COOK, GREEN, MASKELYNE AND THE 1769 TRANSIT OF VENUS: THE LEGACY OF THE TAHITIAN OBSERVATIONS

Wayne Orchiston
National Astronomical Research Institute of Thailand, 191 Huay Kaew Road, Suthep District, Muang, Chiang Mai 50200, Thailand.
Email: wayne.orchiston@narit.or.th

Abstract: The 1769 transit of Venus was seen by astronomers as an important opportunity to pin down a figure for the solar parallax (*P*), and thus establish the Astronomical Unit and the size of the Solar System. Britain therefore mounted a number of expeditions, the most important of which was led by Lieutenant James Cook in the *Endeavour*, with Tahiti as the intended observing location.

In this paper we trace the planning that preceded this expedition; provide biographical accounts of the *Endeavour's* two astronomers and others who also carried out astronomical observations; describe the astronomical instruments taken on the voyage; document the various transit observations; and track the post-transit path of the *Endeavour* as it returned to England. We then discuss the values of *P* that derived from this expedition and others, and end the paper by examining a number of research issues relating to the astronomical aspects of Cook's voyage that have yet to be resolved.

Keywords: 1769 transit of Venus, Tahiti, James Cook, Charles Green, solar parallax, Thomas Hornsby, Simon Newcomb, astronomical records, scientific instruments, Daniel Solander

1 INTRODUCTION

Transits of Venus are rare astronomical events, and it was the Scottish mathematician and astronomer James Gregory (1638–1675) who first suggested that they could be used to determine the Astronomical Unit (i.e. the distance from the Earth to the Sun). The celebrated English astronomer Edmund Halley (1656–1742) and the French astronomer Joseph-Nicolas Delisle (1688–1768) elaborated on this idea, and so it was that the pair of eighteenth century transits (in 1761 and 1769) came to assume immense importance for the international astronomical fraternity.

The critical measurements were the precise times of the second ingress and first egress contacts during the transit (i.e. 2 and 3 in Figure 1), and from these one eventually could calculate a figure for the solar parallax, *P* (defined as "Half of the angular equatorial diameter of the Earth, as seen from the Sun").

The 1761 transit of Venus (Woolf, 1959) produced a plethora of figures for the solar parallax, but the range in values from 8.28″ to 10.6″ was unacceptable, and so the focus shifted to the 1769 transit (Betts, 1993; Moore, 1977). In this paper we build on Orchiston (2005) and examine the British 1769 transit program, especially that associated with James Cook and Tahiti.

2 PLANNING THE BRITISH EXPEDITIONS

Britain and Prussia were at war with Austria, France, Russia, Saxony and Sweden when the 1761 transit occurred, but by 1769 the Seven Years' War was becoming a distant memory for some. Thus, what better way could Britain demonstrate her scientific supremacy than through astronomy, and particularly the up-coming transit of Venus? Thomas Hornsby (1733–1810), the highly respected Savilian Professor of Astronomy at Oxford University (Wallis, 2008), more or less suggested this when he wrote:

> It behoves us therefore to profit as much as possible by the favourable situation of Venus in 1769, when we may be assured the several Powers of Europe will again contend which of them shall be most instrumental in contributing to the solution of this grand problem. (Hornsby, 1765: 343).

Clearly, British pride was at stake.

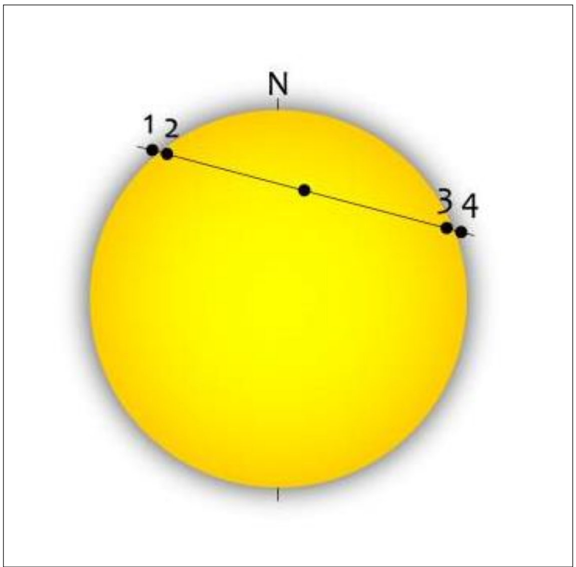


Figure 1: A drawing of a transit of Venus, showing the two ingress contacts (1 and 2) and two egress contacts (3 and 4). Critical for calculation of the solar parallax, *P,* and hence the Astronomical Unit, were contacts 2 and 3 (http://blogs.esa.int/venustransit/2012/24/transit-terminology/).

The Royal Society responded by forming a Transit of Venus Committee in 1767, two years before the grand event, and its members included Nevil Maskelyne (1732–1811; the Astronomer Royal), and three of London's leading astronomers, Dr John Bevis (1693–1771), and the Scots James Ferguson (1710–1776) and James Short (1710–1768). They began by reviewing the very useful 19-page paper, "On the transit of Venus in 1769", that Hornsby (1765) had published in the *Philosophical Transactions of the Royal Society*, where he identified three ideal overseas observing sites: North Cape in Norway, Hudson Bay in Canada and a suitable spot in the Pacific Ocean. The trouble was that no known land existed at this Pacific location at the time Hornsby wrote his paper, but fortune favoured the British because in May 1768—just over a year before the all-important transit—HMS *Dolphin* arrived back in port after a lengthy voyage of exploration in the Pacific (see Robertson, 1948), and its commander, Samuel Wallis, reported his discovery on 17 June 1767 of 'King George III Island' (now called Tahiti) at precisely the desired Pacific location! He also reported that the climate was pleasant, Port Royal (now Matavai Bay) offered an excellent harbour, and the local Tahitian people (eventually) were friendly and co-operative. The Transit of Venus Committee then adopted all three observing sites (see Beaglehole, 1963(I): 20–21), and so the Tahitian expedition was born (Herdendorf, 1986). However, Tahiti (Figure 2) was seen as host to the principal station, for two important reasons: the beginning *and* end of the transit could be observed there, and the duration of the transit would be significantly shorter than at the North Cape or Hudson Bay (Hornsby, 1765).

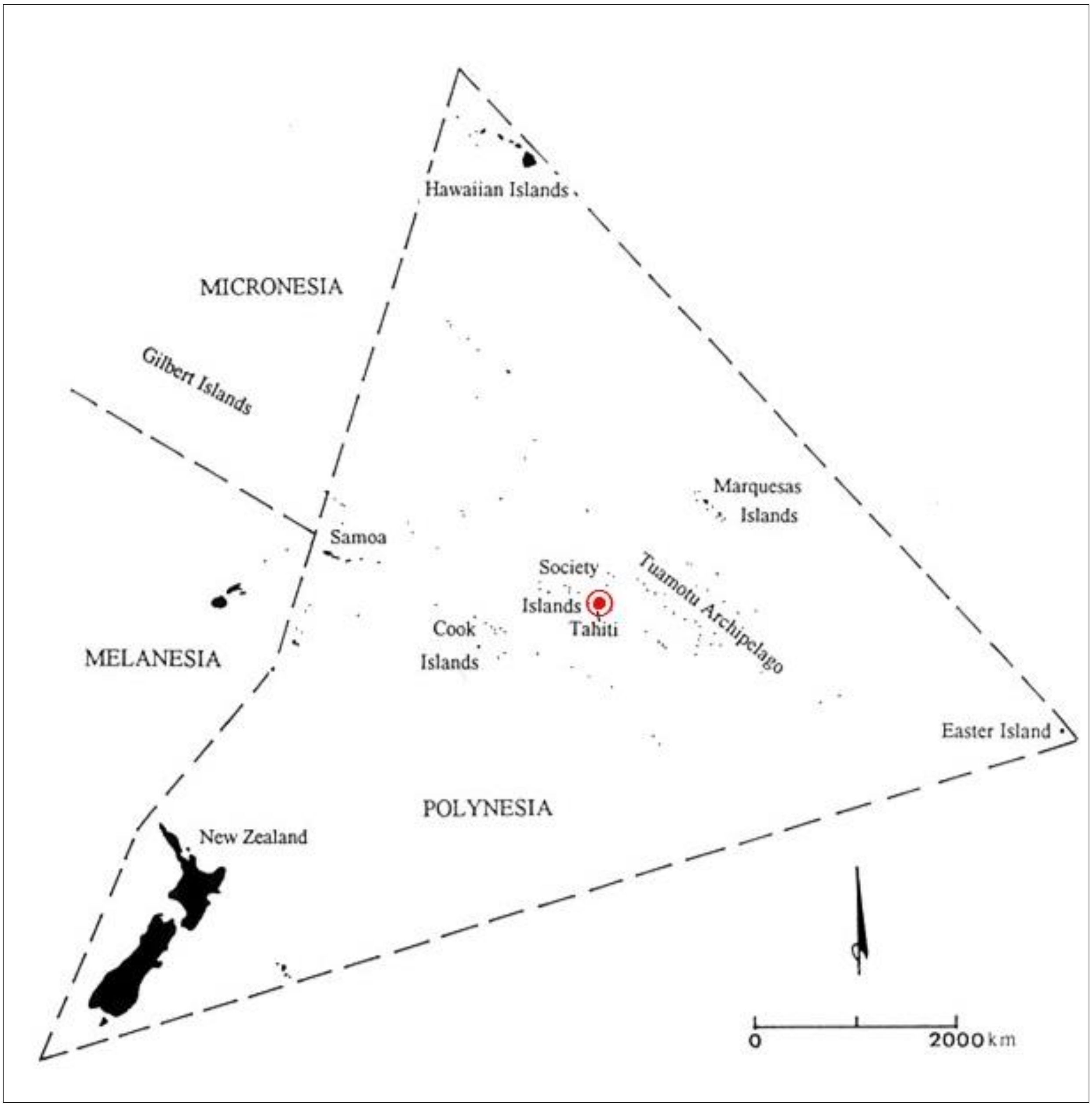


Figure 2: Map showing the location of Tahiti, the largest island in the Society Islands, very close to the centre of the 'Polynesian Triangle', which is bordered by the Hawaiian Islands, Easter Island and New Zealand (Map: Wayne Orchiston).

3 THE TAHITIAN EXPEDITION

3.1 The Vessel

The Transit of Venus Committee petitioned King George III to provide funding for the South Seas transit of Venus expedition (Banks, n.d.: 512–513), and he was happy to oblige. The Seven Years' War may be over, but what better way of demonstrating continued British supremacy than to excel in scientific endeavours. Elsewhere (Orchiston, 2005: 52) I have used the term "… fighting the peace ..." to characterise this philosophy. In hindsight, it is not surprising that King George III supported the transit of Venus proposal, as he was

> ... the first British monarch to have studied science as part of his formal education. He was known 'for his love of the sciences' and had been taught physics and chemistry as a boy, holding a particular interest in *scientific instruments*, *astronomy*, the quest for longitude, botany and *the work of the Royal Society*. (Wulf, 2012: 101; my italics).

The Admiralty then spent £2,307.5s.6d purchasing a suitable vessel, the 370-ton *Earl of Pembroke* (Deptford Yard Officers, 1768a), and a further £2,293.17s.7d modifying it for the voyage (Deptford Yard Officers 1768b). This ex-Whitby collier was renamed *Endeavour* (Figure 3), and was a type of vessel very familiar to Cook from his pre-naval days. However, even after refitting, space was at a premium, and it was to prove cramped quarters for close on 100 men, comprising officers, marines and able-bodied seamen from the Royal Navy, and non-naval personnel referred to collectively as 'supernumeraries'. Most of the supernumeraries were members of Joseph Banks' team of scientists, artists and servants, but there were two notable exceptions: Charles Green, who was one of the two official astronomers on the *Endeavour*, and his servant, John Reynolds.

3.2 The Astronomers

The Royal Society appointed two astronomers to accompany the *Endeavour* on its voyage of scientific investigation to the South Seas. As we have just noted, Charles Green was one of these, but surprisingly, the other was James Cook.

3.2.1 James Cook

Lieutenant James Cook (Figure 4) would serve the dual roles of astronomer, *and* commander of the *Endeavour* and of the expedition. Badger (1970: 30) claims that we are fully justified in classing Cook as a 'scientist' (*cum* 'astronomer'), in that he was "… a scrupulously careful observer … [and] His attitude to measurement

Figure 3: Close-up photograph of the HMS Bark *Endeavour* full-scale replica (en.wikimedia.org).

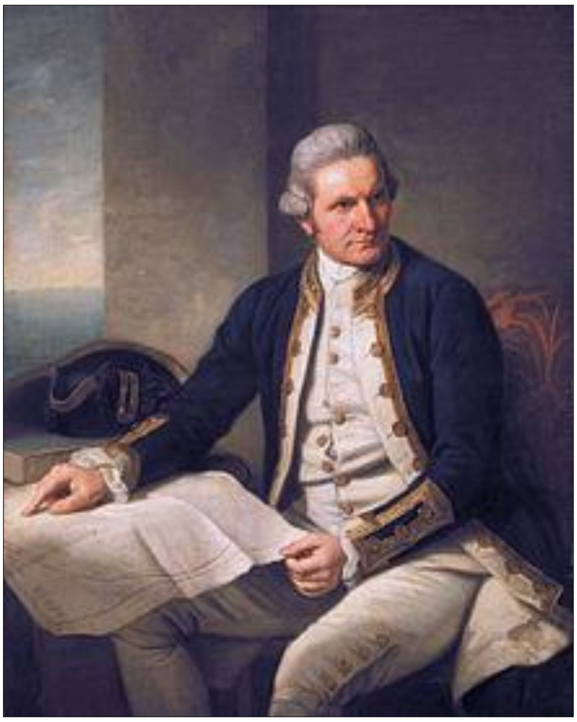


Figure 4: Oil painting of Captain James Cook by Nathaniel Dance-Holland, ca. 1775, and now in the National Maritime Museum, Greenwich (en.wikipedia.org).

and inquiry would do credit to any conventionally-trained scientist."

James Cook was born on 27 October 1728 in Marton-on-Cleveland in Yorkshire (for English and Scottish localities see Figure 5) to a Scottish labourer father and an English mother (Beaglehole, 1974), but soon after the family moved to a farm at Great Ayton. This is where young James grew up and was educated (see Beaglehole, 1968: cvi). Apparently, to his fellow school-pupils he had

> ….such an obstinate and sturdy way of his own, as made him sometimes appear in an unpleasant light; notwithstanding which, *there was a something* in his manners and deportment, which attracted the reverence and respect of his companions. (Beaglehole, 1974: 5; his italics).

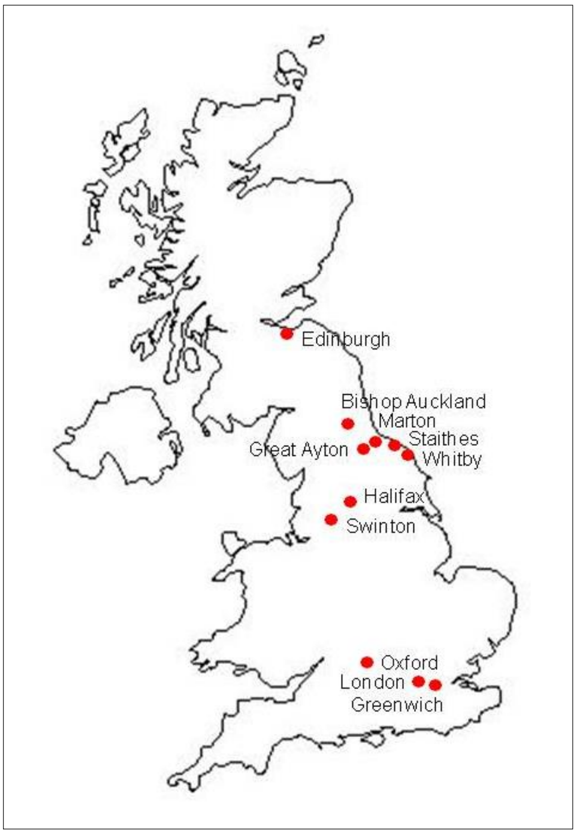


Figure 5: English and Scottish localities mentioned in this paper are shown in red (after Orchiston, 2016: 116).

After completing his schooling Cook worked briefly for a grocer and draper in the nearby small fishing port of Staithes, before choosing his future career by going to sea. From July 1746 he served a 3-year apprenticeship with the respected Whitby-based ship-owner, John Walker, and it was during this period of transferring coal between North Sea ports along the east coast of England that he received sound training in mathematics and navigation (Beaglehole, 1968: cvi).

In 1746, when he was just 24 years of age, Cook was promoted from ordinary seaman to Mate, and in 1755 Walker offered him the command of his own ship. However, Cook saw war approaching and felt he would have a better future in the Navy so he turned down this generous offer. At the time this must have been a brave move when compared to the merchant service, for Royal Navy

> … physical conditions were worse; its pay was worse; its food was worse, its discipline was harsh, its record of sickness was appalling. To the chance of being drowned could be added the chance of being flogged, hanged or even shot, though it was true that deaths in battle were infinitely fewer than deaths from disease. The enemy might kill in tens, scurvy and typhus killed in tens of hundreds. (Beaglehole, 1974: 15).

Despite this depressing description, Cook joined the Navy as an able seaman, or A.B. as it was known. He joined at the bottom of a hierarchy that extended from able seamen, to petty and warrant officers, and culminated in the commissioned officers. Initially Cook was assigned to the *Eagle* under Captain (later Sir) Hugh Palliser (1723–1796), and must have impressed for within a month he was promoted to Master's Mate, and after two years had progressed to Boatswain and then Mate (Beaglehole, 1968: cvii).

On 27 October 1757—his 29th birthday—Cook joined the *Pembroke* with a rank equivalent to Navigating-Lieutenant. This was during the height of the Seven Years' War (or the 'French and Indian War', as it was referred to at the time in North America) when Britain was mounting a concerted campaign to consolidate its own hold on the North American continent and capture French territory in what is now Canada and the USA. The British had the most formidable navy in the world, and it was to play a crucial role in these campaigns (e.g. see Anderson, 2000; Fowler, 2005). Therefore, Cook's timing in joining the Royal Navy was perfect, and it was during the siege of the French fortress of Louisbourg that he gained invaluable hydrographic surveying and cartographic experience charting the St Lawrence River (see Ritchie, 1978; Skelton, 1954), which hosted the major population centres of Quebec and Montreal. Louisbourg was strategically located on Cape Breton Island near the mouth of the river.

Cook then transferred to the *Northumberland* as a Master, and

> … began to emerge from that valuable body of persons, the masters of His Majesty's ships, as an unusually valuable person; and that the senior officers with whom he has come in contact are aware of the fact. In the context of naval journals, under their standard headings, he can virtually be classed, along with court martials and Public Demonstrations of Joy, as a Remarkable Occurrence. (Beaglehole, 1974: 55).

After conducting further cartographic work on the St Lawrence River Cook returned to England, and on 21 December 1762 he married 20-yr old Elizabeth Batts (1742–1835) at St. Margaret's Church in Barking, Essex. He was 14 years her senior.

In April 1763, following the end of the Seven Years' War, Cook sailed for North America again, to chart the coasts of Nova Scotia and Newfoundland. Then, through the influence of his old commander Hugh Palliser, he was offered his own command in 1764, the 60-ton naval schooner *Grenville* (Beaglehole, 1974). By this time Palliser was Governor and Commander in Chief of Newfoundland, and he had not forgotten the enthusiastic young man who began life on the *Eagle* as a common sailor, quickly moved through the petty officer ranks, and showed much promise as a marine navigator, surveyor and cartographer. Patronage was an important factor in British military life at this time, and Cook had a powerful supporter.

