen to a ſufficient Exactneſs to determine the Longitude at Sea, within a Degree, as appeared by the Trials of ſeveral Perſons who made Uſe of them. The Difficulty and Length of the neceſſary Calculations ſeemed the only Obſtacles to hinder them from becoming of general Uſe: To remove which this EPHEMERIS was made; the Mariner being hereby relieved from the Neceſſity of calculating the Moon's Place from the Tables, and afterwards computing the Diſtance to Seconds by Logarithms, which are the principal and only very delicate Part of the Calculus; ſo that the finding the Longitude by the

The first page of the Preface of *The Nautical Almanac* for 1767, showing the (deservedly) high claims made for it.

Astronomically, the bicentenary must be regarded as relating to *The Astronomical Ephemeris*, but space will only permit the briefest references to the development of its astronomical content. This article is therefore restricted mainly to a description of the events leading to the original publication and of those with which this Society has been directly concerned.

Although it is far from the truth that the ancient and medieval sailors hugged the coasts, it was only after the great voyages of discovery in the

PLATE 2



THE

NAUTICAL ALMANAC

AND

ASTRONOMICAL EPHEMERIS,

FOR THE YEAR 1767.

Published by ORDER of the

COMMISSIONERS OF LONGITUDE.

LONDON:

Printed by W. RICHARDSON and S. CLARK,
PRINTERS;
AND SOLD BY
J. NOURSE, in the Strand, and Mess. MOUNT and PAGE,
on Tower-Hill,
Bookfellers to the faid COMMISSIONERS.
M DCC LXVI.

The title page of the first edition of *The Nautical Almanac* for 1767.

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fifteenth century that a desperate need was felt for a method of determining position at sea, independently of landmarks or of dead reckoning. Position is, of course, expressed in terms of latitude and longitude; and, even with such relatively crude instruments as the cross-staff or back-staff and an elementary knowledge of the Sun's changing declination, a precision of 20 or 30 miles could readily be obtained in latitude. However, the determination of longitude at sea posed a problem of the greatest difficulty.

It was early recognized that longitude was inseparably associated with the rotation of the Earth on its axis, and thus with time; the difference in longitude, measured in time-units, between any two places is merely the difference between the local times at the two places at the same instant. What is required is a predictable rapidly-changing phenomenon which is independent of, and can be observed from, the ship's position; one obvious answer is a transportable mechanical clock, but it was not until John Harrison succeeded in designing and making his marine chronometer, in 1761, that a sufficiently accurate (that is, predictable) clock could be carried on board ship. As is well known, Harrison was belatedly awarded the full £20,000 prize offered by Act of Parliament in 1714 for a practical method of finding longitude at sea to within thirty miles; however, for a long time afterwards chronometers were expensive and, even when carried, were not trusted during long voyages. It is an interesting commentary that the chief judge of the tests carried out on Harrison's chronometer was Maskelyne, the chief proponent of the rival method of lunar distances. For the main purpose of checking the chronometer, lunar distances were in fact included in *The Nautical Almanac* until 1906, and instructions for their calculation, with illustrations of their reduction and use, until 1924; by this time the increasing availability of radio time signals was providing a completely independent method.

It may be briefly recorded that, in spite of the brilliant investigations of Edmond Halley, attempts to find position by measurements of the Earth's magnetic field were doomed to failure.

In principle any fast-moving, observable astronomical body can be used as a basis for time-keeping providing its motion can be predicted; and the Moon provides the obvious choice. The use of the Moon as a clock, reading the time by means of observing 'lunar distances' (the angular distances between the Moon and the Sun, a planet or a star), was suggested by the German astronomer, Regiomontanus, as early as 1474*; the suggestion was frequently repeated by subsequent writers,

*Doubt has been cast on the authenticity of this reference, which apparently stems from the eleventh edition of the *Encyclopaedia Britannica*. The earliest verifiable reference is to John Werner (1514) in his commentary on the 1514 edition of Ptolemy's *Almagest*.

REPORT

OF

THE COMMITTEE OF THE ASTRONOMICAL SOCIETY OF LONDON,

Relative to the Improvement of the Nautical Almanac: adopted by the Council, November 19, 1830; approved by the Right Honourable the Lords Commissioners of the Admiralty, and ordered by them to be carried into effect.

NAMES OF THE COMMITTEE.

*Professor Airy.
Right Hon. Lord Ashley.
*C. Babbage, Esq.
*F. Baily, Esq.
P. Barlow, Esq.
*Capt. F. Beaufort, R.N.
Capt. F. W. Beechey, R.N.
Lieut.-Gen. Sir T. M. Brisbane, K.C.B.
Right Rev. Bishop of Cloyne.
Lieut.-Colonel Colby, R.E.
A. De Morgan, Esq.
Hon. Capt. Dundas, R.N.
Davies Gilbert, Esq., P.R.S.
Dr. Gregory.
Capt. Basil Hall, R.N.
Professor Hamilton.
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Capt. James Horsburgh.
Rev. Dr. Inman.
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Dr. Lee.
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T. Maclear, Esq.
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*J. Pond, Esq.
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*Rev. Dr. Robinson.
Rev. R. Sheepshanks.
Capt. Shireff, R.N.
Capt. W. H. Smyth, R.N.
*Sir James South, *President*.
*Lieut. W. S. Stratford, R.N.
*Professor Struve.
Dr. Tiarks.
E. Troughton, Esq.
J. Wrottesley, Esq.

N.B.—Those Members, to whose names an asterisk is prefixed, formed the Sub Committee.

ASTRONOMICAL SOCIETY OF LONDON.

The COMMITTEE *appointed by the* COUNCIL *of the* ASTRONOMICAL SOCIETY *to take into consideration the Letter addressed to them by the Right Honourable the* LORDS COMMISSIONERS *of the* ADMIRALTY, *relative to the improvement of the* NAUTICAL ALMANAC, *have agreed on the following*

REPORT.

1. The attention of the Committee was, in the first instance, directed to a subject of general importance, as affecting almost *all* the results in the Nautical Almanac; viz.,

The introduction to the 'Report of the Committee of the Astronomical Society of London' on *The Nautical Almanac* in 1830, showing the members of the Committee.

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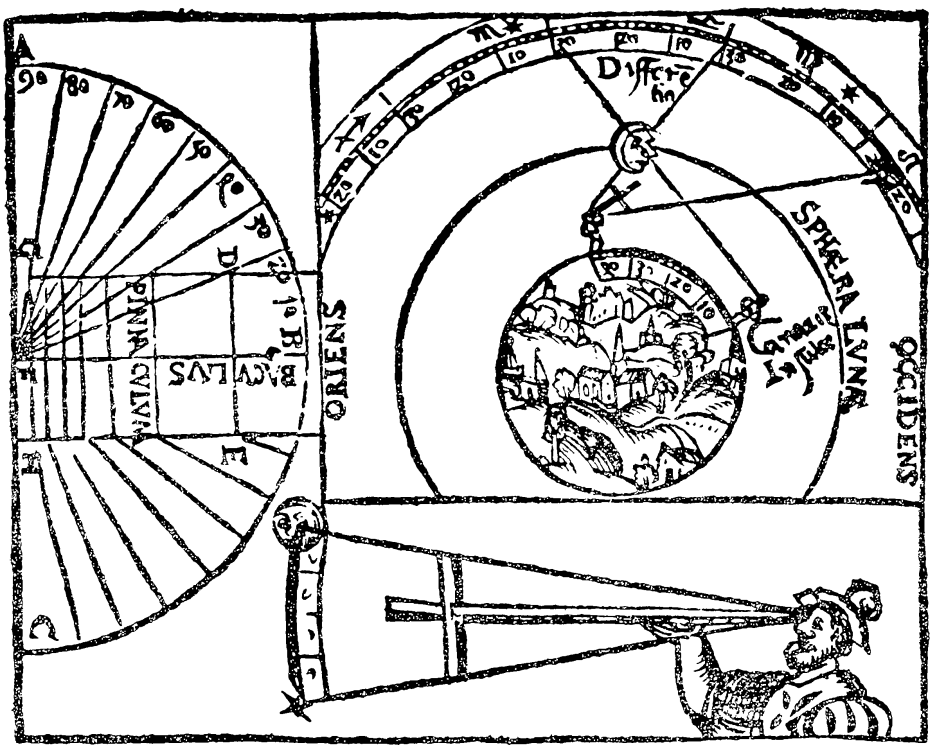
and investigated in detail by many generations of astronomers, but it was to be nearly 300 years before it became practicable to predict the motion of the Moon and to observe its position among the stars with sufficient precision. This may be compared with the progress of Radio Astronomy in 20 years and that of Space Research in 10 years. In the meantime Galileo's invention of the telescope, his discovery of the satellites of Jupiter, and his application of the pendulum for the timing of astronomical observations, made possible the use of the motions of Jupiter's satellites for the determination of longitude. Galileo himself, in 1616 and 1617, put forward the method for consideration of the prize offered by King Philip of Spain for a practicable solution; he again suggested it in 1636, on this occasion to the States-General of what is now the Netherlands. Directly arising from this possibility of finding the longitude, King Louis XIV in 1666 founded the French Academy, leading to the foundation of the Paris Observatory in the following year, and to the *Connaissance des Temps* in 1679; predictions of the phenomena of Jupiter's satellites were included as from 1690, and were extensively used for determining the longitudes of many places in Europe, Africa, Asia and America. However, the