For the next three years, Cook and his crew continued the North American survey (see Figure 6), but with winter interludes in London,

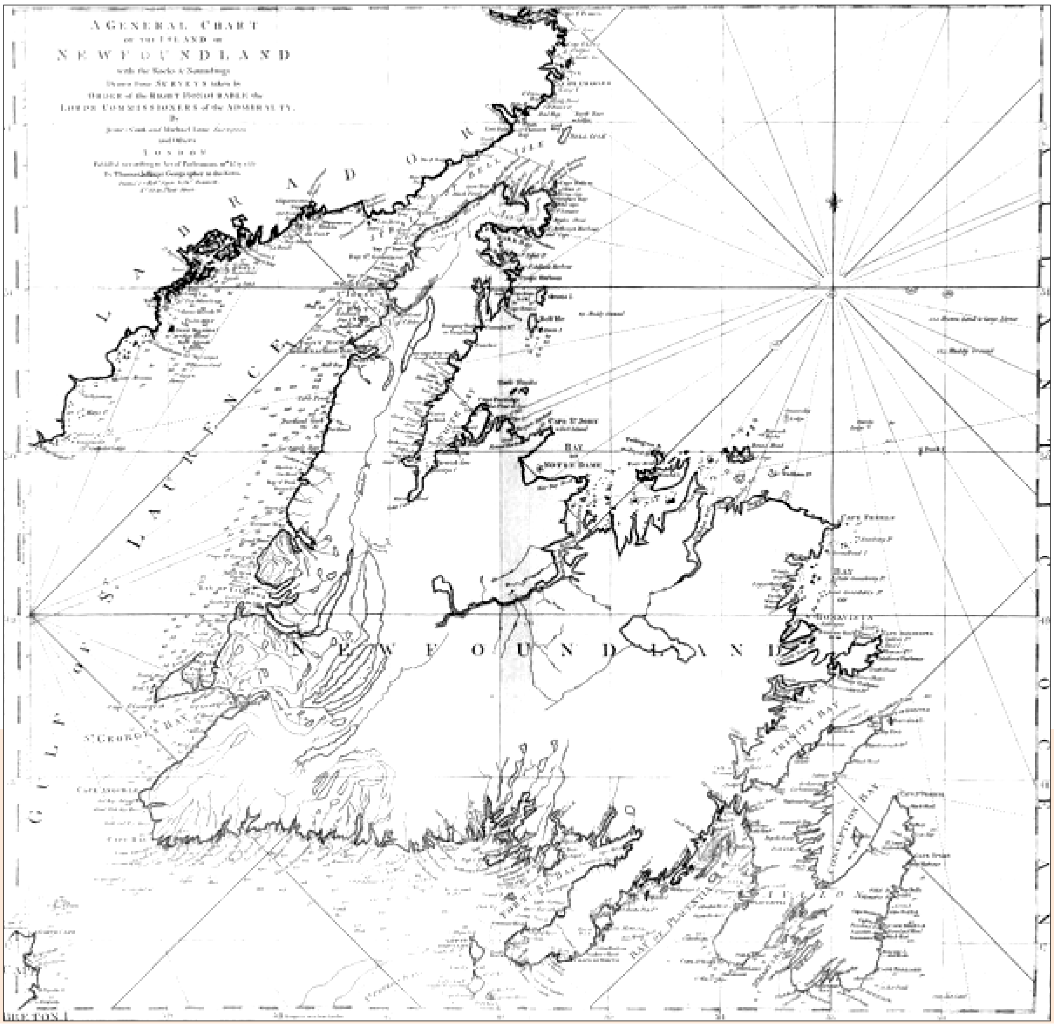
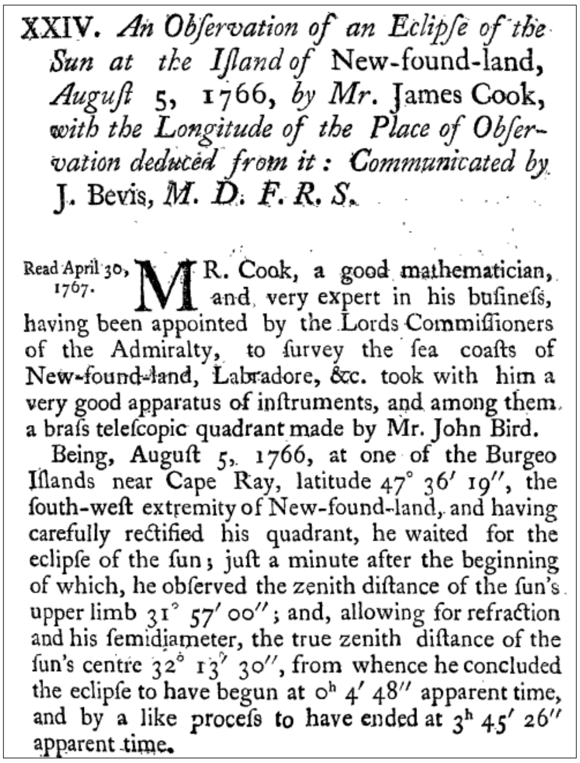


Figure 6: Cook's chart, published in 1775, was the first detailed map of the coast of Newfoundland, and reflected his skills in both hydrographic surveying and cartography (after Prowse, 1896).



XXIV. *An Obſervation of an Eclipſe of the Sun at the Iſland of* New-found-land, *Auguſt* 5, 1766, *by Mr.* James Cook, *with the Longitude of the Place of Obſervation deduced from it: Communicated by* J. Bevis, *M. D. F. R. S.*

Read April 30, 1767.

MR. Cook, a good mathematician, and very expert in his buſineſs, having been appointed by the Lords Commiſſioners of the Admiralty, to ſurvey the ſea coaſts of New-found-land, Labradore, &c. took with him a very good apparatus of inſtruments, and among them a braſs teleſcopic quadrant made by Mr. John Bird.

Being, Auguſt 5, 1766, at one of the Burgeo Iſlands near Cape Ray, latitude 47° 36′ 19″, the ſouth-weſt extremity of New-found-land, and having carefully rectified his quadrant, he waited for the eclipſe of the ſun; juſt a minute after the beginning of which, he obſerved the zenith diſtance of the ſun's upper limb 31° 57′ 00″; and, allowing for refraction and his ſemidiameter, the true zenith diſtance of the ſun's centre 32° 13′ 30″, from whence he concluded the eclipſe to have begun at 0h 4′ 48″ apparent time, and by a like proceſs to have ended at 3h 45′ 26″ apparent time.

Figure 7: The first page of Cook's short paper in the *Philosophical Transactions of the Royal Society* reporting his observation of the 5 August 1766 partial solar eclipse.

and it was during this period that Cook continued his self-education by carefully reading Charles Leadbetter's books, *A Compleat System of Astronomy* and *The Young Mathematician's Companion of 1739* (see Villiers, 1971). He also engaged in his first serious non-nautical astronomy project by observing a partial eclipse of the Sun from Newfoundland on 5 August 1766, and publishing a short account in the *Philosophical Transaction of the Royal Society* (Cook, 1767; see Figure 7). This was his first astronomical publication in this prestigious scientific journal, but it would not be his last.

Figure 8: Hugh Palliser, 1723–1796 (art-books.com).

Through these exploits, by the end of 1767 the 'power-brokers' in the Admiralty and the Royal Society were well aware of Cook's talents and capabilities, and although he was only a lowly Master and there were others of superior rank in the Royal Navy (Beaglehole, 1974), and astronomers with more experience, he was the obvious choice as the *Endeavour's* commander *and* one of its astronomers. We can presume that Palliser (Figure 8), shortly to become Comptroller of the Navy Board, would have played a role in reaching this decision (Beaglehole, 1968: cviii).

This may have been an easy decision for the Admiralty and the Royal Society, but when Cook received a letter dated 25 May 1768 (Admiralty, 1768) informing him that he had been promoted to First Lieutenant and offered the dual posts on the *Endeavour* he was fully aware of the onerous workload that captaincy of the vessel commanded, so he only agreed also to serve as an astronomer on condition that the Royal Society paid him a salary supplement of 100 guineas (see Beaglehole, 1968: cv; cxxvi; Banks, n.d.: 513–514).

That he subsequently was offered two further voyages to the South Seas only serves to demonstrate that Cook admirably carried out the role of captain of the *Endeavour* (and later the *Resolution*), while the following pages will show that he also served the Royal Society effectively and efficiently as an astronomer. Cook also combined the duties of commander and astronomer on his third voyage to the South Seas (see Orchiston, 1998a; 1998b), but both distinguished careers were prematurely terminated on 14 February 1779 when he was suddenly slain while the *Resolution* and *Discovery* were visiting Hawaii. He was just 50 years of age, and elsewhere I have written: "Thus ended the life of a colossus of British discovery, exploration, hydrographic surveying and nautical astronomy." (Orchiston, 1998b: 19). Meanwhile, Lloyd (1968: 230) epitomizes Cook as surely the "… classic example of how a man could rise [in rank] if he had exceptional talent, opportunity and patronage."

3.2.2 Charles Green

The second astronomer on the *Endeavour*, Charles Green, was a Yorkshireman like Cook, but was born in Swinton in 1735 (making him seven years Cook's junior). Green's father was a prosperous farmer (Howse, 1993). It seems that Green's education fell to his older brother, the Reverend John Green, who was the master of a school known as 'the Academy', which was in Denmark Street in London (Wales, 2008). Charles so excelled in mathematics that he was appointed an assistant teacher at the school. While at the school he taught himself astronomy, so successfully as it turned out that towards the end of 1760 he joined the staff of the Royal Observatory at Greenwich as assistant to James Bradley (1693–1762), the Astronomer Royal (Kippis, 1788). For many, the idea of working at a professional observatory may have seemed exciting, but for an 'assistant' at the Royal Observatory nothing could be further from the truth:

> Nothing can exceed the tediousness and ennui of the life the assistant leads in this place, excluded from all society, except, perhaps, that of a poor mouse which may occasionally sally forth from a hole in the wall, to seek after crumbs of bread dropt by his lonely companion at his last meal ... Here forlorn, he spends days, weeks, and months, in the same long wearisome computations, without a friend to shorten the tedious hours, or a soul with whom he can converse. (cited in Morris, 1980).

Bradley planned to observe the 1761 transit from the Royal Observatory but became ill and could not do so. Instead it was his close friend, the Reverend Nathaniel Bliss (1700–1764, Savilian Professor of Geometry at Oxford), who observed it, with assistance from Green (see Bliss, 1762).

When Bradley died in 1762 Bliss became Astronomer Royal, and Green remained at the Observatory. In 1763 he and the Reverend Dr Nevil Maskelyne (Figure 9) sailed to Barbados in the Caribbean aboard the *Princess Louisa*, by order of the Board of Longitude, so that they could determine the longitude of the capital, Georgetown. They would do this by observing Jovian satellite phenomena and by using Maskelyne's system of lunar distances, and then comparing both results with the longitude offered by Harrison's H4 marine chronometer (see Higgitt, 2010). John Harrison (1693–1776) was keen to claim the Board of Longitude's £20,000 'longitude prize' (see Betts, 2006; Sobel, 1995), but Maskelyne—with an obvious conflict of interest (see Kippis, 1788)—was equally determined the prize should be awarded for his system of 'lunars' that also could be used to determine longitude on land or while at sea (Howse, 1989). Green was not involved in this 'competition', and Harrison's chronometer did not go on the *Endeavour's* voyage to the South Seas.

Although Maskelyne apparently wrote a very good report on Green (Paulding, 2000), during the Barbados expedition Maskelyne and Green did not see eye-to-eye on all matters because when Bliss died suddenly in 1764 and Maskelyne became the new Astronomer Royal, after a brief interval he and Green argued and Green promptly resigned (Kippis, 1788). But, as Higgitt (2010) perceptively points out,

> ... because Bradley and Bliss … were both quite unwell while Green was there, he was effectively in charge of the Observatory himself for some of the time. So he was a sort of Astronomer Royal stand-in for some of the period ... and he [also] tided over the period between Bliss's death and the arrival of Maskelyne as Astronomer Royal.

After investigating London's water supply, in 1768 Green joined the Royal Navy and served as a Purser on HMS *Aurora* (Kippis, 1788). A Purser was a warrant officer whose primary responsibility was meant to be the ship's accounts and supplies, but in reality astronomers were sometimes listed as Pursers (Beaglehole, 1968:

Figure 9: The Reverend Nevil Maskelyne, 1732–1811 (en.wikipedia.org).

119), and they assisted in navigation, where astronomical knowledge was at a premium. So if Green could not work as an official astronomer he did the next best thing.

However, his return to the ranks of 'astronomer' was not long in coming, for later that same year (1768) the Royal Society appointed him as one of the two astronomers on the *Endeavour*. Despite their prior differences, Maskelyne was one of his supporters (Kippis, 1788). Green, who was married (Wales, 2008), agreed to a salary of 200 guineas, plus 100 guineas per year if the voyage extended beyond two years (Beaglehole, 1974: 131). Subsequently, on 30 July 1769 Cook was sent the following order by the Admiralty:

> You are hereby requir'd and directed to receive the said Mr Charles Green with his Servant

> [John Reynolds] Instruments and Baggage, on board the said Bark, and proceed in her according to the following Instructions ... (cited in Morris, 1981).

Following the transit, Green was one of many who were destined to die before the *Endeavour* arrived safely back in England. After safely circumnavigating New Zealand, Green fell ill with scurvy during the exploration and mapping of the east coast of Australia. Cook then headed for Batavia (present-day Jakarta) in the Dutch East Indies (Indonesia) as the *Endeavour* needed further repairs if it was to successfully sail to England. However, Batavia would turn out to be a hell-hole for the *Endeavour* and its crew, for looks can be deceiving. At the time Batavia was:

> … a rather picturesque city showing evidence in its architecture of the Dutch colonists. However, it was built on swampy ground. The climate was most unappealing – high temperatures and high humidity proved debilitating. There were frequent thunderstorms. Additionally, in 1699 Batavia had suffered a severe earthquake. The rivers about it were choked with mud and flooded the surrounding country. Batavia became notorious for being unhealthy and was in danger of being abandoned. In the 22 years from 1730 to 1752, 1,100,000 deaths are said to have been recorded. *Endeavour* had been a healthy ship but at Batavia the ship's company were exposed to dysentery, malaria and a variety of other tropical diseases. Green's servant, Reynolds, died of dysentery here on 18 December 1770 ... (Morris, 1981).

At the time, Batavia had a thriving astronomical society with an observatory, and Pastor Johan Maurits Mohr (1716–1775) also had an impressive private observatory atop his mansion on the outskirts of the city (Figure 10). People with an interest in astronomy were delighted by the *Endeavour*'s visit (ibid.), and since Mohr had observed the 1761 *and* 1769 transits (see van Gent, 2005; Zuidervaart and van Gent, 2004), it is a safe assumption that he met with Green (and maybe also Cook). Subsequently, the *London Evening Post* printed a letter from 'a gentleman' on board the *Endeavour* which described how

> ... great respect was paid here to Mr. Green by the principal people of Batavia, but no particular notice was taken of the rest of us by the Dutch. (cited in Morris, 1981).

Yet all was not well for Green, as towards the end of his stay in Batavia he also contracted dysentery, and his condition continued to deteriorate. Nearly two weeks after the *Endeavour* left Batavia he was gravely ill and on 29 January 1771 Cook recorded in his journal:

> In the night Died M^r Charls Green who was sent out by the Royal Society to Observe the Transit of Venus; he had long been in a bad state of hilth, which he took no care to repair but on the contrary lived in such a manner as greatly promoted the disorders he had had long upon him, this brought on the Flux which put a period to his life. (Beaglehole, 1968: 448).

Figure 10: A view of Paster Mohr's mansion and observatory (after van Gent, 2005: 69).

He was buried at sea, in the middle of the Indian Ocean. Between them, scurvy and dysentery almost decimated the *Endeavour* at this time: Green was but one of twenty-three different crew members (about a quarter of the entire complement) who died within the space of six short weeks (see Watt, 1979). Given this mortality rate, elsewhere I have suggested that "... fatalists could be excused for thinking that the Tahitian transit carried a curse of Tutankhamen-like proportions!" (Orchiston, 2005: 58).

Subsequently, the *General Evening Post* newspaper in London published a rather graphic account of Green's demise:

> Mr. Greene, the astronomer, who went out with Mr. Bankes, died soon after the ship left Batavia. He had been ill some time, and was directed by the surgeon to keep himself warm, but in a fit of phrensy he got up in the night and put his legs out of the portholes, which was the occasion of his death. (Cited in Morris, 1981).

The *General Evening Post* also stated that

> All his papers relative to the transit of Venus, of which he had made the most accurate observation, were happily completed and preserved. (ibid.).

As we shall see, shortly, this was a gross overexaggeration.

Nonetheless, Green had proved himself a competent astronomer, and faithfully trained the officers and some of the seamen in the specifics of nautical astronomy, including the calculation of Maskelyne's 'lunars' (Beaglehole, 1968: 599). Among his effects was a log-journal (Green, 1768–1770) which Beaglehole (1968: ccxlii) thought somewhat pedestrian in nature, but it did show that Green was "… a highly conscientious as well as sprightly person." and thought himself a wit. Given the events that precipitated his death, we might judge that he was half right! Meanwhile, Green's brother-in-law, William Wales (who was destined to go on Cook's Second Voyage as an Astronomer), said that Green "... was a most excellent observer ... and tolerably well versed in most branches of mathematics." (cited in Morris, 1981).

Notwithstanding extensive searches, no drawings or paintings of Charles Green are known to exist (ibid.).

3.2.3 The '*De Facto* Assistant Astronomers'

As we have noted, above, Cook and Green were the official astronomers assigned by the Royal Society to the *Endeavour*, but

> … a coterie of officers, seamen, and even supernumeraries were involved in astronomical observations during the voyage, effectively serving as *de facto* assistant astronomers. These included Clerke, Harvey, Hicks, Hood, Molyneux, both Monkhouses, Pickersgill, Saunders, Smith, Solander and Spöring. Some of these acquired their observational skills from Green during the voyage, and even those with prior training honed their expertise between England and Tahiti – in anticipation of the Transit. (Orchiston, 2004a: 32).

Brief biographies of those who were involved in observing the transit of Venus will be presented later, in Section 3.6.

3.3 The Astronomical Instruments

If successful observations of the 1769 transit of Venus were to be made, then appropriate scientific instruments were essential (Howse, 1979; Howse and Hutchinson, 1969a). Accordingly, with Maskelyne's assistance, the Royal Society assigned the *Endeavour*

> … 2 Reflecting telescopes of two feet focus, with a Dolland's micrometer to one of them and moveable wires for the other … 2 Wooden Stands for the telescopes with polar axes suited to the Equator … an astronomical quadrant of one foot radius, made by Mr. Bird … An Astronomical Clock [by Shelton] and Alar[e]m Clock … [and] a Journeyman Clock bespoke of Mr Shelton ... 1 Stand for Bird's quadrant. (Beaglehole, 1968: cxliii).

Apart from the all-important transit of Venus, these instruments also would serve for other astronomical observations required throughout the voyage, mainly for the determination of latitude and longitude, both of which were vital for navigation and in charting the coasts of newly-discovered islands and other land masses.

Latitude was best obtained from altitude observations of the Sun as it crossed the meridian, using either a sextant (if at sea) or the quadrant (if ashore). Longitude was a more difficult proposition as it relied on accurate time-keeping. One commonly-used technique when ashore was to use the telescopes to observe specific astronomical events (e.g. occultations of stars by the Moon, Jovian satellite phenomena, solar or lunar eclipses, transits of Mercury) and compare the local occurrence times (provided by the clocks) with those listed for Greenwich in the *Nautical Almanac*. Alternatively, one could employ Nevil Maskelyne's 'lunars' method', and use a sextant to measure the angular separation of selected stars from the limb of the Moon. The longitude could then be determined by reading off the listed values in the *Nautical Almanac*. This type of astronomy, widely used on voyages of exploration during the eighteenth century, was known as 'nautical astronomy' or 'maritime astronomy', and it played a vital role, linked as it was with navigation. It has been suggested, somewhat melodramatically, that "Astronomy and navigation were mutually inseparable ..." on Cook's three voyages to the South Seas, and "… without

Figure 11: A painting of James Short (courtesy: Museum of the History of Science, Oxford University).

the astronomers these voyages could have ended in tragedy." (Orchiston, 1998b: 9).

3.3.1 The Telescopes

The two telescopes supplied by the Royal Society were made by the noted Scottish telescope-maker and astronomer, James Short (Green and Cook, 1771: 398), "… a full-faced, well-built man of medium height." (Bryden, 1968: 6). Short (1710–1768; Figure 11) had an M.A. degree and had qualified as a Church of Scotland minister, but had a passion for scientific instrument-making, and also observational astronomy (cf. Turner, 1969). Initially he began commercial operations in Edinburgh, but in 1738 moved his business to London, the acknowledged centre of the British scientific instrument-making industry (Clifton, 1996; King, 1979). Short has been described as "A most celebrated personality he accrued a fortune by supplying excellent instruments (about 1360) to amateurs and professionals." (Andrews, 1996: 99). The two Short telescopes consigned to the *Endeavour* were Gregorian reflectors, with perforated speculum metal primary mirrors 4 inches in diameter, and speculum metal ellipsoidal secondary mirrors (see Figure 12). Short received the contract to make all of the astronomical telescopes for the British 1769 transit of Venus expeditions, which must have pleased him given that he had personally carried out successful observations of the 1761 transit (see Short, 1764).

Figure 12: A Gregorian telescope by James Short, very similar if not identical to the ones that accompanied Cook and Green to Tahiti. At the bottom right is an object-glass micrometer that was used for measuring the angular separation of Venus from the limb of the Sun in the course of the transit (courtesy: The Royal Society, London).

The object glass micrometer supplied with one of the Short telescopes was made by John Dollond (Figure 13), and is described by him in a paper that was published in the *Philosophical Transactions of the Royal Society* (Dollond, 1754). This ingenious device was invented by Dollond in 1753, and allowed astronomers to measure the angular separation of two nearby celestial objects or two parts of the same object (see Dollond, 1753). This would surely prove useful during the transit.

In addition to the two Short telescopes, two other telescopes went to the South Seas on the *Endeavour*. One was Cook's own telescope, which he had used while surveying the North American coast, and which he describes as follows:

> The Navy Board have been pleas'd to supply His Majestys Bark the Endeavour under my command with the Reflector Telescope that was on board the Grenville Schooner for makeing Astronomical Observations at Newfoundland … (cited in Beaglehole, 1968: 621).

Cook (1768) then had a micrometer made for it, "… which will be of great service in the observation of the Transit Vinus …" Documentation provided during Cook's later Second and Third Voyages to the Pacific reveals that this Gregorian reflector was made by Watkins, had a focal length of 18 inches and was owned personally by Cook (Beaglehole, 1969: 532; Beaglehole, 1967, I: 243; Green and Cook, 1771: 416). In telescope-making circles, the Watkins name was not as well known as Short, but the *Directory of British Scientific Instrument Makers 1550–1851* (Clifton, 1995) lists an eighteenth-century London instrument-maker named Francis Watkins, who began his optical apprenticeship in 1737 and practised as a scientific instrument-maker from 1747. He made a variety of instruments, and apparently had close links with the renowned London telescope-maker John Dollond. Andrews (1997:157) gives Watkins' birth and death dates as ca. 1732–1782. Figure 14 shows a Watkins telescope of the same vintage, that we can presume is similar in appearance to the one owned by Cook.

In addition, Dr Daniel Solander, one of Banks' party, had a telescope that he used to successfully observe the transit, and Green and Cook (1771: 411–412) mention that it was a 3-ft long reflecting telescope and magnified more than their two Short reflectors, but nowhere do they, or Solander, describe this instrument or even mention the name of its manufacturer.

A Gregorian telescope 3-ft in length is considerably longer than the other telescopes of this type that accompanied the various British transit of Venus expeditions in 1769, so any telescope of this length with reputed Cook First Voyage associations in a museum collection warrants close scrutiny. Such a telescope exists in the scientific collections of The Museum of New Zealand Te Papa Tongarewa in Wellington (Accession Number NS000010), which has a convoluted history with supposed links to either Sir Joseph Banks or Charles Burney, both of whom were closely associated with Cook and his voyages to the South Seas. In a paper published in the *Journal of the Antique Telescope Society* in 1999 (where the telescope features on the front cover), I examine the documentation accompanying this telescope, particularly its supposed Cook voyage provenance, and conclude

> The only possible Cook-voyage association that we have been able to identify for this instrument is that it was the Gregorian reflector used by Dr Daniel Solander in 1769 to observe the transit of Venus. However, the evidence for this is slim and largely circumstantial, and the fact that Solander was part of Banks' retinue should not be seen as persuasive.
>
> Scientific instruments, memorabilia and indigenous artifacts of eighteenth century vintage and reputedly associated with Cook's voyages were eagerly sought after during the nineteenth and twentieth centuries and attracted high sale prices. As a result, many objects with bogus 'Cook' histories made their way into private collections and the world's museums … and it is possible that the Wellington telescope is yet another example of this trade. (Orchiston, 1999: 8).

Upon subsequently re-examining all of the available documentation I decided that perhaps I was overly cautious in my 1999 paper, so at the International Astronomical Union's 2004 transit of Venus conference in Preston, England, I announced that "... the telescope used by Solander at Fort Venus is probably the Heath and Wing reflector now housed in The Museum of New Zealand Te Papa Tongarewa, in Wellington ..." (Orchiston, 2005: 62).

Figure 13: An oil painting of John Dollond by Benjamin Wilson now in the Royal Museums, Greenwich (en.wikipedia.org).

In fact this idea was first promoted by Edward Rock Garnsey (1864–1935), the New South Wales Agent-General in London, who had an intimate knowledge

> ... of art, literature, history, and science [which] led to his being chosen from time to time to decide the authenticity or the value of documents, manuscripts, paintings, or relics alleged to have some connection with the early history of Australia. (Garnsey ..., 1935).

Acting on behalf of the Australian Government, in 1930 Garnsey carefully examined the telescope and associated documentation and concluded

Figure 14: A brass Gregorian telescope made by Francis Watkins in about 1765 and similar to the one that Cook took to Tahiti for the transit of Venus (adapted from www.arsmachina.com/t-watkins5038.htm).

> … that he had no doubt in his own mind that it was the identical Instrument used by Dr. Solander of the British Museum on the memorable voyage with Cook & Banks & others undertaken in 1769 to observe the transit of Venus at Tahiti. (Ellis, 1932).

So what does this telescope look like? Figure 15 shows its present appearance, and in a letter written in 1918, the owner of the telescope at that time included the following 'bullet point' summary of its features:

> Gregorian Reflector
> Mounted as an altimuth [*sic*.], with horizontal circle and vertical circle attached to the body of the Telescope, both circles graduated and having verniers attached.

Figure 15: The Gregorian telescope in the Museum of New Zealand Te Papa Tongarewa in Wellington that has tentatively been identified as the one Solander used to observe the transit at Fort Venus (courtesy: Museum of New Zealand Te Papa Tongarewa, NS000010/1).

> Aperture 5" diameter.
> Made by Heath & Wing, London. No date.
> Two eyepieces, high and low, each having its own small concave lens.
> Diameter 1½".
> Length of low eye piece 5¾".
> Length of high eye piece 4¼".
> Both fitted with sun glasses.
> Length of Telescope 2ft. 10½ins.
> Height of vertical column 1ft.
> The instrument can be clamped so that by holding each screw with either hand the star, etc. can be kept in the field of vision.
> Unclamped the instrument is free to move in any direction.
> There is also a finder which is a refractor with cross wires in the eye piece.
> Diameter of object glass 1". (Relton, 1918)

The tube of the telescope and fittings were made of brass, and the telescope came with an oak travelling case into which it fitted (Ellis, 1932).

Apart from its excessive length, in overall appearance this telescope bears a striking resemblance to the Gregorian reflectors manufactured by Short that were supplied to Cook and Green. Furthermore, it may be more than a coincidence that Solander's telescope was almost identical in length to the Heath and Wing Gregorian reflector in the museum in Wellington.

What do we know of the firm 'Heath & Wing London', whose name is engraved on the telescope, near the eyepiece assembly? Thomas Heath was one of London's most prominent scientific instrument-makers during the first half of the eighteenth century, before going into partnership with Tycho Wing, who was some years his junior (and with a name like that surely could be excused for making astronomical telescopes). The firm of Heath and Wing ran successfully from 1751 to 1773 as makers of mathematical, philosophical and optical instruments. So this time-frame sits comfortably with an acquisition date some during the late 1760s, prior to Cook's First Voyage. Apart from astronomical telescopes, Heath and Wing also made barometers, protractors, sextants, sundials, theodolites and thermometers. Thomas Heath died in 1773 and Tycho Wing retired in that same year and died just three years later (B. Ariail, pers. comm., 1999; Clifton, 1995).

3.3.2 The Quadrant

As we have seen, one 12-inch quadrant made by John Bird (see Figure 16) was taken on the *Endeavour*, and this was used ashore to make positional observations of the Sun, Moon and selected stars, which after an intricate series of calculations produced values of longitude, while meridian observations of the Sun provided the latitude. Chapman (1983) has demonstrated that quadrants underwent a rapid evolution during the late eighteenth century.

John Bird (1709–1776; Figure 17) was an accomplished British scientific instrument-maker (Hellman, 1932), and was famous for his astronomical quadrants (Bird, 1768). Chapman (1995: 75) described these as

> ... mechanical, not optical, instruments, and aimed to eliminate every possible source of tension or imbalance in the fabric, for which they employed the simplest optical system.

Bird began his adult life as a weaver, but in 1740 moved to London and joined the well-known instrument-maker, Jonathan Sisson, where he gained his training (see Gould, 1976). He then decided to open his own business, and this soon became the centre of the astronomical instrument-trade, "... especially after Bradley [the

Astronomer Royal], with £1000 available for new instruments, gave Bird his first large order." (King, 1979: 115). Apart from quadrants, Bird also made a few reflecting telescopes, as well as thermometers, barometers and drawing instruments (King, 1979: 117). Astronomy was his hobby, and he used one of his own Gregorian telescopes to observe the 1761 transit of Venus and an annular solar eclipse in 1765 (Andrews, 1992: 122). Beaglehole (1968: 87) notes that Bird "... displayed a talent for delicate and precise work which brought him European fame."

On Cook's First Voyage, when in use the quadrant normally was housed in a tent observatory, which protected it from the elements:

> [Near the main tent] ... stood the observatory, in which were set up the journeyman clock and astronomical quadrant: this last, made by Mr. Bird, of one foot radius, stood upon the head of a large cask fixed firm in the ground, and well filled with wet heavy sand. (Green and Cook, 1771: 398).

In May 1769 the quadrant was 'borrowed' by some of the local Tahitians and damaged. Although Spöring did his best to repair it (Beaglehole, 1968: 527–529), after this event there was always some doubt about its reliability.

3.3.3 The Astronomical Clocks

Time-keeping was critical on Cook's First Voyage, not only in recording the all-important contacts during the transit of Venus, but throughout the voyage, for accurate time gave the astronomers access to longitude. There were three different types of clocks on the *Endeavour*: an astronomical clock, a journeyman clock and an alarum clock.

The astronomical clock was the largest, most expensive and most accurate of the three (providing time to the nearest second), and was only used when a shore-based tent could be set up. The usual procedure was to install the clock inside a tent that afforded protection from the elements and uninvited human interference, as the following Tahitian account dating to April 1769 indicates:

> The astronomical clock, made by Shelton and furnished with a gridiron pendulum, was set up in the middle of one end of a large tent, in a frame of wood made for the purpose at Greenwich, fixed firm and as low in the ground as the door of the clock-case would admit, and to prevent its being disturbed by any accident, another framing of wood was made round this, at the distance of one foot from it. (Green and Cook, 1771: 397).

The Royal Society had already purchased astronomical clocks by John Shelton (costing 30 guineas each) for the 1761 transit of Venus, and these were available for the 1769 event. One Shelton clock was taken on the *Endeavour*, and Figure 18 shows this, while Figure 19 reveals the instructions that Shelton supplied for setting up the clock.

Figure 16: A 12-inch quadrant made by John Bird, which may have been on one of the British 1769 transit of Venus expeditions, but not necessarily the one to Tahiti (courtesy: The Royal Society, London).

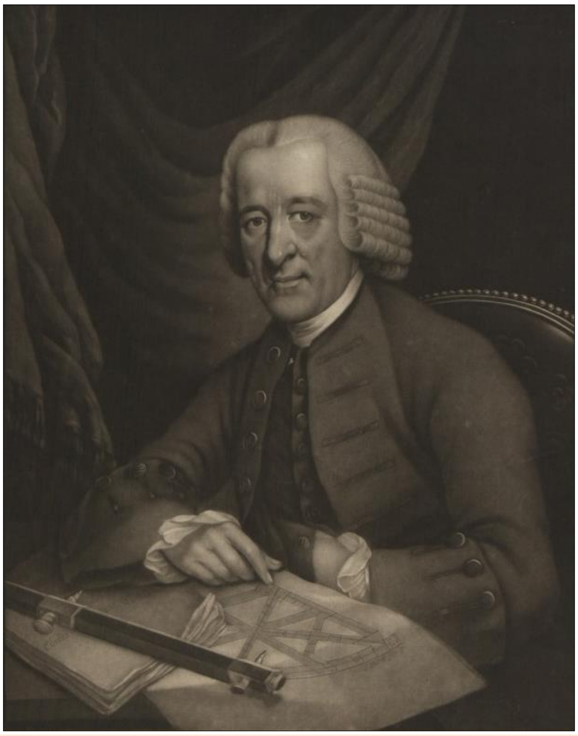


Figure 17: A mezzotint of John Bird of London, by Valentine Green after Lewis, Published by Valentine Green, London, 1776. Inv 14176 (https://blogs.mhs.ox.ac.uk/insidemhs/making-prints-public-john-bird-connecting-collections/).

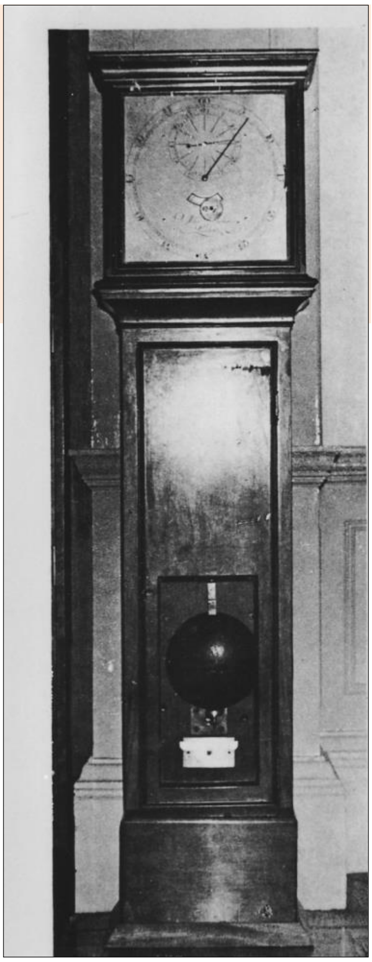
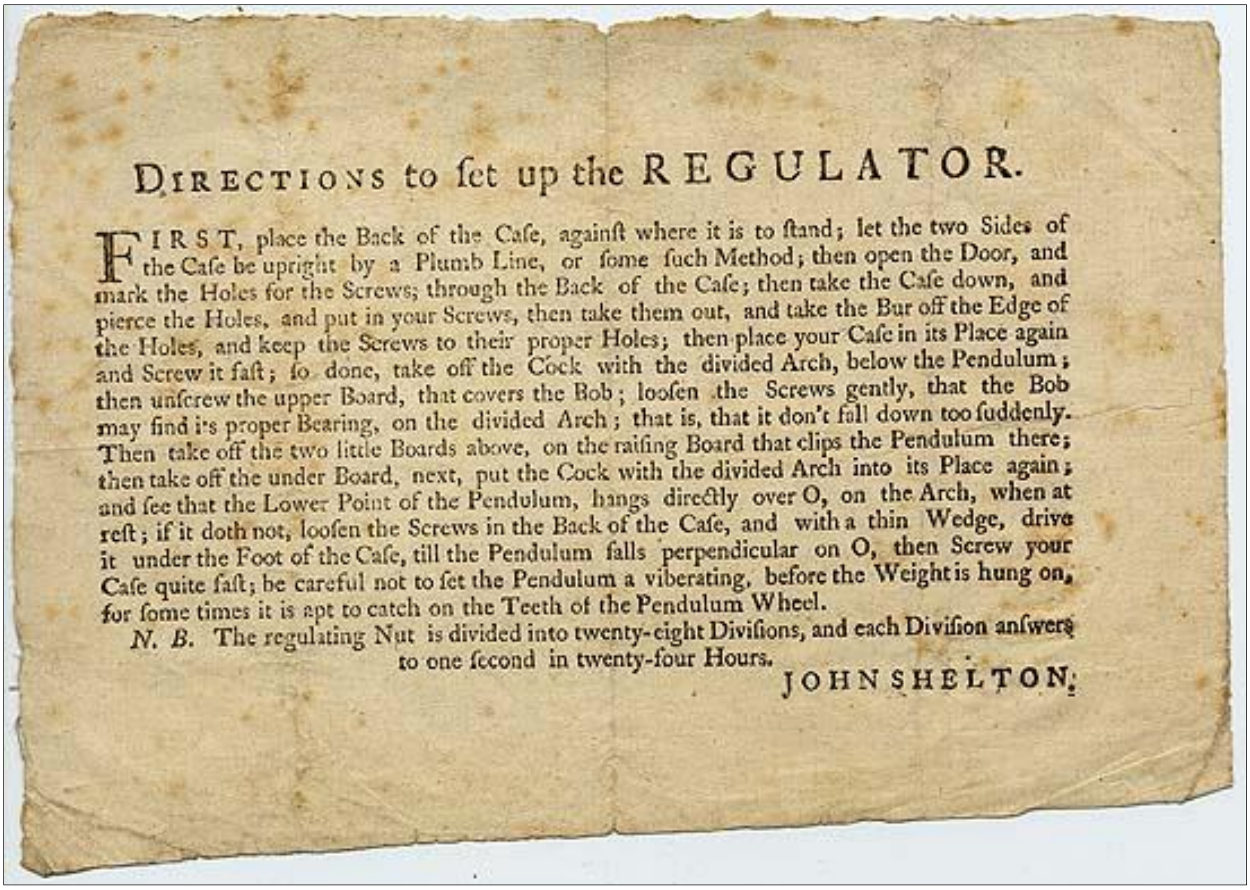


Figure 18: This Shelton astronomical clock has been identified by Howse and Hutchison (1969b) as the one that accompanied the *Endeavour* to Tahiti (courtesy: the late Derek Howse).