The earliest known illustration of the method of lunar distances; this diagram, first published in 1524, which vividly illustrates the principle, is reproduced by courtesy of the Trustees of the National Maritime Museum from *Cosmographia Petri Apiam per Gemma Frissium.*

practical difficulties of observing the satellites of Jupiter from a moving ship, especially using the long telescopes that were then necessary, were too great for the method to be used at sea. The story of the attempts to do this deserves a separate telling.

At about the same time King Charles the Second, in founding the Royal Observatory at Greenwich in 1675, commanded John Flamsteed, the first Astronomer Royal, to apply himself 'with the utmost care and diligence to the rectifying of the tables of the heavens, and the places of the fixed stars, in order to find out the so much desired longitude at sea, for the perfection of the art of navigation'. It is hardly necessary to relate to Fellows of this Society how well the Astronomers Royal have complied with that command! In the meantime, in 1687, Newton had published the *Principia* and had there given all the principal inequalities in the motion of the Moon; but it was still to be a further 80 years before Tobias Mayer, using Euler's first theory of 1753, was able to compile tables that represented observations within one minute of arc. The actual tables used by Maskelyne in the calculations for *The Nautical Almanac* were the 1763 manuscript, which was not printed until 1770.

By a fortunate coincidence, John Hadley had, in 1731, invented the reflecting quadrant, on the same principle as a modern sextant; the development of this instrument (it soon became a sextant so as to measure distances greater than 90°) provided the means of observing lunar distances to a precision corresponding to that with which the Moon's position was known—rather better than the one minute of arc, which corresponds to about half a degree of longitude.

The stage was now set for Nevil Maskelyne. With typical energy and thoroughness he first extensively compared Mayer's tables with his own observations and then experimented with the method of lunar distances at sea during his voyage to observe the transit of Venus at St Helena in 1761. On his return he was able to report on the success of the method in the *British Mariner's Guide*, in which he first suggested a plan for a nautical ephemeris.

The simple principle of the method of lunar distances is that the Moon, in its motion round the Earth, can be used as a clock; the geocentric values of the angular distances from the Moon to the Sun, planets and stars can be tabulated, so that the time corresponding to an observed lunar distance can be found by inverse interpolation to the corresponding geocentric value. The practical difficulties are, however, considerable as the observed lunar distance is affected by parallax and refraction; and the parallactic shift of the Moon can be as much as half the time shift. Including the two in Maskelyne's *Requisite Tables* . . . , well over a hundred methods for reducing or 'clearing' the

observed distance, with appropriate tables and instructions, were published by the middle of the nineteenth century. The method given in *The Nautical Almanac* for 1924 requires about 25 entries into 5-figure trigonometrical tables, together with many additions or subtractions; even today the calculation is formidable and would certainly not be regarded as acceptable by a modern navigator. Yet it is stated that the *Requisite Tables* . . . sold 10,000 copies immediately on publication!