In *The Clocks and Watches of Captain James Cook 1769-1969* Howse and Hutchinson (1969b: 289–291) supply the following description of a typical Shelton astronomical clock, based on one now in St John's College, Cambridge, which was manufactured for one of the 1761 British transit of Venus expeditions (and therefore would have been very similar to the clock that accompanied Cook and Green to Tahiti):

> *The basic movement* consists of a pair of shaped brass plates ... The average dimensions in the series are approximately 10.25 × 6.25 in. The six pillars are riveted to the back plate; the front plate is fastened by latches.
>
> *The train* has five wheels and is constructed for a month's duration. Where feasible, the pivots bear on end-plates which minimise friction and preserve the oil. One large end-plate covers all pivot holes on the back plate ...
>
> *The escapement* is dead-beat, and has a 30 tooth brass wheel with relieved teeth; the anchor is steel and has a long shank and curved arms which terminate in the pallets. The collets for the escape wheel and anchor are characteristically long ...
>
> *Bolt-and-shutter maintaining power* is fitted, with an additional device to prevent the clock stopping while the mechanism is being engaged. Although the movement is weight driven, stopwork (acting on a principle similar to that used in fuzee clocks) is fitted to prevent



DIRECTIONS to ſet up the REGULATOR.

FIRST, place the Back of the Caſe, againſt where it is to ſtand; let the two Sides of the Caſe be upright by a Plumb Line, or ſome ſuch Method; then open the Door, and mark the Holes for the Screws; through the Back of the Caſe; then take the Caſe down, and pierce the Holes, and put in your Screws, then take them out, and take the Bur off the Edge of the Holes, and keep the Screws to their proper Holes; then place your Caſe in its Place again and Screw it faſt; ſo done, take off the Cock with the divided Arch, below the Pendulum; then unſcrew the upper Board, that covers the Bob; looſen the Screws gently, that the Bob may find it's proper Bearing, on the divided Arch; that is, that it don't fall down too ſuddenly. Then take off the two little Boards above, on the raiſing Board that clips the Pendulum there; then take off the under Board, next, put the Cock with the divided Arch into its Place again; and ſee that the Lower Point of the Pendulum, hangs directly over O, on the Arch, when at reſt; if it doth not, looſen the Screws in the Back of the Caſe, and with a thin Wedge, drive it under the Foot of the Caſe, till the Pendulum falls perpendicular on O, then Screw your Caſe quite faſt; be careful not to ſet the Pendulum a viberating, before the Weight is hung on, for ſome times it is apt to catch on the Teeth of the Pendulum Wheel.

N. B. The regulating Nut is divided into twenty-eight Diviſions, and each Diviſion anſwers to one ſecond in twenty-four Hours.

JOHN SHELTON.

Figure 19: Shelton's instructions for successfully setting up his transit of Venus astronomical clocks (after Johnston, 2005).

> overwinding.
>
> *The motion work* is conventional; the hour-wheel pipe carries a friction-mounted hour circle instead of an hour hand. The cannon pinion and minute wheel are only partially crossed out, and thus counterpoise the minute hand. The minute wheel and pinion are pivoted on a cock screwed to the front plate, and the arbor is extended to pivot on the back plate.
>
> *The dial* is a square plate of brass – engraved, waxed, and silvered ... The dial is mounted on four pillars and can be removed by the screws ... The pillars are turned with wide feet, and are located with steady pins and screwed to brass plates which in turn are fastened to the front plate ...
>
> *The pendulum* is of gridiron construction and is suspended from the back cock by a steel strip. The crutch is steel and has a brass pin which engages in a slot in the central rod ...
>
> *Shelton's punch-mark* on the Cambridge movement is on the front plate ...
>
> *The movement* is rigidly mounted, and is secured to the seat-board with four brass holdfasts and screws. Two more holdfasts are screwed to the back plate, and line up with brackets screwed to the back-board.

The constant motion of the ship made it impossible for the astronomers to use the Shelton astronomical clock (also termed a 'regulator') on board the *Endeavour*, while it was at sea. The clock could only be used ashore, and even then after being properly set up.

The second type of clock assigned to the *Endeavour* was a journeyman (or assistant) clock. This was a smaller, less accurate clock that was generally used on shore in a tent or observatory, alongside an astronomical quadrant. Maskelyne (1764: 373) provides an excellent description of one of these clocks:

> ... I fixed up a little clock there, which may be called a journeyman, or secondary clock, having a pendulum swinging seconds, which after being well adjusted would keep time very regularly for several hours. It had only a minute and second hands, and struck every minute exactly as the second hand came to sixty, which was very convenient for the counting of seconds ...

The Royal Society ordered a new journeyman clock from Shelton, costing £5, and this was taken on the *Endeavour*.

An alarum clock appears to have been a small, portable clock that was used when astronomical observations were made. It cost only a small fraction of the price of an astronomical clock, and seemed prone to damage and breakdown. As Howse (1969a) notes, since none of these clocks survived from any of Cook's voyages and written descriptions of them have not been found, we know very little about them. The Royal Society also ordered a new alarum clock for the *Endeavour*, and this probably also was made by Shelton.

The final time piece taken on the *Endeavour* was a watch made by George Graham. This was owned by Nevil Maskelyne, who loaned it the Royal Society (Howse, 1969a; 1969b).

As we have noted, all of the clocks were manufactured by John Shelton (1712–1777), who at the time was one of Britain's foremost makers of astronomical time-pieces. At the age of seven he began an apprenticeship with the London clock-maker Henry Stanbury, and in 1720 he became a member of the Clockmakers' Company. By the middle of the eighteenth century Shelton was the main person used by the noted London instrument-maker George Graham to fabricate astronomical clocks, yet despite his obvious technical acumen and orders for transit of Venus clocks in 1761 *and* 1769 Shelton did not have a good business sense and soon after was in financial straits (Bonhams ..., 2006; Clifton, 1995).

3.4 The Voyage (1768–1771)

The Seven Years' War ended with the signing of the Treaty of Paris on 10 February 1763 between Great Britain and France, and involved a complex series of land exchanges, mainly in North America, the Caribbean and India (see Baugh, 2011; Marston, 2001). No longer would international scientific expeditions run the threat of military intervention—as sometimes occurred during the 1761 transit of Venus—and with the world now at peace, British (and also French) astronomers attracted by the 1769 transit were free to proceed unimpeded to far-flung observing destinations. This must have been a great relief to Cook, given the long and hazardous journey he was facing to the far side of the globe.

Thus on 26 August 1768 Cook sailed from Plymouth on

> … one of the most expensive and ambitious expeditions ever undertaken by Mother England … To all intents and purposes this was a scientific voyage: at issue was the most pressing problem in world astronomy, and at stake was British pride and prestige. (Orchiston, 2005: 54).

After sailing across the Atlantic Ocean and rounding Cape Horn, the *Endeavour* penetrated the Pacific, and on 13 April 1769 anchored in Matavai Bay on the northern coast of Tahiti (see Figure 20). This left Cook, Green and others who would observe the transit more than seven weeks to prepare for the grand event on 3 June.

Only after the transit would Cook open the sealed orders provided by the Royal Society, and discovered his charter for the remainder of the voyage, which would take the *Endeavour* in search of Terra Australis Incognita, the large southern continent that was assumed to exist in the Pacific and counter-balance the presumed over-accumulation of land masses in the Northern Hemisphere. So the voyage of scientific exploration would become one of geographical exploration, and lead to the re-discovery and circumnavigation of New Zealand and the exploration and charting of the east coast of Australia. After carefully threading its way through the seemingly endless islands, reefs and shoals of the Great Barrier Reef and sailing through Torres Strait, the *Endeavour* would head for England via Batavia (present-day Jakarta, in Indonesia), Cape Town and Ascension Island, eventually reaching Plymouth on 13 July 1771.

3.5 The Tahitian Observing Sites

Let us now return to Tahiti and the transit. Soon after the *Endeavour* arrived in Matavai Bay Cook and Green decided that nearby Point Venus was an ideal site for the observatory: it was easy to reach from the ship, and lay on a narrow strip of land that could be fortified (which would ensure there were no interruptions during the transit, when precise observations and measurements called for total concentration). Figures 21 and 22 show details of the Fort.

Fort Venus was established, with an assortment of tents for men and instruments:

> The astronomical clock ... was set up in the middle of one end of a large tent, [and] ... Without the end of the tent facing the clock, and 12 feet from it, stood the observatory, in

Figure 20: Part of the lithograph 'View of Matavai Bay in Otaheite from One Tree Hill', showing the *Endeavour* at anchor, and on shore to starboard (to its right) is Fort Venus (based on the original lithograph in Hawkesworth, 1774).

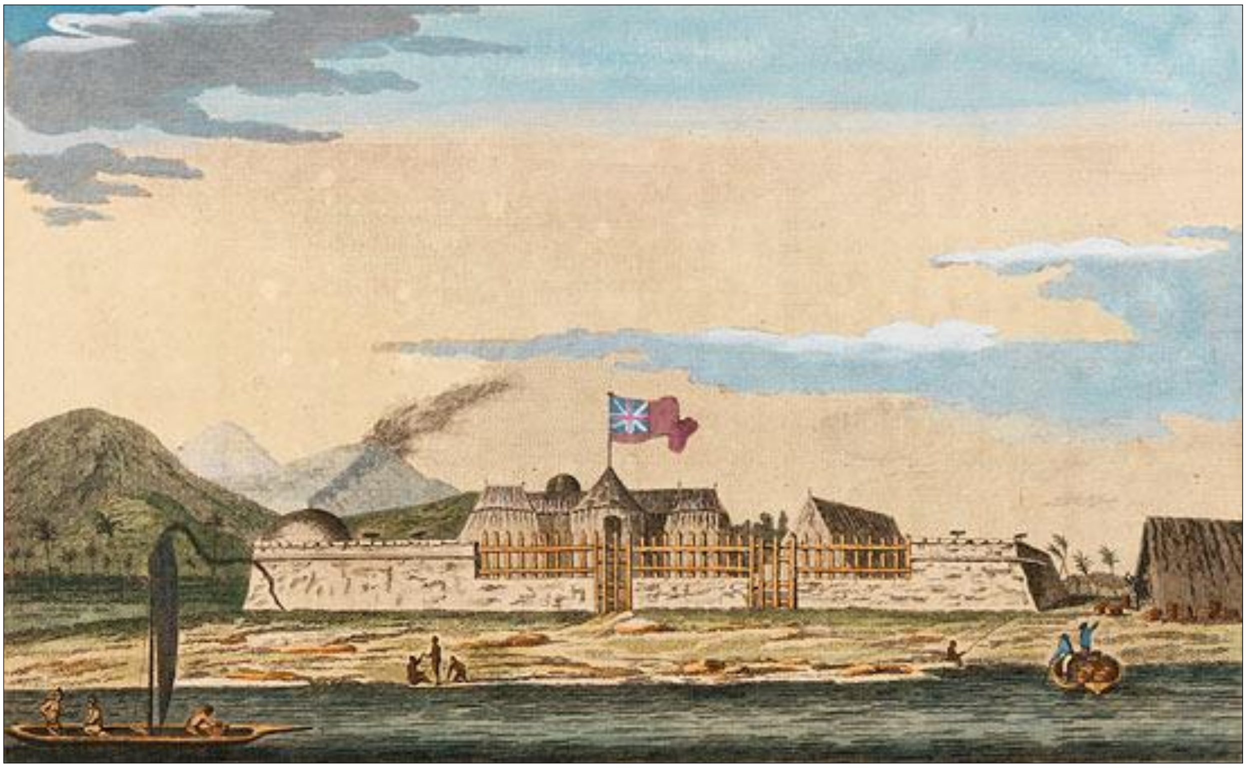


Figure 21: This undated tinted lithograph is based on an original untinted lithograph that was published by Parkinson (1784). Although it displays some artistic licence, it does show the *general* appearance of Fort Venus (Orchiston Collection).

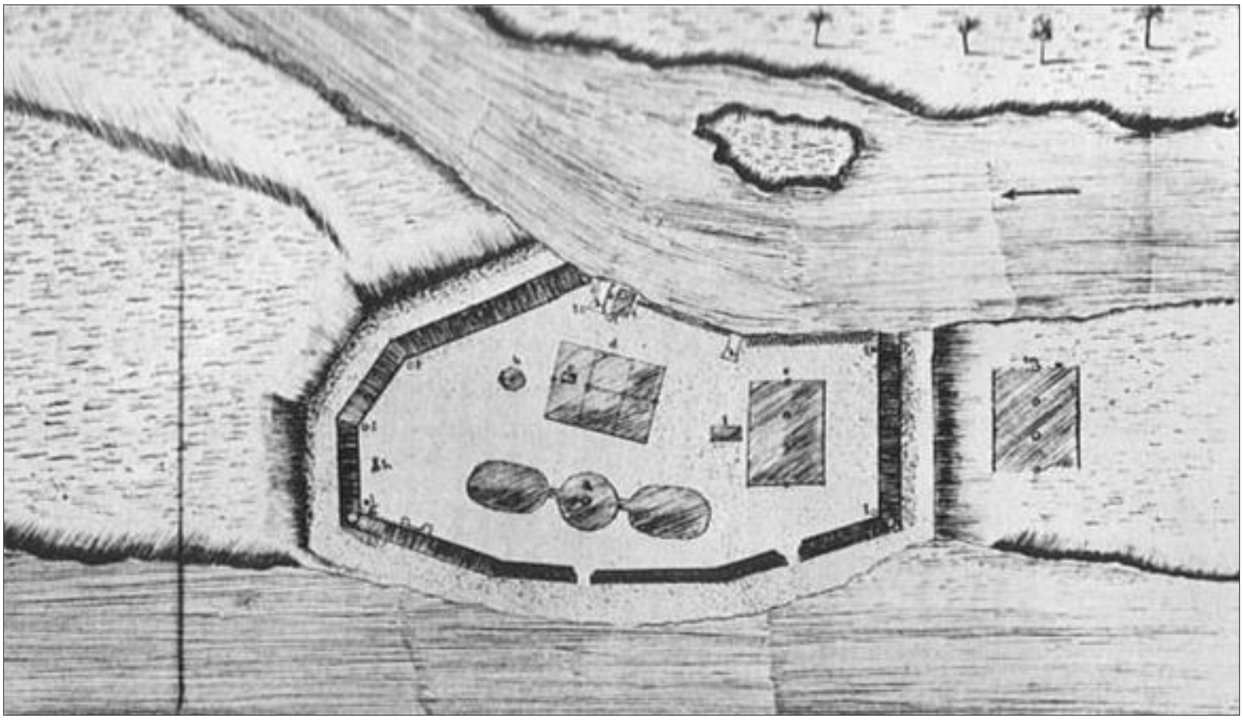


Figure 22: Plan view of Fort Venus, showing the palisade, three adjacent tents near the foreshore, two large rectangular tents, the centrally located one housing the astronomical clock, and to the left of this tent the small circular tent-observatory where the journeyman clock and the quadrant were located (adapted from Parkinson, 1784: Plate IV).

which were set up the journeyman clock and astronomical quadrant ... (Green and Cook, 1771: 397–398).

The 'observatory' mentioned above was an important innovation. It was a portable tent observatory, designed by Smeaton (who built the Eddystone Lighthouse), and constructed under the direction of Maskelyne and Cook (Beaglehole, 1968: cxliii).

Once Fort Venus was set up, establishing its latitude and longitude became one of Green's priorities. For latitude he used quadrant observations of meridian zenith distances of the Sun obtained between 6 May and 27 June and meridian zenith distances of fifteen bright stars observed between 21 June and 4 July. These produced a mean value of 17° 29′ 15″ S (Green and Cook, 1771: 405–406). For longitude, he measured 'lunars' with the quadrant or a sextant on sixteen evenings between 30 April and 30 June, deriving a figure of 149°36′38″ W of Greenwich, which was similar to the value of 149° 32′ 30″ W, that Green and Cook obtained from observations of Jovian satellite eclipses made using the Short telescopes on seven nights between 4 June and 6 July (see Green and Cook, 1771: 407–409). In order to conduct these latter observations, the telescopes were mounted on top of empty casks that were sunk into the sand, and ballasted internally with more sand for stability (Green and Cook, 1771: 398). Figure 23 shows how these telescopes were used.

As the date of the transit neared, Cook notic-

Figure 23: A reconstruction at the Royal Observatory Greenwich of how the Short telescopes were used for astronomical observations on Cook's first voyage (courtesy: the late Derek Howse).

ed that the anchorage at Matavai Bay experienced as many cloudy days as clear ones (see Beaglehole, 1963 (I): 283), and so as a safeguard against inclement weather at Fort Venus on the critical day he decided to heed the sage advice proffered him before the voyage by the President of the Royal Society (see Douglas, n.d.: 516) and establish two temporary ancillary observing stations. One of these was on Irioa Island off the north-eastern tip of adjacent Moorea, and comprised no more than

> … a Coral rock about 150 yards from the shore … It was about 80 yards long and 60 broad and had in the middle of it a bed of white sand large enough for our tents …" (Beaglehole, 1963(I): 284n).

The other supplementary observing station was on Taaupiri Island, an islet off the shore of Tahiti to the east-southeast of Fort Venus (see Beaglehole, 1968: 97n). The locations of these three different 1769 Tahitian transit stations are shown in Figure 24. According to Cook (1770) there were enough instruments to equip the three observing stations, while on the voyage out to the Pacific Green offered instruction in nautical astronomy and transit of Venus observations (see Orchiston, 1998b), guaranteeing that there would be 'qualified' observers at each transit station.

3.6 The Observers and the Transit Observations

3.6.1 Fort Venus

The observing team at the principal transit station, Fort Venus, comprised James Cook, Charles Green, Daniel Solander and Robert Molyneux (Beaglehole, 1968: 559). We have already met Cook and Green in Section 3.2, so what do we know of Solander and Molyneux?

Dr Daniel Carl Solander (1733–1782; Figure 25) was a Swedish-born scientist who studied under the distinguished Professor of Botany, Linnaeus (Carl von Linné) at the University of Uppsala. Linneaus encouraged Solander to go to England to promote his system of botanical classification. Arriving in London in June 1760 he ultimately found employment at the newly established British Museum as Assistant Librarian and never returned to Sweden or completed his Uppsala Ph.D. although he was referred to as 'Dr Solander' (and indeed this title was formalised in 1771, after the *Endeavour* returned from the South Seas, when Solander was awarded an honorary doctorate by Oxford University). At the British Museum, Solander was able to catalogue the natural history collections using the Linnaean system (Gilbert, 1967), and in 1764 he was elected a Fellow of the Royal Society. With so much in common as natural history *oficionados*, it was inevitable that Daniel Solander would meet Joseph Banks (1743–1820) and the two became life-long friends. As "... the ablest botanist in England."