Maskelyne's outstanding contribution was that he not only showed that the method was possible in the hands of an expert, but that he also made it practicable at sea for an eighteenth-century seaman.

Maskelyne's organizational genius did not end there, for he was responsible for the continued calculation and production of *The Nautical Almanac*. He arranged the work so that all calculations were made, under his direction and in accord with his instructions, by two

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lite, which were calculated from the Tables of the ſame further improved by Mr. WARGENTIN, and publiſhed alſo by M. DE LA LANDE in the CONNOISSANCE DES MOUVEMENTS CELESTES of 1766.

All the Articles of the EPHEMERIS were computed by Two ſeparate Perſons, and examined by a Third, except the Moon's Longitude, Latitude, Right Aſcenſion, Declination, Semidiameter, and Parallax, which, for Noon, were computed by One Perſon, and for Midnight by another, and the Truth of theſe Calculations aſcertained by means of Differences, which, for the Moon's Longitude, were carried as far as the Fourth Order.

NEVIL MASKELYNE,
ASTRONOMER ROYAL.

The last page of the Preface of *The Nautical Almanac* for 1767, indicating the great care that Maskelyne exercised in the control of the calculations.

computers independently, whose results were then collated by a comparer. These computers and comparers worked at their own homes, and very complete records exist, in the Board of Longitude papers at the Royal Greenwich Observatory, of the details of their employment and remuneration. Several of the computers, such as George Witchell (Head Master of the Royal Academy at Portsmouth) and William Wales (Master of the Royal Mathematical School in Christ's Hospital) became

well known; and the Rev. Malachy Hitchens was a comparer for 42 years from 1767 to his death in 1809.

Under the direction and keen personal interest of Maskelyne the system worked well; he was wise, and perhaps fortunate, in his choice of computers, but he insisted on the absolute independence of the calculations and instantly dismissed two computers who copied each other's work. It will be recalled that he also dismissed his observing assistant, Kinnebrook, in 1796 (most unjustly as it subsequently transpired) because of his different 'personal equation'. Before leaving Maskelyne it is of interest to quote Herschel's remark on first meeting him 'That is a devil of a fellow'; in view of his cloth and his acknowledged mild and genial temper this must have been a compliment to his rare ability, rather than a criticism of his irascibility. On Maskelyne's death in 1811 the system deteriorated; *The Nautical Almanac* lost its reputation for accuracy and fell into grave disrepute; in fact, in the House of Commons in 1818 it was stated that it had become 'a bye-word amongst the literati of Europe'.

At this point, it is tactful to gloss over the somewhat depressing details, of which an excellent account has been given by J.L.E.Dreyer in the *History of the Royal Astronomical Society*, which can be recommended to provide both interesting and rewarding reading.

The Act of 1818 'for more *effectually* discovering the Longitude at Sea . . . ' revised the constitution of the Board of Longitude (which was formally responsible for *The Nautical Almanac*) and appointed a paid secretary, Thomas Young, to serve also as 'Superintendent of the Nautical Almanac'. Although he quickly restored the reputation for accuracy, Young, the distinguished discoverer of the wave-theory of light, the authority on Egyptian hieroglyphics and one of the foremost scientists of his day, was not the right man for the post. He was unable, or perhaps unwilling, to meet the increasing demands for the complete revision of the content of the Almanac. The demand for reform came principally from the astronomers, led by Francis Baily and James South (the navigators throughout seemed to be remarkably complaisant); apart from relatively minor criticisms of the Almanac as a navigational ephemeris they each proposed extensions of the ephemerides, in respect both of precision and scope, for use by astronomers. Baily insisted on a change to mean time, but oddly enough South defended the retention of apparent time as argument of the ephemerides, and for all astronomical observations, relegating 'mean time' to the needs of culinary philosophy! Young's attitude in resisting these proposed reforms has been severely criticised and much of the criticism (especially in respect of detail) is undoubtedly justified; but his contention that seamen don't like change and would be confused

by astronomical data they did not want is sound. Less happy, perhaps, was his argument that astronomers had no special claim to be aided in their work at the public expense!