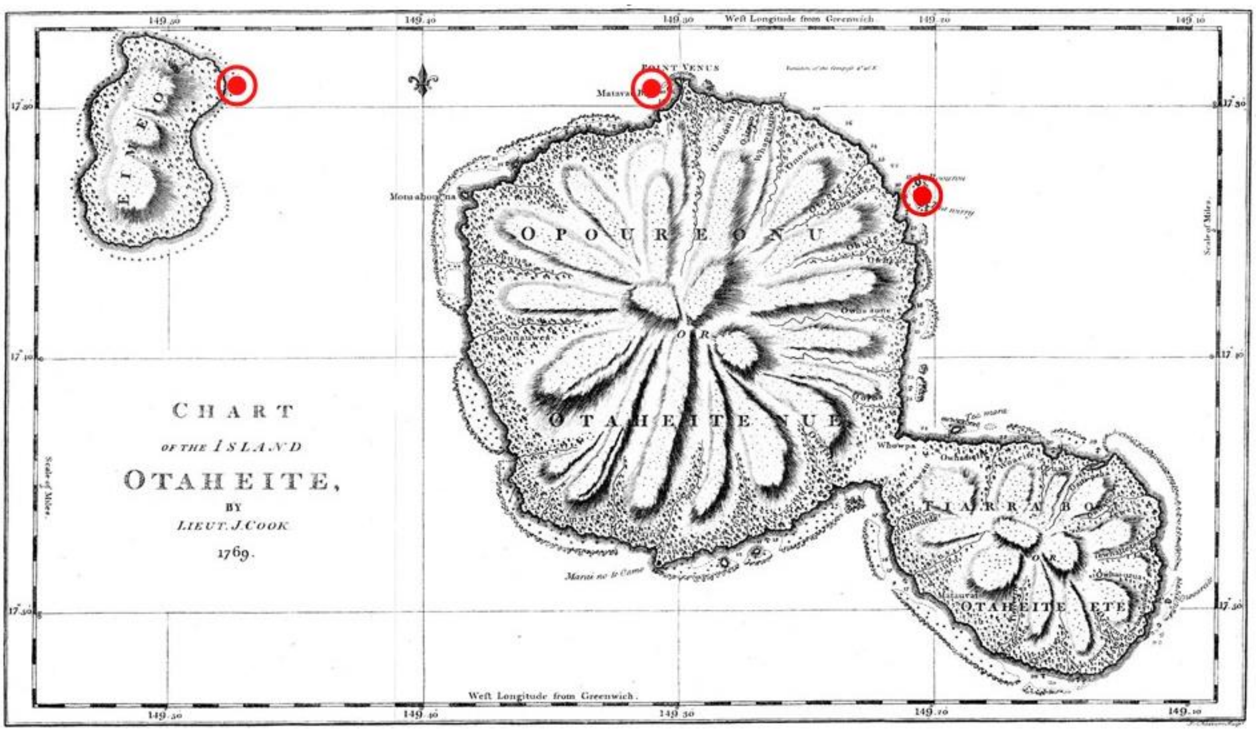


Figure 24: A modified version of Cook's original map of Tahiti, with the locations of the three different observing sites superimposed. From left to right they are Irioa Island, just off the north-eastern tip of Morea; Fort Venus at Matavai Bay, Tahiti; and Taaupiri Island, just off the coast of Tahiti (map modifications: Wayne Orchiston).

(Beaglehole, 1968: cxxxv), it was only natural that Banks would invite Solander to join his personal entourage of scientists and artists who would sail on the *Endeavour* to the Pacific (Duyker, 1998). Accompanying Solander was his assistant, Herman Spöring, who would prove to be a competent artist. When the *Endeavour* left England Solander was 35 years of age, and he was described as

> ... short and somewhat stout, with fair hair and complexion. He [was] ... a jovial sort of man, kind and obliging, with charm and humility ... By some writers he has been described as lazy, dissipated, indolent, dilatory and even in one case as being nothing more than a parasite. These accusations are most unjust ... (Marshall, 1977: 51).

In 1773, less than two years after the return of the *Endeavour*, Solander was appointed Keeper of the Natural History Department at the British Museum, and he also served as
' Curator-Librarian at Soho Square. He lived with Banks up until his death on 12 May 1782. Figure 21 shows a painting of Solander made after the return of the *Endeavour* to England.

Robert Molyneux was born in Hale, Lancashire, in 1746, and served as a Master's Mate on the *Dolphin* before joining the *Endeavour* with the rank of Master (Beaglehole, 1968: 593). He showed much aptitude in surveying and cartography, skills that were greatly appreciated by Cook (see Beaglehole, 1968: cxxxii). Molyneux was one of those who died when the *Endeavour* was returning to England, on 16 April 1771, as the vessel was leaving Cape Town (Beaglehole, 1968: 593), and although he reputedly had "... a good measure of intelligence ..." (Beaglehole, 1968: cxxxii) Cook's obituary of him paints a picture of a young man who "... had unfortunately given himself up to extravecancy and intemperance which brought on disorders that put a pirod to his life." (quoted in Beaglehole, 1968: cxxxii). Professor Arnold Wood (1926) is somewhat more forthright: Robert Molyneux, "The Master—a very important officer, who looked after matters of navigation—[was] ... an able fellow, who drank himself to death."

For their transit observations Green and Cook used the two Short telescopes supplied by the Royal Society; as we have noted already, Solander had access to his own telescope, while it appears that Cook loaned Molyneux his Watkins reflector. All four observers used the Shelton astronomical clock to record the times of the four contacts. As we have noted previously, critical from the viewpoint of calculating the solar parallax, *P*, were the second ingress contact and the first egress contact (numbered 2 and 3 respectively, in Figure 1).

Transit day, 3 June, was fine and sunny, although warmer than expected, and Cook reported on the observation of the transit in his journal:

> This day prov'd as favourable to our purpose as we could wish, not a Cloud was to be seen the whole day and the Air was perfectly clear, so that we had every advantage we could desire in Observing the whole of the passage of the Planet Venus over the Sun's disk ... (Beaglehole, 1968: 97–98).

The transit lasted about six hours, and Cook's account would suggest that all four observers succeeded in observing it and recording the times of the four contacts depicted in Figure 1. This was confirmed by Molyneux's comments, which are published by Beaglehole (1968: 560).

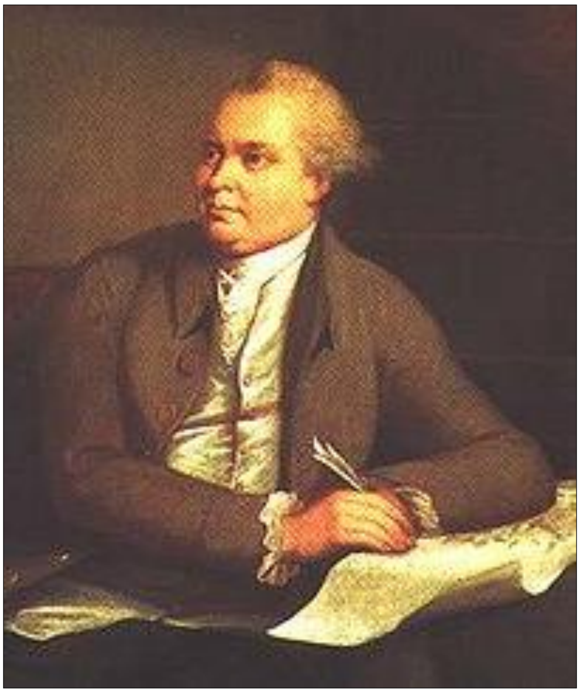


Figure 25: A post-First Voyage painting of Daniel Solander (en.wikipedia.org).

We also know that during the transit Green and Cook measured the diameter of Venus using the Short telescope with the Dollond object-glass micrometer, and obtained mean values of 54.97″ and 54.77″ respectively. Cook also measured the diameter with his Watkins telescope and a Dollond micrometer on three different occasions, and obtained mean values of 56.8″, 56.28″ and 56.02″ (Green and Cook, 1771: 412–418). Cook certainly was busy, for in addition he used his Short reflector and a Dollond micrometer to take a series of measurements of the separation between Venus' limb and the limb of the Sun, and to measure the diameter of the Sun (Green and Cook, 1771: 413–415).

3.6.2 Taaupiri Island

There were four members of the observing team located on Taaupiri Island, just off the east coast of Tahiti: Zachary Hicks, Charles Clerke, Richard Pickersgill and Patrick Saunders (Beaglehole, 1968: 559).

As a Second Lieutenant, Zachary Hicks was ranked number two on the *Endeavour*, after Cook. He was born in Stepney (London) in 1739 and first served in the Royal Navy as an able seaman and later a Master's Mate on the sloop *Launceston* in 1766–1767. In August 1767 he was transferred to the *Hornet* as an acting Lieutenant, and in March 1768 this rank was confirmed (Beaglehole, 1968: 591). As an officer, he was familiar with the rudiments of nautical astronomy and also was one of those trained in the niceties of transit observations on the voyage out to the Pacific. Beaglehole (1974: 138) on the one hand describes Hicks as "... experienced and mature, a good sailor and officer, a man with a good eye ... forethought and independent judgement." On the other hand, he somewhat less flatteringly says Hicks was "... an efficient, dependable, but quite unimaginative man ..." (Beaglehole, 1968: ccxxix). Fate would decree that the Tahitian transit would be his first and last major astronomical venture: he was ill in Batavia but recovered, only to die of tuberculosis on 26 May 1771 during the final leg of the voyage home (Beaglehole, 1968: 471).

Clerke was a Third Lieutenant and was ranked fourth on the *Endeavour*. Just four years Hicks' junior, he was born in Wethersfield (Essex) in 1743, and went to sea as a Captain's servant, but by the time he returned from Byron's voyage to the South Seas on the *Dolphin* in 1765 he was a Midshipman (Beaglehole, 1968: 593). Like Hicks, he was trained in nautical astronomy, and also tutored by Green on the voyage out to Tahiti. Clerke's astronomical talents were to prove most useful after Green died, as he was the one who assumed the role of the *Endeavour's* second astronomer (Beaglehole, 1968: cclxiv). Great things were expected of Clerke, as reflected in the fact that he later was invited to join Cook's Second and Third Voyages to the Pacific, and on the latter Voyage commanded the *Discovery*, which was the consort to Cook's *Resolution*. Following Cook's death, he was in charge of the entire expedition until he died at sea on 22 August 1779 (Beaglehole, 1969: 878). Clerke was yet another example of a talented young naval officer who met an untimely death while in the service of King and country. Already terminally ill, five days before his death he wrote:

> ... my friends will have no reason to blush in owning themselves such, for I have most perfectly and justly done my duty to my country, so far as my abilities would enable me.

Apparently, according to his friends, his spirits were high and his talk was jolly right up to his demise (cited in Wood, 1926). Beaglehole (1974:139) has described Clerke as "... always cheerful, talkative, amusing, with some of the rollicking vices as well as the rollicking virtues; a generous spirit who made friends easily; tall, long-nosed, with an eye both roving and sparkling." He had "... enough mathematical ability to become a good navigator; with some interest in the scientific side of his profession ..." (Beaglehole, 1968: cxxxi).

Richard Pickersgill, was born at West Tanfield (Yorkshire) in 1749, and went to sea as a Captain's servant on the *Tartar* in 1766. Then he joined Wallis on his voyage to the South Seas in 1766–1767. Beginning as an able seaman, he had risen to Master's Mate by the end of the voyage. After joining the *Endeavour* he "... added to his reputation as a man of ability and a useful surveyor and maker of charts ..." and upon Molyneux's death in April 1771 was promoted to Master (Beaglehole, 1968: 592). Beaglehole (1968: ccxxxii), described him as "... a good observer, [who] ... drew numerous charts ... We see in him ability and amiability: unfortunately some instability as well." He also was

> ... able and amiable, a natural romantic, a little over-sensitive, a little given to the grandiose concept and the swelling word, yet a successful subordinate, he was to do good work for Cook. (Beaglehole, 1974: 139).

Pickersgill (1769–1770) kept a journal, and at the end of this is an interesting 2-page listing titled "A Table Shewing the Exact Lattd & Longitude of Capes Bays & head Lands seen in his Majestys Bark Endeavour & Settled by Astronimacal Observations." While he may have had obvious astronomical, cartographic and hydrographic surveying skills, spelling was not one of his fortés! Pickersgill also joined Cook on his Second Voyage to the Pacific (as a Third Lieutenant), and after that Voyage he took command of the *Lyon* but subsequently was court-martialled for 'drunkenness and other irregularities'. In July 1779 he was attempting to board a ship and slipped and fell into the Thames and drowned (Beaglehole, 1968: 592).

The fourth member of the Taaupiri Island observing team was the mysterious Patrick Saunders. We do not know where or when he was born (or, for that matter, when he died). He began the voyage as a Midshipman on the *Endeavour*, but following a series in indiscretions was demoted to ordinary seaman. His interest in the women of Tahiti led him to abandon ship there, and this also may have motivated him to desert ship in Batavia on the way home (Beaglehole, 1968: 594). It is not known what became of him after this.

While there is no description of the scientific equipment that was assigned to them, we can assume that because of the number of highranking officers involved Hicks' party was given the journeyman clock. Molyneux (1769) states that Green provided both ancillary transit parties "... with Telescopes & every thing necessary ... to observe the transit." Precisely how many telescopes were supplied is not stated, or whether these were Gregorian reflectors like Cook, Green, Solander and Molyneux had at Fort Venus, or the smaller telescopes that formed components of the astronomical quadrant and sextants. Since there is no First Voyage documentation to support the existence of more than four Gregorian reflectors on the *Endeavour*, my view is that the Taaupiri Island observers used sextants owned by the ship's officers and perhaps the quadrant to observe the transit. Although of modest aperture, all of the telescopes on these instruments had the requisite resolution to afford clear views of the transit. Long after the transit Cook (1771a: 694) stated that all four members of this transit party were observers.

There are no log or journal entries by the four observers describing their observations of the transit, but from Molyneux's comments (published in Beaglehole, 1968: 560) we do know that all four successfully observed the transit.

3.6.3 Irioa Island (Moorea)

The transit team that went to Irioa Island (Moorea) also contained four members: John Gore, Jonathan Monkhouse, William Monkhouse and Herman Spöring (Moylneux, 1769: 559). All played important roles on the *Endeavour.*

Gore was the leader of the party, and after Cook and Hicks as a Third Lieutenant ranked third amongst the naval officers and crew on the *Endeavour*. The only senior member of the expedition of trans-Atlantic extraction, Gore was born in the American colonies in about 1730. He went to sea in 1755, serving on the *Windsor*, *Bellona* and *Aeolus* in the Atlantic, the West Indies and the Mediterranean (Beaglehole, 1968: 595; 1974: 138). Then he visited the South Seas with both Byron and Wallis, each time as a Master's Mate, before joining Cook's expedition. He has been described as

> ... a particular type of sailor ... a man of commonsense and able practice − with the reputation in his maturity of being the best practical seaman in the navy ... he is ceaselessly active; he is the great sportsman of the expedition ... he is ready for any expedition into the country anywhere, of pleasure or of duty. (Beaglehole, 1968: cxxxi).

Gore excelled during the voyage to the point where Cook was happy to promote him to Second Lieutenant following Hicks' death in May 1771, and as well as being an excellent officer, Wood (1926) somewhat facetiously mentions that he also was ":.. a first-rate shot, [as] the first Englishman who ever shot a kangaroo." Like Clerke, Gore could look forward to a successful naval career, and like Clerke, he also joined Cook on the Third Voyage, serving as Cook's understudy or second in command on the *Resolution*. When Cook was murdered in Hawaii, Gore took command of the *Discovery* when Clerke transferred to the *Resolution* and assumed command of the entire expedition. Upon Clerke's demise Gore then took on this role and successfully brought the two vessels back to England. In commenting on Gore's scrappy, commonplace First Voyage journal, Beaglehole (1968: ccxxxi) perceptively remarks that "... no one would foresee in it a future commander of the Third Voyage." Obviously Gore's talents lay elsewhere than in record-keeping! After the Third Voyage he was promoted to Captain, and took the post at Greenwich Hospital vacated by Cook. He died in England in 1790 (Beaglehole, 1968: 595), one of the very few from Cook's First Voyage who lived to what, in those days, might be considered a 'ripe old age'.

The second member of the observing team was Jonathan Monkhouse, but little about his background has been documented, other than that he was the son of George Monkhouse of Penrith in Cumberland (Beaglehole, 1968: 634). He joined the *Endeavour* as a Midshipman, and was "Much trusted by Cook, and evidently the most responsible of the midshipmen." (Beaglehole, 1968: 594). He was an intelligent, hard working young man (Beaglehole, 1968: cxxxii), and was one of many on the *Endeavour* who died between Batavia and Cape Town—on 6 February 1771, to be precise (Beaglehole, 1968: 594)—on the way home to England after the transit.

The third member of the transit party was Jonathan's older brother, William Brougham Monkhouse, and we also have no knowledge of his date of birth. William Monkhouse served as the Surgeon on the *Endeavour*. Prior to this he had been the Surgeon on the *Niger* for some years (Beaglehole, 1974: 139). Although "... a man of some professional merit and a good observer." (Beaglehole, 1968: 594) he was also rather disorganised (Beaglehole, 1968: cxxxii). However, there is no trace of this latter trait in the surviving remnant of his journal kept on Cook's First Voyage. To the contrary, Beaglehole speaks glowingly of his literary skills:

> ... if the original journal was continuously as perceptive, fully detailed and well-written as this fragment it provided a description of eighteenth century New Zealand quite as good as Banks's, and perhaps better − which is praise of a very high order. It is composed with great vigour and lucidity, and the writer was obviously an extremely intelligent man. (Beaglehole, 1968: cccxxxi).

Intemperance eventually took its toll, and just like his brother, William Monkhouse died prematurely, but three months earlier, on 5 November 1770, while the *Endeavour* was anchored in Batavia. Notwithstanding his liking for 'the grog', Wood (1926) has described Monkhouse as "... a *most* excellent man; a splendid doctor, and a delightful companion if you get the chance of a walk ashore."

Rounding out the transit team was Swedish-born Herman Diedrich Spöring (Marshall, 1977) who was born in about 1733 at Åbo (now Turku, in Finland), where his father was Professor of Medicine at the local university. After also training in medicine, Spöring moved to Stockholm in 1753 where he practised surgery. In 1755 he settled in London, working at first as a watch-maker, and in February 1766 he was employed at the British Museum as Solander's assistant. When Solander joined Banks on Cook's First Voyage, Spöring went along too. In addition to his duties as an artist and draftsman, he also served as a 'Secretary and Recorder'. Spöring was "... a draughtsman of great ability, as some beautiful drawings show." (Beaglehole, 1968: cclxvii). He was one of those who perished in January 1771 (Beaglehole, 1968: 599) while the *Endeavour* was *en route* from Batavia to the Cape of Good Hope.

On the day of the transit Banks identified the two observers on Irioa Island as Jonathan Monkhouse and Gore (Beaglehole, 1963, 1: 284), while Cook says "... I sent Lieutenant Gore in the Long-boat to York Island [Moorea] with D^r^ Monkhouse and M^r^ Sporing to observe the transit of Venus, M^r^ Green having furnished them with Instruments for that purpose." (Beaglehole, 1968: 97). To confuse matters further, long after the transit Cook (1771a: 694) identified Spöring and Jonathan Monkhouse as the two observers. We should note that although Joseph Banks accompanied the Irioa Island party, he took no part in the transit observations (Beaglehole 1963(I): 284–285).

Nor do we know the number of telescopes involved, or their appearance. In his journal entry of 2 June, Banks describes how:

> Before night our observatory was in order, *telescopes all set up and tried* &c. And we went to rest anxious for the events of to-morrow. (Beaglehole, 1963(I): 284, my italics).

This indicates there were two or three different telescopes, and although the preparations mentioned by Banks suggest Gregorian reflectors, there is in fact no evidence to support this. Nor is there any information about the time-keeper used, which had to be the journeyman clock or the alarum clock. So the record of instrumentation supplied to the two ancillary transit stations remains confusing, to say the least.

All we know though, again on the basis of Molyneux's comments published in Beaglehole (1968: 560) and from letters penned by Cook (e.g. see Cook, 1770), is that all three teams successfully observed the transit.

3.7 Publication of the Transit Observations

Eventually a research paper co-authored by Charles Green (posthumously) and James Cook and titled "Observations made, by appointment of the Royal Society, at King George's Island in the South Seas" was published in 1771 in the *Philosophical Transactions of the Royal Society*. This 25-page paper provides details of the transit, including contact timings (see Table 1 and Figure 26) and contact drawings by Cook and Green (Figure 27); lists observations made for timekeeping purposes and in order to determine the latitude and longitude of Fort Venus; and includes some magnetic and tidal records. The transit itself occupies approximately half of the paper, but details only the observations made by Cook, Green and Solander (notwithstanding the aforementioned problems associated with Green's contact timings). Perhaps this is why, at the bottom of the very last page of the paper, Cook acknowledges Maskelyne's assistance in preparing the final manuscript. Surprisingly, none of the contact timings made at Irioa Island or Taaupiri Island is included, and indeed the sole mention of these two observing stations is almost an aside:

> Some of the other gentlemen, who were sent to observe at different places, saw at the ingress and egress the same phenomenon as we did; though much less distinct, which no doubt was owing to their telescopes being of less magnifying power ... (Green and Cook, 1771: 411).