In 1827, Airy and Herschel were the leaders of a reforming party inside the Board of Longitude itself, but Young resisted change as much as possible. The Board of Longitude, which had long outlived its great past, was abolished by the Act (The Nautical Almanac Act) of 1828; the sections of this Act relating to the printing, publishing and vending of *The Nautical Almanac* are still retained in the Statute Book; but Young still remained as Superintendent.

The clamour grew, leading, in 1829, to a Memorandum to the Chancellor of the Exchequer and a full Parliamentary enquiry, with the usual demand for the production of papers; these were published on 17 March of that year. They include a temperate, but unconvincing, Report by Young in answer to the criticisms of the Almanac in the Memorandum; objectively it can be said that some of them were, in fact, misplaced or exaggerated—including the number of errors in the Almanac for 1830. South published on 25 April a typically virulent 'Refutation of the numerous mis-statements and falacies contained . . .' in Young's Report, which brought considerable sympathy for Young from no less a figure than George Biddell Airy, then Plumian Professor at Cambridge; he was not a man lightly to tolerate inefficiency. Airy told South of his disapproval of his attack and said that he would assist Young in the way he had asked; he convened a meeting with Baily and South on 11 May 1829. However, Young died on the previous day whereupon Airy applied for the post of Superintendent, only to be informed that it devolved on the Astronomer Royal, John Pond.

Pond introduced a few reforms by the addition of a supplement, but after only a year the Board of Admiralty, on 28 July 1830, formally requested the advice of the Council of the Astronomical Society of London on the reform of *The Nautical Almanac*. (The Society was in process of receiving its Royal Charter.) The Council acted with a speed that is truly remarkable: it appointed a Committee of 40 members whose lengthy and comprehensive report, which included every detail of the proposed ephemeris, was approved by the Council on 19 November of the same year. And at the meeting of the Council in the following month, it was reported that the Admiralty had directed the Astronomer Royal to carry out the suggestions in full.

Shortly afterwards Lieutenant W.S.Stratford, R.N., who was at the time Secretary of the Society, was appointed Superintendent of the Nautical Almanac, and he introduced all the changes (with very minor exceptions) into the Almanac for 1834. Both Stratford and Pond were members of the sub-committee of ten that prepared the report, with

South as Chairman; but Baily was responsible for the colossal task of preparing the report. It would be right to think, however, that some at least of the efficiency with which this matter was handled was due to the Society's secretary!

It is not necessary here to give details of the changes, except to say that the emphasis for navigation was still on lunar distances and the Committee specifically drew attention to the extension of the other ephemerides, and the inclusion of additional data, so that 'the work might be rendered equally useful for all the purposes of practical astronomy'.

There is an interesting sidelight on this revision. The main change was the substitution of mean time instead of apparent time as the argument of the ephemerides, a direct reflection of the increasing use of chronometers. But longitude continued to be derived (separately and almost independently of latitude) from the longitude- or time-sight taken near the prime vertical—and there are many who still do so today! It is almost inconceivable that any of the 40 members of the Committee could have been unaware that an observed altitude of a body at a known time places the observer on a small circle (a position circle or position line) on the Earth's surface; yet it was not until 18 December 1837 that an American shipmaster, Thomas Sumner, sailing in bad weather up St George's Channel, discovered that such a sight determines a position line (for long known as a Sumner Line) on which the ship must be. This discovery, coupled with that of the 'intercept method' of constructing a position line made by a French naval captain, Marcq St Hilaire, in 1875, revolutionized the practice of navigation. Impressive as the 1830 report was, there is some feeling that it tended to divorce the Almanac (as Young had feared) from the practical requirements of the navigator; certainly no change directed towards its use for navigation was made until 1914 (if we exclude the rather derisory separate publication of the first part only as from 1896), and neither the Society nor the Nautical Almanac Office can be particularly proud of their contributions to the theory and practice of astronomical navigation during that period.