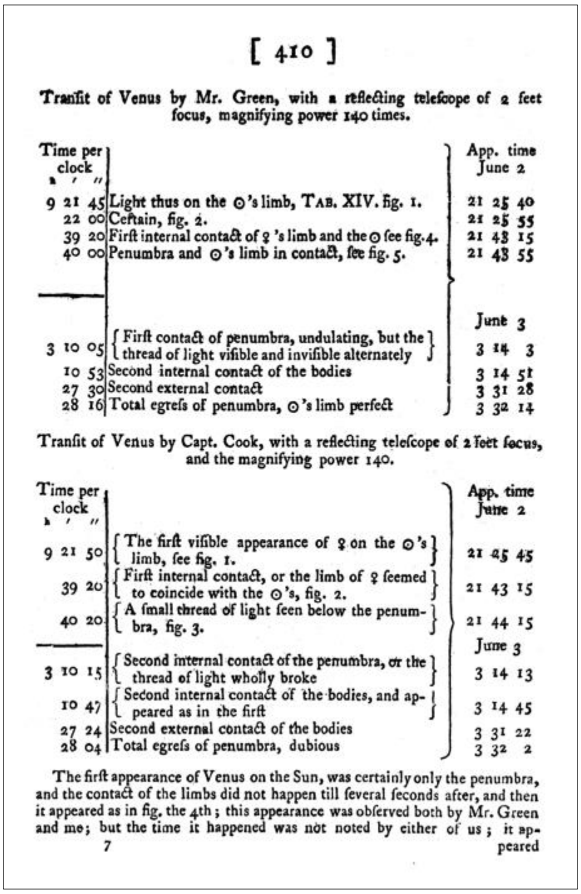
This appears to confirm the suggestion that the 'telescopes' that they used at the two ancillary observing stations were those associated with sextants and the quadrant rather than Gregorian reflectors.

For the purposes of calculating the solar parallax, *P*, the timings that were deemed critical were of the second ingress contact and the first egress contact (i.e. the second and third positions of Venus along each transect in Figure 1), and both Cook and Green had problems in accurately establishing these. Cook explains in his journal:

> ... we very distinctly saw an Atmosphere or dusky shade round the body of the Planet which very much disturbed the times of the Contacts particularly the two internal ones. Dr Solander observed as well as Mr Green and my self, and we dffer'd from one another in observeing the times of the Contacts much more than could be expected. Mr Green's Telescope and mine were of the same Magni-

Table 1: Contact timings listed in the Green and Cook paper.

Contact	Cook	Green	Solander
1	07h 21m 25s	07h 21m 20s	07h 21m 46s
2	07h 38m 55s	07h 38m 55s	07h 39m 08s
3	13h 09m 56s	13h 09m 46s	----
4	13h 27m 45s	13h 27m 57s	13h 27m 56s


[410]

Tranſit of Venus by Mr. Green, with a reflecting teleſcope of 2 feet focus, magnifying power 140 times.

Time per clock h ′ ″		App. time June 2
9 21 45	Light thus on the ☉'s limb, TAB. XIV. fig. 1.	21 25 40
22 00	Certain, fig. 2.	21 25 55
39 20	Firſt internal contact of ♀'s limb and the ☉ ſee fig. 4.	21 43 15
40 00	Penumbra and ☉'s limb in contact, ſee fig. 5.	21 43 55
		June 3
3 10 05	Firſt contact of penumbra, undulating, but the thread of light viſible and inviſible alternately	3 14 3
10 53	Second internal contact of the bodies	3 14 51
27 30	Second external contact	3 31 28
28 16	Total egreſs of penumbra, ☉'s limb perfect	3 32 14

Tranſit of Venus by Capt. Cook, with a reflecting teleſcope of 2 feet focus, and the magnifying power 140.

Time per clock h ′ ″		App. time June 2
9 21 50	The firſt viſible appearance of ♀ on the ☉'s limb, ſee fig. 1.	21 25 45
39 20	Firſt internal contact, or the limb of ♀ ſeemed to coincide with the ☉'s, fig. 2.	21 43 15
40 20	A ſmall thread of light ſeen below the penumbra, fig. 3.	21 44 15
		June 3
3 10 15	Second internal contact of the penumbra, or the thread of light wholly broke	3 14 13
10 47	Second internal contact of the bodies, and appeared as in the firſt	3 14 45
27 24	Second external contact of the bodies	3 31 22
28 04	Total egreſs of penumbra, dubious	3 32 2

The firſt appearance of Venus on the Sun, was certainly only the penumbra, and the contact of the limbs did not happen till ſeveral ſeconds after, and then it appeared as in fig. the 4th; this appearance was obſerved both by Mr. Green and me; but the time it happened was not noted by either of us; it ap-

7 peared

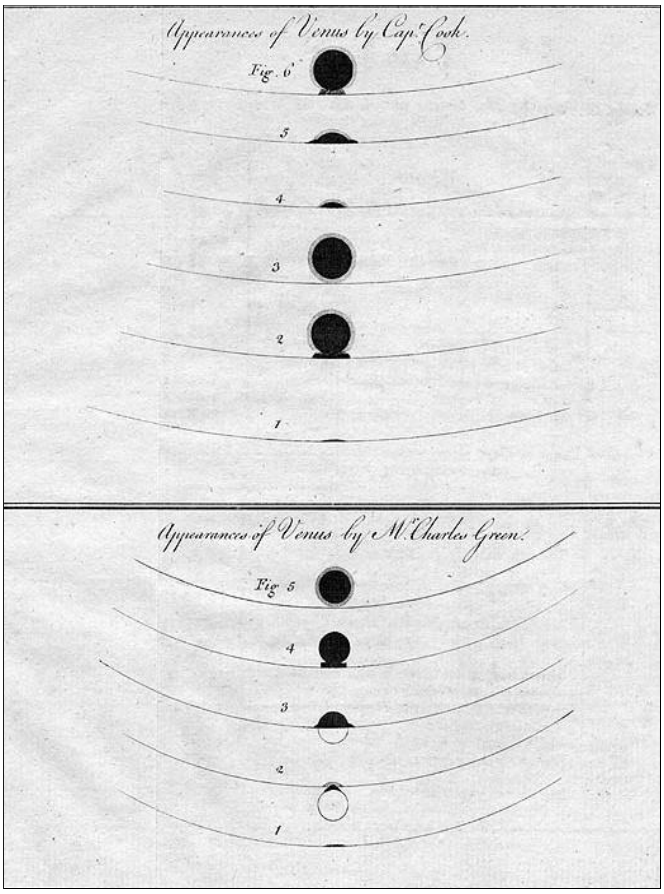


Figure 26 (left): The page in the *Philosophical Transactions of the Royal Society* paper listing the different contact times (after Green and Cook, 1771: 410).
Figure 27 (right): The page in the *Philosophical Transactions of the Royal Society* paper showing drawings of the different contacts made by Cook and Green (after Green and Cook, 1771: facing page 410).

> fying power but that of the Dr was greater than ours. (Beaglehole, 1968: 97–98).

These disparate contact times are listed in Table 1. Cook and Green also allude to this problem in their 1771 paper:

> ... it appeared to be very difficult to judge precisely of the times that the internal contacts of the body of Venus happened, by reason of the darkness of the penumbra at the Sun's limb, it being there nearly, if not quite, as dark as the planet. At this time a faint light, much weaker than the rest of the penumbra, appeared to converge towards the point of contact, but did not quite reach it ... in like manner at the egress the thread of light was not broke off or diminished at once, but gradually, with the same uncertainty: the time noted was when the thread of light was wholly broke by the penumbra. (Green and Cook, 1771: 410–411).

Green noted the same thing, and his sketches of this contact, along with Cook's, are reproduced here in Figure 27. What was presumed to be the atmosphere of Venus is clearly represented in Green's sketch '5', and the internal contact is illustrated by '4'. What Cook and Green actually encountered was the notorious 'black drop effect' (see Pasachoff et al., 2005; Schaefer, 2001), which also was seen by some observers of the 1874 transit of Venus, and the dilemma then, as in 1769, was to decide precisely when Venus 'broke free' from the Sun's limb during ingress and make contact with it at egress.

When we examine Table 1 we see that the times that Cook, Green and Solander registered for the two critical internal contacts varied by as much as 13 seconds, and similar discrepancies also characterized the first and fourth contacts. With the various contact times listed in Table 1, Cook and Green were sometimes in accord and Solander's was the anomalous value, while at other times Green and Solander agreed and Cook's was the dissident reading. So there is no consistent pattern, and it is therefore impossible to derive correction factors for the different observers. However, we now know that discrepancies of this order are to be expected during a transit of Venus, with variations in contact timings of tens of seconds making little difference within the context of the total duration of the transit when values of *P* are calculated.

Nonetheless, it is fair to say that Cook was more than a little disappointed with the variations recorded in the contact timings (see Beaglehole, 1968: 98), and perhaps it was this that prompted the famous Cook biographer, Professor John Cawte Beaglehole (1963(I): 29), to erroneously claim that the Tahitian observations were a failure. Fortunately, nothing could be further from the truth, as we will see in Section 4 below.

4 HORNSBY'S ANALYSIS

In England it was left to Professor Thomas Hornsby to produce a value for the solar parallax, *P*, and in order to achieve this he combined the transit observations made by the British parties at Tahiti and Hudson Bay with those from three non-British stations: Chappe's French expedition to Baja California, Rumovsky's Russian site at Kola and Hell's Danish station at Vardö.

Reduction of the observations demanded consistent contact timings and an intimate knowledge of the latitude and longitude of each observing station, and then involved considerable computations (e.g. see Figure 28). It is interesting that Hornsby circumvented the problem we have encountered with the disparate Fort Venus contact timings by utilising Cook's figure for the ingress and a mean of Cook and Green's figures for the egress, and ignoring the values provided by Solander.

Hornsby published the outcome of his calculations in a short paper titled simply "The quantity of the Sun's parallax, as deduced from the observations of the transit of Venus, on June 3, 1769" which appeared in the same 1771 volume of the *Philosophical Transactions of the Royal Society* as the Green and Cook paper, but about 150 papers later (see Figure 29). Hornsby's result was a figure of 8.78″ (Hornsby, 1771), and to illustrate its reliability, we need only mention that when Howse and Murray (1997) reanalysed Hornsby's calculation using modern methods of reduction they arrived at a value of 8.74 ± 0.05″. Working from his figure of 8.78″, Hornsby (1771: 579) proceeded to calculate the Astronomical Unit:

> ... if the semidiameter of the Earth be supposed = 3985 English miles, the mean distance of the Earth from the Sun will be 93,726,900 English miles.

Hornsby (1771: 574) was very pleased with

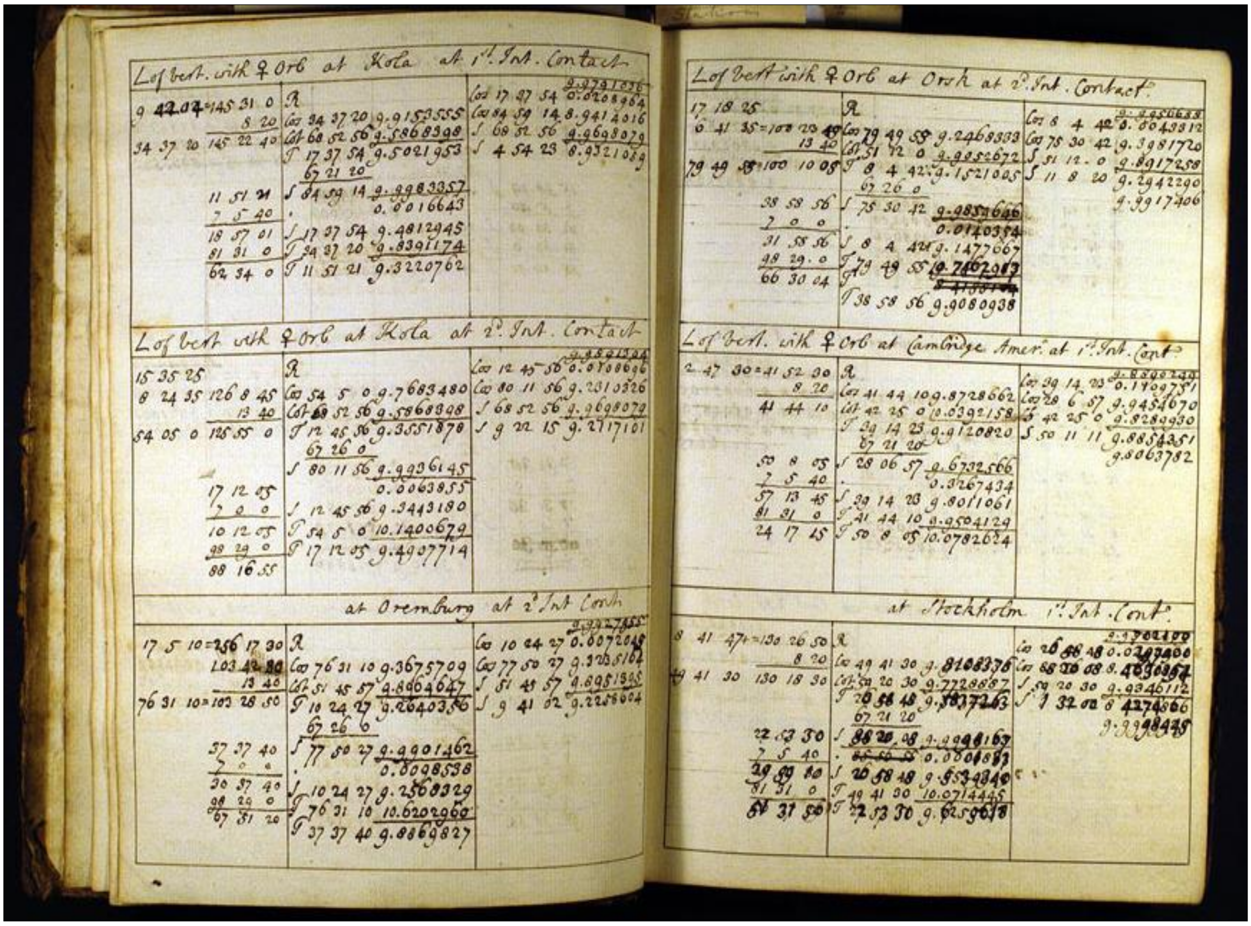


Figure 28: Examples of Hornsby's 1769 transit of Venus calculations, MHS Radcliffe MS 7 (after Johnston, 2005).

with his result, believing that

> ... from the observations made in distant parts by the astronomers of different nations, and especially from those made under the patronage and direction of this Society [the Royal Society, of London], the learned of the present time may congratulate themselves on obtaining as accurate a determination of the Sun's distance, as perhaps the nature of the subject will admit.

Meanwhile, Hornsby's French colleague, Professor Alexandre Guy Pingré (1711–1796; Figure 30) from the University of Rouen and a Corresponding Member of the Academie des Sciences, also conducted an analysis of French and some non-French observations of the transit (including the Tahitian results), coming up with P = 8.80″, a figure remarkably close to Hornsby's result.

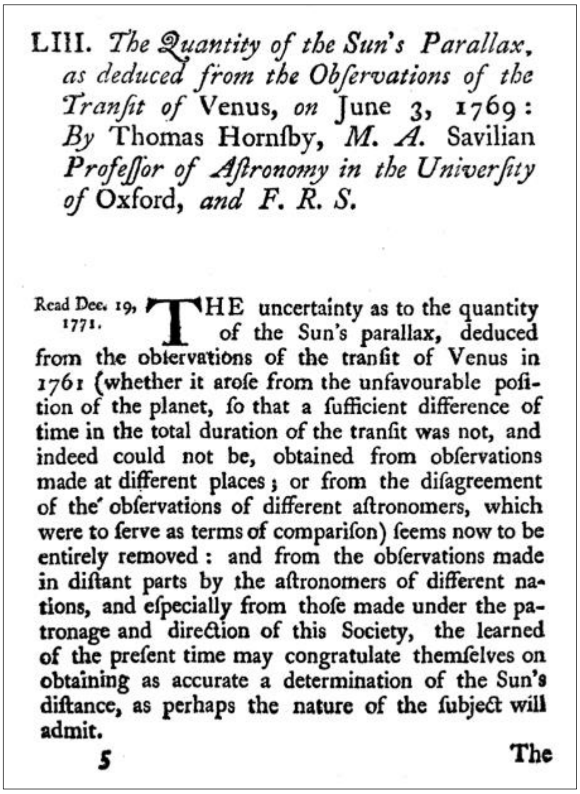
If these were the only values of P that were published following the transit there would have been no doubt that a mean value of 8.79″ was the best possible estimate for the solar parallax, meaning the a.u. was equal to 149,623,007 kilometres, but other astronomers dashed these hopes when they published their results. Admittedly, Hell's value of 8.70″ was not too far removed from the figures listed by Hornsby and Pingré, but Euler's value of 8. 63″, Lalande's of between 8.55″ and 8.63″, and especially Planmann's of 8.43″ (see Woolf, 1959: 190–191) plunged the overall interpretation into chaos. After all, the difference between 8.43″ and 8.80″ amounted to an uncertainty in the a.u. of about 6.5 million km! So the 1769 transit of Venus did not solve the puzzle of the distance from the Earth to the Sun, and astronomers were forced to wait for the 1874 and 1882 transits.

5 PROBLEM SOLVED: A FINAL FIGURE FOR THE ASTRONOMICAL UNIT

As we have seen, the 1769 transit produced values of P that ranged from 8.43″ to 8.80″. There were critics of the figures at the top end of this range that were published by Hornsby and Pingré, but as Waldersee (1969: 119) has commented, their concerns showed

> ... rather more evidence of professional and national rivalries than of serious mathematical disagreement ... [but] the mere fact that discordant notes had been sounded was sufficient to create the impression that the whole scheme had failed ...

Furthermore, Encke's subsequent re-analysis of the 1761 and 1769 transits merely added to the confusion when he published a figure of 8.57116″ in 1824, only to modify this slightly eleven years later (see Dick et al., 1998). This encouraged some astronomers to use other astronomical events, such as the oppositions of Mars during the 1850s and 1860s, in a bid to determine the



LIII. *The Quantity of the Sun's Parallax, as deduced from the Obſervations of the Tranſit of* Venus, *on* June 3, 1769: *By* Thomas Hornſby, *M. A.* Savilian *Profeſſor of Aſtronomy in the Univerſity of* Oxford, *and F. R. S.*

Read Dec. 19, 1771.

THE uncertainty as to the quantity of the Sun's parallax, deduced from the obſervations of the tranſit of Venus in 1761 (whether it aroſe from the unfavourable poſition of the planet, ſo that a ſufficient difference of time in the total duration of the tranſit was not, and indeed could not be, obtained from obſervations made at different places; or from the diſagreement of the obſervations of different aſtronomers, which were to ſerve as terms of compariſon) ſeems now to be entirely removed: and from the obſervations made in diſtant parts by the aſtronomers of different nations, and eſpecially from thoſe made under the patronage and direction of this Society, the learned of the preſent time may congratulate themſelves on obtaining as accurate a determination of the Sun's diſtance, as perhaps the nature of the ſubject will admit.

5 The

Figure 29: The title page of Hornsby's 1771 *Philosophical Transactions of the Royal Society* paper.

Astronomical Unit, but these also produced results that were as discordant as those derived from the eighteenth century transits of Venus. This, then, led to renewed interest in the 1874 and 1882 transits.

Fortuitously, both of the nineteenth century transits were visible—in full or in part—from Australia and New Zealand; as a result, transit parties from England, France, Germany and the

Figure 30: A bust of the distinguished French astronomer, Alexandre Guy Pingré (en.wikipedia.org).

USA flocked to the Antipodes, to join local professional and amateur astronomers (see Orchiston (2004b) for a useful overview).

As we have seen, the eighteenth century transits produced a wide range of values for *P*, the solar parallax, which can be divided into what I like to call the 'high values' (promoted by Hornsby and Pingré) and the 'low values' (published by Euler, Lalande and Planmann). What the 1874 and 1882 transits showed conclusively was that the true value lay among the 'high values'.

Later, the Canadian-American astronomer Simon Newcomb re-analysed all four eighteenth and nineteenth century transits, and in 1895 published a figure of 8.794″ ± 0.018″, which compares very favourably with the value of 8.794148″ ± 0.000007″ that was derived from radar observations and was ratified as the internationally-accepted value by the International Astronomical Union in 1976. This corresponds to a mean Earth-Sun distance of 149,597,870 km (see Van Helden, 1995: 168).

Note, incidentally, that Newcomb's 1895 value for *P* was almost identical to the figure published by Hornsby more than a century earlier, providing somewhat belated justification for the astronomical agenda of Cook's First Voyage.

6 PROBLEMS UNSOLVED: MYSTERIES SURROUNDING COOK'S 1769 TRANSIT EXPEDITION

During more than two decades I have been researching the historic transits of Venus, including their Cook-voyage associations, and I have encountered a number of aspects that warrant further discussion. These are discussed below.

6.1 Where Are All Those Records?

Once the transit was over, all of the observers from Fort Venus, Taaupiri Island and Irioa Island handed their records to Green for safe-keeping (Cook, 1771a: 692), and he then made copies of them and when the *Endeavour* reached Batavia he sent these to the Royal Society, enclosed in a packet that Cook sent to the Admiralty on a Dutch ship (Cook, 1771b: 694).

The *Endeavour* left Batavia on 26 December 1770 and it was only after Green died (about one month later) that Cook discovered the shocking state of the astronomical records:

> ... my first care was, to preserve, for the perusal of the Royal Society, all his papers that contained any Astronomical observations of what nature soever; many of which I had never seen before; and I found far from having been kept in that clear order their importance seemed to require ..." (ibid.; cf. Wales, 1788: i).

Unfortunately, Green had never briefed Cook on precisely which records he had sent to the Royal Society from Batavia, so Cook

> ... caused copies of all those that had any relation to the Transit of Venus, and for fear of any accident happening to us, I put them on board His Majesty's Ship Portland addressed to Mr Maskelyne ... (Cook, 1771b: 695).

This occurred on 10 May 1771, when the *Endeavour* and the *Portland* were anchored together at Ascension Island (Beaglehole, 1968: 469).

Cook (1771a: 693–694) reveals that his letter to Maskelyne contained the following enclosures:

> 1. Observations of equal altitudes of the sun for the time; and observed altitudes or Zenith distances of the sun and stars for the latitude.
> 2. Observations of Jupiters Satellites for the longitude; and of the times of the contacts of the limbs of the sun and Venus observed by M^{r} Green.
> 3. Lunar observations of the Moons distances from the sun and fixed stars for the longitude; and Capt^{t} Cook's observations of the times of the contacts of the limbs of the sun and Venus.
> 4. M^{r} Green's observations of the diameters of the Sun and Venus; nearest approach of their centers; difference of Declination, distances of their limbs in a direction parallel to the Equator; all observed with Dollond's Micrometer.
> 5. Observations of the transit of Venus made at York Island [= Moorea] by M^{r} Monkhouse and M^{r} Sporing; and Dr Solander's observations of the two external and first internal contacts of Venus at Georges Island.
> 6. Observations of the transit of Venus at Morton's Island [= Taaupiri Island] by Lieu^{t} Hicks, Clerk, Saunders, and Pickersgill.

Cook (1771a: 693) also explained to Maskelyne why these documents were sent to him rather than to the Royal Society:

> If I recollect right M^{r} Green has made some mistake in the observations he sent home, of the beginning and end of the Transit, as it was by him observed; at least I do not find the true times that he observed the different contacts faithfully entered in any of his books or papers; on the contrary I find them put down in two places, and different from each other, and neither the one nor the other are precisely the same as they were observed; the alterations that have been made will appear from the inclosed papers, and from them you will be able to judge how far it was reasonable to make such alterations, and this is the reason why I wish you to have the perusal of these papers before they are laid before the Royal Society ..."

Cook had yet another copy made "... of all or most of the observations relating to the Transit, that I know to be authentic, made by M^{r} Green, my self and others ..." (Cook, 1771b: 695), and on 11 July 1771, when the *Endeavour* reached England, he sent these plus all of Green's original papers to the Secretary of the Royal Society (ibid.).

The foregoing chronological narrative clearly reveals that at one time or another three copies of all of the Fort Venus, Irioa Island and Taaupiri Island transit observations were sent directly to the Royal Society or to Nevil Maskelyne, and that all of the original transit papers also were dispatched to the Royal Society once the *Endeavour* reached England. Yet despite searches in the Royal Society's archives and at other 'obvious' repositories such as the RGO Archives in Cambridge and the National Maritime Museum in Greenwich, none of these records seems to have survived. This is frustrating because it means that

> ... we cannot examine the original records to determine why Cook chose not to include contact times from the ancillary observing stations. Nor can we see what observations — if any — Molyneux contributed from Fort Venus, and how Green's various timings listed in the original records compare and contrast with those in the published paper. (Orchiston, 2005: 60).

Clearly, a further, more thorough, search for these all-important records is warranted.

6.2 Where Are the Instruments Now?

Like the records of the transit, most of the scientific instruments used during the Tahitian transit observations have disappeared, and the current whereabouts of very few of them is known with any degree of certainty.

Prior to his death, my friend and colleague the late Lieutenant-Commander Derek Howse (1919–1998), once Head of the Department of Navigation and Astronomy at the National Maritime Museum, Greenwich, was the undisputed authority on Cook voyage scientific instruments. He spent decades researching them, and in the process published a succession of papers and monographs, along with a handy biography of Astronomer Royal Nevil Maskelyne (Howse, 1989).

Although he had difficulty correlating extant telescopes, quadrants, sextants, clocks and chronometers in libraries, museums and private collections with specific Cook's voyage instruments, Howse (1979: 125) made a promising start by associating two Gregorian reflectors by Short lodged in the Science Museum, London, with the British 1769 transit of Venus expeditions. Although one of these has a Dollond micrometer, there is no proof that it was actually one of the two Short reflectors on the *Endeavour*. But if it was not, we are justified in assuming that it was remarkably similar—if not identical—in appearance. Therefore it is appropriate that we describe this telescope.

Gregorian reflector number 1900-136 (shown here in Figure 12) is on loan to the Science Museum from the Royal Society (which, as we have seen, supplied telescopes for the 1769 transit) and is inscribed with Short's serial number 44/1198 = 24. This code was deciphered by Baxandall during the 1920s, and the numerator refers to the serial number of the telescope of that aperture, the denominator gives the total number of telescopes made to that date, and the value after the equals sign indicates the focal length in inches (King, 1979: 87). This instrument therefore has a focal length of 24 inches (61 cm). Associated with this telescope is an object glass micrometer of the type described by Dollond in his 1754 paper.

Derek Howse (1979) also was able to attribute a second Short reflector in the Science Museum to the 1769 transit. This instrument (number 1939-389) was presented to the Museum by the Air Ministry, and the catalogue entry specifies that it was "Made by James Short c.1764". It is very similar in appearance and dimensions to the aforementioned Short telescope, and has a similar serial number (i.e. 42/1195 = 24). Stimson (1985) has established that originally the Royal Society and the Board of Longitude housed their scientific instruments in the same warehouse, where they were cared for by a single curator. As a result, the precise provenance of some of the instruments was lost. After the Board was abolished in 1828, what were thought to be its instruments were transferred to the Royal Navy, and during the 1840s the supposed Royal Society's instruments were relocated to the King's Observatory in Richmond Park. This Observatory subsequently was taken over by the British Association and then by the Air Ministry (for the Meteorological Office), which proceeded to transfer some instruments to the Science Museum (Howse, pers. comm., 1997). Given this historical chain of events, it is reasonable to associate this second Short reflector with the 1769 transit of Venus, but once again there is no proof that this was in fact one of the two instruments assigned to the *Endeavour*.

Unfortunately, the current whereabouts of Cook's own telescope—the 18-in Gregorian reflector made by Watkins—is unknown. After Cook died in Hawaii his property, including this telescope, was forwarded to Mrs Cook (Howse 1979). From all accounts, Elizabeth Cook (1742–1835; Figure 31)

> … was a hoarder, [and] the house in Clapham where she spent most of her widowhood, 'crowded and crammed in every room with relics, curiosities, drawings, maps, and collections'. Her will runs to more than ten pages of closely written script. It gives us an inkling of the many friends and relatives who were important in Elizabeth's life. As well as detaill-

> ing how her £60,000 should be distributed, the will also takes into account specific items—her husband's Copley Medal to the British Museum, the contents of the kitchen, washhouse and scullery to one of her servants, bedroom furniture to others. *Other items had already been distributed. Elizabeth lived long enough to see her husband pass into history, and knew the value of Cook memorabilia*. (Day, 2003, my italics; cf. Beaglehole, 1974: 690–695; Beddie, 1970).

Through into the late nineteenth century Cook memorabilia that can definitely be traced back to Mrs Cook and her sons and other Cook relatives would appear on the market, including the Mackrell Collection of 'ethnographic curiosities' that was acquired in 1887 by the New South

Figure 31: A portrait of Mrs Elizabeth Cook painted by William Henderson in 1830 (en.wikipedia.org).

Wales Government and ended up in the Australian Museum in Sydney (e.g. see Orchiston, 1972). I suspect that the Watkins reflector was one of the items donated by Mrs Cook, or her sons or other contemporary Cook relatives to a friend or relative, and it now lies forgotten in a private collection, waiting to be recognised!

As we have seen already, the only possible First Voyage telescope we have been able to track down is the 3-ft Gregorian reflector that probably was used by Solander at Fort Venus. This telescope, made by the London firm of Heath and Wing, now resides in The Museum of New Zealand Te Papa Tongarewa, in Wellington (see Orchiston 1999; 2005).

There is considerable confusion as to the current whereabouts of the Bird quadrant that journeyed to Tahiti on the *Endeavour*. Currently there are two virtually identical 12-inch Bird quadrants in the Science Museum, London (1900-138 and 1900-139), and both reputedly were associated with the British 1769 transit of Venus program. Both are owned by the Royal Society and were placed on long-term loan with the Museum in 1900. Documentation held by the Museum suggests that these two quadrants were made in about 1767, were used by Bailey at the North Cape and Dixon on the island of Hemmerfest, and are duplicates "... of the one provided by the Royal Society and used by Cook for observing the transit of Venus at Tahiti." Both of the telescopes have 1.9-cm objectives of 33-cm focal length, and the eyepiece end of the lower telescope is "… fitted with verniers, clamping screw and slow motion which traverses the limb which is divided into two scales one into 90° and the other 96°, according to Bird's method, each reading to 1' of arc ..." (Science Museum catalogue entry). Figure 16 shows one of these instruments.

In addition, there is a third Bird pillar quadrant in the Science Museum with a Cook-voyage attribution. This was donated to the Royal Astronomical Society in 1873 by a Dr W.T. Radford, and is listed in the catalogue of the Society's instrument collection as "Captain Cook's sextant [it is actually a quadrant], wooden frame; c. 1765; R [radius] = 18 in" (Howse, 1986: 224). No other information is available, and the Cook attribution is just that—an attribution only. This instrument was loaned to the Science Museum in 1908 (it now has a Museum number, 1908-159), and the display caption provides no further information, but it does place the date of manufacture at "... about 1772 ..." rather than 1765. It is important to stress that there are many items of reputed Cook voyage association with bogus or at best embellished histories (e.g. see Kaeppler, 1972), and until additional documentation of a more persuasive nature comes to light the imputed Cook origin of this quadrant must be treated as suspect.

Finally, as if to complicate matters further, Howse (1979) has reported the existence of another 30.5-cm Bird quadrant (catalogue number 1876-542), of unknown provenance, which is owned by the Science Museum but is on loan to the National Maritime Museum.

The saga of the Cook voyage time-keepers is only marginally better: to our knowledge, the First Voyage journeyman clock and the alarum clock have not survived (Howse and Hutchinson, 1969b), and a complicated history surrounds the five surviving Shelton astronomical clocks that reputedly were taken on Cook's three voyages to the Pacific:

> In the 1780s, the clocks became thoroughly mixed up, largely because the Board [of Longitude] and the [Royal] Society shared a warehouse and a storekeeper. It would not have been impossible at this time for the pendulums and even the movements of several clocks to have been cannibalised to produce one working clock. (Howse and Hutchinson, 1969b: 282).

Despite this, Howse and Hutchinson were able to tentatively identify the astronomical clocks now known as RS34 and RS35 with Cook's Second and Third Voyages, although they point out that it is not possible to exclude either the 'Royal Society Clock' or the 'Herstmonceux Clock' as possible contenders. However, the RS35 attribution seems sound, given the discovery of filled-in holes in the clock case which match those required for the attachment of the style of wooden tripod used on the Third Voyage (see Howse, 1969b). Indeed, in 1968 staff at the National Maritime Museum constructed and attached a replica of this tripod to RS35, and this is shown below in Figure 32.

Back in 1969 Howse and Hutchinson (1969b) had difficulty identifying the Shelton astronomical clock which went on the *Endeavour*, believing at the time that the 'KO Clock' at the Royal Observatory, Edinburgh (shown here in Figure 14) had the best claim. More recently, Howse and Murray (1997) confirmed this suspicion, stating that the Shelton regulator in question "... is almost certainly the one now preserved in the National Museum of Scotland in Edinburgh."

6.3 Daniel Solander's Astronomical Background and his Telescope

Daniel Solander is an astronomical enigma. He joined Banks' party and the *Endeavour* as a distinguished natural historian, not as an astronomer, yet he ended up at the principal transit station, armed with a substantially-larger Gregorian telescope than the two supplied by the Royal Society to the voyage's two official astronomers! And then, when the official account of the transit observations was published, he was the only person other than its authors, Cook and Green, to feature.

What little evidence there is (see Orchiston, 1999) suggests that Solander owned the Heath and Wing telescope himself—it was not owned by his friend and colleague Joseph Banks and simply loaned to him for the transit. Note that Banks is not known to have owned an astronomical telescope at this time, and that he did not wish to participate in the transit observations, even though he was present on Irioa Island at the time.

There is no evidence that Solander carried out any serious or systematic astronomical observations prior to Cook's First Voyage (Duyker, 1998), so it would appear that he purchased the Heath and Wing telescope specifically in order to observe the transit and that he was one of those tutored by Green on the trip out from England. Thus, by the time the *Endeavour* reached Tahiti he had acquired the requisite observing knowledge, skills and experience.

As we have seen, after the First Voyage Solander returned to his first passion, natural history, and there is no evidence to suggest that he continued to carry out astronomical observations. So it would appear that the 1769 transit of Venus was to be his first and last escapade in observational astronomy. Dedicated astronomers could only dream of observing a single astronomical event—albeit an important one like a transit of Venus—and then seeing their results included in a major paper that appeared in that most prestigious of scientific outlets, the *Philosophical Transactions of the Royal Society*!

Figure 32: Shelton astronomical clock RS35, showing the replica tripod support (courtesy: the late Derek Howse).

7 THE FIRST VOYAGE ASTRONOMICAL LEGACIES

One invaluable legacy of Cook's First Voyage is the official record of the astronomical observations that were made. Had circumstances been different, Green would have been responsible for preparing this, but his untimely death meant that its preparation devolved to William Wales (1734–1799), one of the two astronomers who accompanied Cook on his Second Voyage to the South Seas. Wales (Figure 33), who was

Figure 33: Pastel portrait of William Wales painted by J. Russell in 1894, now at Christ's Hospital, Horsham (photograph: Wayne Orchiston).

married to Charles Green's sister, was well qualified for this task as he was one of those who observed the 1769 transit of Venus from Hudson Bay. Beaglehole (1969: cxl) was impressed with Wales, in particular "... the breadth and play of his mind, his capacity for observation, his scientific exactitude, and his integrity as a man." After the *Resolution* returned to England in 1775, Wales and William Bayly (1737–1810), the other astronomer on the Second Voyage, worked together preparing the official astronomical account, and this was published two years later (Wales and Bayly, 1777). Only then could Wales devote himself to the task of preparing the First Voyage astronomical volume, but it was not until 1788 that *Astronomical Observations Made in the Voyages Which Were Undertaken By Order of His Present Majesty, for Making Discoveries in the Southern Hemisphere* ... rolled off the press. The full title goes on for several more lines and is truly astronomical in length! Part of the reason for the extraordinary delay in the publication of this volume was because Wales was obliged to also include the astronomical observations made during the earlier British Pacific voyages of Wallis and Byron. By the time Wales' weighty tome appeared, Bayly and James King (1750–1784) had already produced the Third Voyage official astronomical volume (Cooke, King and Bayly, 1782; note that this book includes a posthumous salute to Cook by including him among the authors, even if his name was spelt incorrectly)!

Another legacy of Cook's First Voyage is the monument at Point Venus (Figure 34) which now supposedly marks the site where the all-important 1769 transit observations took place.

Figure 34: The wrongly-positioned Point Venus monument in Tahiti (courtesy: the late Dr S. Murayama, Tokyo).

However, its position is wrong, and Beaglehole (1968: cxlii) laments the fact that it is some distance from the actual site of the fort, and on the wrong side of the river!

8 CONCLUDING REMARKS

The 3 June 1769 transit of Venus was the primary *raision d'etre* for Cook's First Voyage to the Pacific in the *Endeavour*, and despite his personal concern about the accuracy of the observations, the figure for the solar parallax, *P*, that Oxford University's Professor Thomas Hornsby derived from the Tahitian and other transit observations was remarkably similar to the currently accepted value. Yet despite this outcome, many unanswered questions remain relating to the fate of the various Tahitian records of the transit. Why were most of these not utilised in the official report on the transit published in the *Philosophical Transactions of the Royal Society*? What was Astronomer Royal Nevil Maskelyne's precise role in the preparation of this paper for publication? How were the discrepant contact values recorded by Green accommodated; and was Hornsby aware of this situation when he utilised the Tahitian transit observations in deriving his value for the solar parallax? These and other questions clearly warrant investigation, and currently are the focus of on-going research.

The success of this First Voyage led Cook to embark on to two further voyages to the Pacific, the first of these specifically to locate and chart the coast of the elusive 'Great Southern Continent' and the second to search for the postulated northwest passage between the Pacific and Atlantic Oceans. When the *Resolution* and *Discovery* reached England at the end of the latter voyage it brought ten years of Cook voyage astronomy to a successful close. Elsewhere I have summarised the substantial outcomes of these three voyages:

> Maritime astronomy had performed its task admirably: there were no shipwrecks, hundreds of islands had been placed on the world map, and thousands of miles of coastline had been charted. Three weighty astronomical tomes were published, and the future of the chronometer was assured. Matavai Bay cemented its place in Transit of Venus history, and Queen Charlotte Sound could boast the best-established latitude and longitude in the world after Greenwich. In the process, Cook, Bayly, Green, King and Wales all built on their already-respectable reputations, although two of these paid the ultimate price, losing their lives in the service of astronomy, King and country. For the British public, the terminal transit of a star like Cook was a particularly bitter pill to swallow. (Orchiston, 2004a: 35).