However, in 1890 the Council took the initiative in suggesting to the Admiralty improvements in *The Nautical Almanac*, mainly in respect of the apparent places of stars and ephemerides of the satellites; and these were incorporated in the Almanac for 1896 for which, coincidentally, the first part 'containing such portions as are essential for navigation' was issued separately. In November 1897 the Council discovered that certain changes had been introduced into the Almanac without prior consultation with the Society. The changes, which arose from the recommendations of the 1896 Paris Conference of the Directors of the

National Ephemerides, included the adoption of the fundamental astronomical constants (of solar parallax, precession, nutation, and aberration) that have only recently (Hamburg, 1964) been superseded by the IAU System of Astronomical Constants. At the Council meeting in December it was resolved that the Admiralty should be informed that these changes seriously concerned the Society and expressed the hope that the Society was not in danger of losing the privilege of being consulted. An immediate reply was received, acknowledging the mistake and assuring the Council that 'there was no intention on the part of anyone at the Admiralty to act otherwise than in accordance with precedent'; in a further letter dated 23 December, the Admiralty formally requested the opinion of the Council as to the adoption of the resolutions of the Paris Conference and their incorporation into *The Nautical Almanac*. The 1896 conference led the way to the international exchange of astronomical data, which set a model that has been so successfully followed under the auspices of the International Astronomical Union.

The Society was consulted by the Admiralty on two further occasions. In 1910, after some 70 years, it was at last recognized that the seaman was not being given his astronomical data in the form most useful to him; and the Council, as usual through a Committee on which the Superintendent was a member, made comprehensive and detailed recommendations that resulted in the separate publication of *The Nautical Almanac, Abridged for the Use of Seamen* for 1914. This, again, was an extremely competent piece of work, of which the Society can be proud. Finally in 1917, for the second time as it had already been discussed at some length in 1885, the Council was asked to ascertain the views of astronomers as to changing the beginning of the day from noon to midnight; it is difficult to imagine a more unsuitable time for consultation on a matter of such great international concern. The majority report in favour of the change could hardly be called representative, to say nothing of the fact that navigational interests were not consulted. As a result of this report the change was adopted in *The Nautical Almanac* as from 1925, and in due course adopted universally; but errors still occurred from this change even in H.M. Nautical Almanac Office as late as 1940—and it would have needed a brave man to have defended the change to the navigators of 1925! As far as can be discovered this was the last occasion on which the Society was formally consulted in matters concerning *The Nautical Almanac*; it was not consulted in connection with the comprehensive changes that were introduced in 1931, and since then the content has been discussed within the International Astronomical Union. Recent changes in the navigational publications have been discussed by the Institute of Navigation.

The Astronomical Ephemeris is now 200 years old—and showing signs of its age. Its traditional function of providing the fundamental ephemerides for the comparison of observation with theory has been largely taken over by the electronic computer, since it is now quicker to compute a position directly than to interpolate the printed figures. It provides inadequately for the distance that can now be measured by radar so much more precisely than the direction. Due to the requirements of international exchange agreements it suffers from a grievous time-lag between initial printing and publication, which creates difficulties in keeping up with the rapid pace of theoretical developments. These matters are being actively discussed both internationally and nationally; although it will not be long before one problem at least is solved, namely the complete automation of the type-setting, the design of the content to meet present needs is more difficult. But it would be simple if its redesign could be referred to the Society with the understanding that a full and detailed report, covering every aspect of content and presentation, would be prepared with the same efficiency, speed (and success) as in 1830!

Notes

1. *The Astronomical Ephemeris* and *The Nautical Almanac* for 1967 both include additional Prefaces giving brief historical accounts of the two publications.

2. A reprint of the article 'A modern view of lunar distances' (*J. Inst. Nav.* (1966) **19**, 131), which also contains tabulated lunar distances for August 1967, is available on request to H.M. Nautical Almanac Office.

3. An exhibition to illustrate the bicentenary of *The Nautical Almanac* is being staged in the Old Royal Observatory at Greenwich by the National Maritime Museum. It covers two hundred years of astronomical navigation, with particular emphasis on the method of lunar distances and on modern methods.

4. A booklet *Man is not lost* has been specially prepared in conjunction with the exhibition, and is on sale both at the National Maritime Museum, and at the Royal Greenwich Observatory.