9 ACKNOWLEDGEMENTS

I am grateful to Drs Jonathan Betts and Gloria Clifton (formerly Royal Observatory, Greenwich), Dr Michael Fitzgerald, David Riley and Jennifer Twist (Museum of New Zealand Te Papa Tongarewa, Wellington), Dr Rebekah Higgitt (University of Kent, England), the late Commander Derek Howse (formerly National Maritime Museum, Greenwich), Dr Stephen Johnston (Museum of the History of Science, Oxford University), Katherine Marshall (the Royal Society, London), the late Sir Patrick Moore (Selsey, England) and the late Dr Sadao Murayama (formerly, Gotoh Planetarium and Astronomical Museum, Tokyo) for their assistance. I also wish to thank the Museum of History of Science, Oxford, Museum of New Zealand Te Papa Tongarewa and Royal Society for kindly supplying Figures 11, 12, 15 and 16. Finally, I am grateful to Dr Gloria Clifton, Professor Nick Lomb, Martin George (NARIT, Thailand) and Associate Professor Russell McGregor for reading and commenting on the MS.

10 REFERENCES

Admiralty, 1768. Letter to Lieut. James Cook, dated 25 May. Original in the Public Record Office, London (Adm 2/94). Abstract in Beaglehole, 1968, 609.

Anderson, F., 2000. *Crucible of War: The Seven Years' War and the Fate of Empire in British North America, 1754–1766*. London, Faber and Faber.

Andrews, A.D., 1992. Cyclopaedia of telescope makers. *Irish Astronomical Journal*, 20, 102–183.

Andrews, A.D., 1996. Cyclopaedia of telescope makers. Part 5 (Sae–Sim). *Irish Astronomical Journal*, 23, 57–117.

Andrews, A.D., 1997. Cyclopaedia of telescope makers. Part 7 (T–Z). *Irish Astronomical Journal*, 24, 125–192.

Badger, G.M., 1970. Cook the scientist. In Badger, G.M. (ed.). *Captain Cook. Navigator and Scientist*. Canberra, Australian National University Press. Pp. 30–49.

Banks, n.d. Transactions of the Royal Society relative to the sending out people to observe the transit of Venus in 1769. Original in the National Library of Australia, Canberra. Reprinted in Beaglehole, 1968, 511–514.

Baugh, D., 2011. *The Global Seven Years War, 1754–1763.* Upper Saddle River, Pearson Press.

Beaglehole, J.C. (ed.), 1963. *The Endeavour Journal of Joseph Banks*. Two Volumes. Sydney, Angus and Robertson.

Beaglehole, J.C. (ed.), 1967. *The Journals of Captain James Cook on His Voyages of Discovery. III. The Voyage of the* Resolution *and* Discovery *1778–1780*. Cambridge, Cambridge University Press.

Beaglehole, J.C. (ed.), 1968. *The Journals of Captain James Cook on His Voyages of Discovery. I. The Voyage of the* Endeavour *1768–1771*. Cambridge, Cambridge University Press.

Beaglehole, J.C. (ed.), 1969. *The Journals of Captain James Cook on His Voyages of Discovery. II. The Voyage of the* Resolution *and* Adventure *1772–1775*. Cambridge, Cambridge University Press.

Beaglehole, J.C., 1974. *The Life of Captain James Cook*. London, Hakluyt Society.

Beddie, M.K. (ed.), 1970. *Bibliography of Captain James Cook R.N., F.R.S., Circumnavigator*. Sydney, Trustees of the Public Library of New South Wales.

Betts, J., 1993. The eighteenth century transits of Venus, the voyages of Captain James Cook and the early development of the marine chronometer. *Antiquarian Horology*, 21, 660–669.

Betts, J., 2006. *Time Restored: The Harrison Timekeepers and R.T. Gould, the Man who Knew (Almost) Everything*. Oxford, Oxford University Press.

Bird, J., 1768. *The Method of Constructing Mural Quadrants*. London, Richardson and Clark.

Bliss, N., 1761. Observations of the transit of Venus over the Sun, on the 6th of June 1761 … *Philosophical Transactions of the Royal Society*, 52, 173–177.

Bonhams Auction Catalogue, 2006. [Lot) 85 An important and very rare third quarter of the 18th century month going longcase [John Shelton] regulator now in a modern replica case (http://www.bonhams.com/auctions/14228/lot/85/).

Bryden, D.I., 1968. *James Short and His Telescopes*. Edinburgh, Royal Scottish Museum.

Chapman, A., 1983. The accuracy of angular measuring instruments used in astronomy between 1500 and 1850. *Journal for the History of Astronomy*, 14, 133–137.

Chapman, A., 1995. *Dividing the Circle. The Development of Critical Angular Measurement in Astronomy 1500–1850*. Chichester, John Wiley.

Clifton, G., 1995. *Directory of British Scientific Instrument Makers 1550–1851*. London, Zwemmer and the National Maritime Museum.

Cook, J. 1767. An observation of an eclipse of the Sun at the island of New-found-land, August 5, 1766. *Philosophical Transactions of the Royal Society*, 57, 215–216.

Cook, J. 1768. Letter to the Admiralty Secretary, dated 27 July. Original in the Public Record Office (Adm 1/1609). Reprinted in Beaglehole, 1968, 621.

Cook, J. 1770. Letter to the Admiralty Secretary, dated 23 October. Original in the Mitchell Library. Reprinted in Beaglehole, 1968, 499–501.

Cook, J. 1771a. Letter to Nevil Maskelyne, dated 9 May. In the Royal Society Council Minutes of 11 July 1771. Reprinted in Beaglehole, 1968, 692–694.

Cook, J. 1771b. Letter to the Secretary of the Royal Society, dated 11 July. In the Royal Society Council Minutes of 25 July 1771. Reprinted in Beaglehole, 1968, 694–695.

Cooke, J. [*sic*.], King, J., and Bayly, W., 1782. *The Original Astronomical Observations Made in the Course of a Voyage to the Northern Pacific Ocean, For the Discovery of a North East or North West Passage* ... London, Elmsly.

Day, M., 2003. *Mrs Cook: The Real and Imagined Life of the Captain's Wife*. Allen and Unwin.

Deptford Yard Officers 1768a. Letter to the Navy Board, dated 27 March. Original in the Public Record Office, London (Adm 106/3315). Abstract in Beaglehole, 1968, 606.

Deptford Yard Officers 1768b. Letter to the Navy Board, dated 7 October. Original in the Public Record Office, London (Adm 106/3315). Abstract in Beaglehole, 1968, 624.

Dick, S.J., Orchiston, W., and Love, T., 1998. Simon Newcomb, William Harkness and the nineteenth century American transit of Venus expeditions. *Journal for the History of Astronomy*, 29, 221–255.

Dollond, J., 1753. A description of a contrivance for measuring small angles. *Philosophical Transactions of the Royal Society*, 48, 178–181.

Dollond, J., 1754. An explanation of an instrument for measuring small angles … *Philosophical Transactions of the Royal Society*, 48, 551–564.

Douglas, J. n.d. Hints offered to the consideration of Captain Cooke, Mr Bankes, Doctor Solander, and the other Gentlemen who go upon the Expedition on Board *Endeavour*. Original in the National Library of Australia, Canberra. Reprinted in Beaglehole, 1968, 514–516.

Duyker, E., 1998. *Nature's Argonaut: Daniel Solander 1733–1782: Naturalist and Voyager with Cook and Banks*. Melbourne, Melbourne University Press.

Ellis, F., 1932. Letter to an unspecified Portsmouth antique dealer, dated 18 January. Original in the Archives of the Museum of New Zealand Te Papa Tongarewa (MU000002/067/0002; History: Cook's Relics deposited and presented; 1914-1975; paper).

Fowler, W.H.., 2005. *Empires at War: The Seven Years' War and the Struggle for North America*. Vancouver, Douglas & McIntyre.

Garnsey, Edward Rock (1864–1935). *Sydney Morning Herald*, 10 May 1935, page 17.

Gilbert, L.A., 1967. Solander, Daniel (1733–1782). In *Australian Dictionary of Biography*. *Volume Two*. Melbourne, Melbourne University Press.

Gould, J.A., 1976. John Bird: the astronomer's instrument maker (1709–1776). *Journal of the British Astronomical Association*, 86, 485–486.

Green, C., 1768–1770. Log-Journal. MS, PRO (Adm 51/4545/151).

Green, C., and Cook, J., 1771. Observations made, by appointment of the Royal Society, at King George's Island in the South Seas. *Philosophical Transactions of the Royal Society*, 61, 397–421.

Hawkesworth, J., 1774. *Relation des Voyages Entrepris par Ordre de Sa Majesté Britannique* … Paris.

Hellman, C.D., 1932. John Bird (1709–1776) mathematical instrument-maker in the Strand. *Isis*, 17, 127–153.

Herdendorf, C.E., 1986. Captain James Cook and the transits of Mercury and Venus. *Journal of Pacific History*, 21, 39–55.

Higgitt, R., 2010. Charles Green, Royal Observatory Greenwich Assistant and stand-in Astronomer Royal. London, Royal Museums Greenwich (http://blogs.rmg.co.uk/ontheline/2010/09/03/charles_green_royal_observator/).

Hornsby, T., 1765. On the transit of Venus in 1769. *Philosophical Transactions of the Royal Society*, 55, 326–344.

Hornsby, T., 1771. The quantity of the Sun's parallax ... *Philosophical Transactions of the Royal Society*, 61, 574–579.

Howse, D., 1969a. Captain Cook's minor clocks and watches. In Howse and Hutchinson, 1969a, 138–145.

Howse, D., 1969b. Captain Cook's pendulum clocks. In Howse and Hutchinson, 1969a, 62–76.

Howse, D., and Hutchinson, B., 1969a. *The Clocks and Watches of Captain James Cook 1769–1969*. London, The Antiquarian Horological Society.

Howse, D., and Hutchinson, B., 1969b. The saga of

the Shelton clocks. In Howse and Hutchinson, 1969a, 281–298.
Howse, D., 1979. The principal scientific instruments taken on Captain Cook's voyages of exploration, 1776–80. *Mariner's Mirror*, 65, 119–135.
Howse, D., 1986. The Royal Astronomical Society Instrument Collection: 1827–1985. *Quarterly Journal of the Royal Astronomical Society*, 27, 212–236.
Howse, D., 1989. *Nevil Maskelyne. The Seaman's Astronomer*. Cambridge, Cambridge University Press.
Howse, D., 1993. Charles Green (1734–1771). In *The Dictionary of National Biography: Missing Persons*. Oxford, Oxford University Press. P. 269.
Howse, D., and Murray, A., 1997. Lieutenant Cook and the transit of Venus, 1769. *Astronomy & Geophysics*, 38(4), 27–30.
Johnston, S., 2005. Blast from the past. Measurement and morals in the early transit of Venus. Museum of the History of Science, Oxford University (www.physics.ox.uk/phystat05/Talks/johnston.ppt).
Kaeppler, A., 1972. The use of documents in identifying ethnographic specimens from the voyages of Captain Cook. *Journal of Pacific History*, 7, 195–200.
King, H.C., 1979. *The History of the Telescope*. New York, Dover.
Kippis, A., 1788. *The Life and Voyages of Captain James Cook*. London, George Newnes (the lengthy footnote about Charles Green is in Volume 1, on pages 176–178).
Kurtz, D.W. (ed.), 2005. *Transits of Venus: New Views of the Solar System and the Galaxy*. Cambridge, Cambridge University Press.
Lloyd, C., 1968. *The British Seaman 1200–1860. A Social Survey*. London, Paladin.
Marshall, J.B., 1977. Daniel Solander. In Cook, J. *The Journal of H.M.S. Resolution*. Guildford, Genesis Publications. Pp. 49–60.
Marston, D., 2001. *The Seven Years War.* Oxford, Osprey.
Maskelyne, N., 1764. Astronomical observations made at the island of St. Helena. *Philosophical Transactions of the Royal Society*, 54, 348–349.
Molyneux, R. 1769. Remarks in Port Royal Bay in King George the thirds Island. Original in the Public Record Office (Adm 55/39). Reprinted in Beaglehole, 1968, 551–564.
Moore, P., 1977. Cook, Green and the transit of Venus. In Cook, J. *The Journal of the Endeavour 1768–1771*. Guildford, Genesis Publications. Pp. 61–69.
Morris, M., 1980. Charles Green – man without a face [Part 1]. *Cook's Log*, 3(4), 92.
Morris, M., 1981. Charles Green – man without a face [Part 2]. *Cook's Log*, 4(1), 102.
Orchiston, W., 1972. Maori greenstone pendants in the Australian Museum. *Records of the Australian Museum*, 28(10), 161–213.
Orchiston, W. 1998a. From the South Seas to the Sun. The astronomy of Cook's voyages. In Lincoln, M. (ed.). *Science and Exploration in the Pacific. European Voyages to the Southern Oceans in the 18th Century*. Woodbridge, Boydell Press, in association with the National Maritime Museum. Pp. 55–72.
Orchiston, W., 1998b. *Nautical Astronomy in New Zealand. The Voyages of James Cook*. Wellington, Carter Observatory (Occasional Papers No. 1).
Orchiston, W. 1999. Cook, Banks and the Gregorian telescope in The Museum of New Zealand Te Papa Tongarewa. *Journal of the Antique Telescope Society*, 18, 4–9.
Orchiston, W., 2004a. The astronomical results of Cook's voyages. In Robson, J. (ed.). *The Captain Cook Encyclopaedia*. London, Chatham Publishing. Pp. 31–35.
Orchiston, W., 2004b. The nineteenth century transits of Venus: an Australian and New Zealand overview. *Journal of Astronomical Data*, 10, 219–308.
Orchiston, W., 2005. James Cook's 1769 transit of Venus expedition to Tahiti. In Kurtz, 51–66.
Orchiston, W., 2016. *Exploring the History of New Zealand Astronomy: Trials, Tribulations, Telescopes and Transits*. Cham, Springer.
Parkinson, S., 1784. *A Journey of a Voyage to the South Seas, in His Majesty's Ship*, The Endeavour. London, printed for Stanfield Parkinson.
Pasachoff, J., Schneider, G., and Golub, L., 2005. The black-drop effect explained. In Kurtz, 242–253.
Paulding, B., 2000. Charles Green astronomer. *Cook's Log*, 23, 1713.
Pickersgill, R., 1769–1770. Journal. MS in the National Archives (Kew): Adm 51/4547/141.
Prowse, D.W., 1896. *A History of Newfoundland from the English, Colonial, and Foreign Records*. *Second Edition*. London, Eyre and Spottiswoode.
Relton, H., 1918. Letter to Major S. Maxwell, F.R.S., London, dated March. Typescript copy in the Archives of the Museum of New Zealand Te Papa Tongarewa (MU000002/067/0002; History: Cook's Relics deposited and presented; 1914-1975; paper).
Ritchie, G.S., 1978. Captain Cook's influence on hydrographic surveying. *Pacific Studies*, 1, 78–95.
Robertson, G., 1948. *The Discovery of Tahiti; A Journal of the Second Voyage of H.M.S. Dolphin Round the World Under the Command of Captain Wallis, R.N., in the Years 1766, 1767, and 1768, Written by her Master*. Edited by Hugh Carrington. London, Haklyut Society.
Schaefer, B.E. 2001. The transit of Venus and the notorious Black Drop Effect. *Journal for the History of Astronomy*, 32, 325–336.
Shelton, J., n.d. Directions to set up the Regulator. Copy, Museum of the History of Science, Oxford University.
Short, J., 1764. Observation of the eclipse of the Sun, the 1st of April 1764, made in Surry Street, in the Strand, London. *Philosophical Transactions of the Royal Society*, 54, *107–*108, 105.
Skelton, R.A., 1954. Captain James Cook as a hydrographer. *Mariner's Mirror*, 40, 92–119.
Sobel, D, 1995. *Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time*. New York, Penguin.
Stimson, N., 1985. Some Board of Longitude instruments in the nineteenth century. In de Clercq, P.R. (ed.). *Nineteenth-Century Scientific Instruments and their Makers*. Leiden, Museum Boerhaave. Pp. 93–115.
Turner, G.L'E., 1969. James Short, F.R.S., and his contribution to the construction of reflecting telescopes. *Notes and Records of the Royal Society*, 24, 91–108.

van Gent, R.H., 2005. Observations of the 1761 and 1769 transits of Venus from Batavia (Dutch East Indies). In Kurtz, 67–73.

van Helden, A., 1995. 'Measuring solar parallax: the Venus transits of 1761 and 1769 and their nineteenth century sequels.' In Taton, R., and Wilson, C. (eds.). *The General History of Astronomy. Volume 2. Planetary Astronomy from the Renaissance to the Rise of Astrophysics. Part B: The Eighteenth and Nineteenth Centuries*. Cambridge, Cambridge University Press. Pp.153–168.

Villiers, A., 1971. *Captain Cook, the Seaman's Seaman*. *A Study of the Great Discoverer*. Harmondsworth, Penguin.

Waldersee, J., 1969. Sic transit: Cook's observations in Tahiti, 3 June 1769. *Journal of the Royal Australian Historical Society*, 55, 113–123.

Wales, W., and Bayly, W., 1777. *The Original Astronomical Observations, Made in the Course of a Voyage towards the South Pole, and Round the World* ... London, Strahan.

Wales, W., 1788. *Astronomical Observations, Made in the Voyages Which were Undertaken by Order of His Present Majesty, for Making Discoveries in the Southern Hemisphere* ... London, Elmsly.

Wales, Wendy, 2008. Researching Charles Green after Kippis. *Cook's Log*, 31(1), 32,

Wallis, R., 2008. Hornsby, Thomas (1733–1810). In *Oxford Dictionary of National Biography*. Oxford, Oxford University Press.

Watt, Sir James, 1979. Medical aspects and consequences of Cook's voyages. In Fisher, R., and Johnston, H. (eds.). *Captain James Cook and His Times*. Canberra, Australian National University Press. Pp. 129–157.

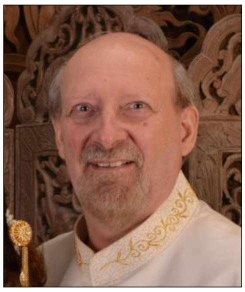
Wood, G.A., 1926. *The Voyage of the Endeavour*. Melbourne, Macmillan and Co. (Gutenburg Australia e-Book).

Woolf, H., 1959. *The Transits of Venus: A Study in the Organization and Practice of Eighteenth-Century Science*. Princeton, Princeton University Press.

Wulf, A., 2012. *Chasing Venus. The Race to Measure the Heavens*. New York, Alfred A. Knopf.

Zuidervaart, H.J., and van Gent, R.H., 2004. "A bare outpost of learned European culture on the edge of the jungles of Java". Johan Maurits Mohr (1716–1775) and the emergence of instrumental and institutional science in Dutch colonial Indonesia. *Isis*, 95, 1–33.

Professor Wayne Orchiston has a Ph.D. from the University of Sydney and is a Senior Researcher at the National Astronomical Research Institute of Thailand and an Adjunct Professor of Astronomy at the University of Southern Queensland (Australia). Wayne has wide-ranging research interests and has published extensively on Cook voyage astronomy



and the 1874 and 1882 transits of Venus, as well as on historic telescopes and observatories, cometary and asteroidal astronomy, solar eclipses and the early development of solar physics, Maori astronomy and the early history of radio astronomy in Australia, France, Japan, New Zealand and the USA. In 1998 Wayne co-founded the *Journal of Astronomical History and Heritage*, and is now the Editor. Currently, Wayne is Vice-President of IAU Commission C3 (History of Astronomy), and he founded the IAU Working Group on Transits of Venus, which ran from 2000 to 2015. In 2013 the IAU named minor planet 48471 Orchiston after him.