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Eise Eisinga and his planetarium

Jolanda Mulder de Ridder
AIM, University of Western Sydney, NSW, Australia
Address for correspondence: rojomulder@wanadoo.nl

Abstract
During the eighteenth century, the intellectual climate of the Dutch Republic was very much influenced by the Enlightenment and Newtonian principles, and the province of Friesland had quite a number of amateur astronomers. One of these was Eise Eisinga, who in his youth wrote four manuscripts on mathematics and astronomy and later in life constructed a remarkable mechanical model of the solar system on the ceiling of his living room in the city of Franeker. Professor Van Swinden visited this planetarium while it was still under construction and was so impressed that he published a thorough description of it. As a result, it became well known throughout Europe and attracted many visitors. The State officially purchased Eisinga's house and planetarium in 1825, guaranteeing its survival and long-term preservation. Today Eisinga's legacy is the oldest operational mechanical planetarium in the world, and its accuracy is such that adjustments hardly ever need to be made.

Keywords: *Eise Eisinga, planetarium, orrery, Netherlands*

1 INTRODUCTION

When William Herschel discovered the planet Uranus in 1781, a Dutch wool-comber named Eise Eisinga (1744-1828) had just completed a remarkable 'planetarium' in the Friesland town of Franeker (for localities mentioned in the text see Figure 1). This was not a planetarium in the sense that the term is used today, but a scale model of the solar system that Eisinga constructed between 1774 and 1781 in the living room of his seventeenth century canal-side home (Figure 2). To this day, Eisinga's planetarium is still operational, making it the oldest fully-functioning mechanical planetarium in the world, and as a result of King's book, *Geared to the Stars ...* (1978) and a number of recent more popular articles also written in English (see Allen-Wytzes, 1994; Rudd, 1999; Schilling, 1994) it is becoming widely known in the international astronomical community.

In this paper we provide biographical material on Eise Eisinga, and describe in detail his unique mechanical planetarium. But in order to provide a context for this study we begin by describing the intellectual climate in the Dutch Republic, and the cultivation of astronomy in the Dutch province of Friesland during the eighteenth century. Our account of Eisinga and his planetarium draws heavily on two particular books. One was first published by Van Swinden in 1780 and provides a detailed description of the planetarium (see Van Swinden, 1994), and the second is an account of the life of Eise Eisinga by Eekhoff published in 1851. All later books, brochures and articles written about Eisinga and his planetarium are based on these two books, but our description of the planetarium and its accuracy also draws on an account written by Eisinga as an instruction manual for his sons so that they could keep the planetarium operating successfully (see Noordmans, 1997). In this paper we also focus on the sale of the planetarium to the State, and largely base our account on primary sources, but particularly the letters, recommendations and decrees in the Algemeen Rijksarchief (General State Archive) in The Hague.

2 THE DUTCH SCIENTIFIC CLIMATE IN THE EIGHTEENTH CENTURY

2.1 A Short Historical Overview

The intellectual climate in Europe during the eighteenth century was very much influenced by the Enlightenment (see Grijzenhout, Mijnhardt, and Van Sas, 1987; Israel, 1995, 2001; Kloek, and Mijnhardt, 2001; Zwager, 1980). The increase of religious persecution in France reached its peak in 1685 when the Edict of Nantes was cancelled, and this lead to an enormous exodus of Huguenots who sought refuge in, among other places, the Dutch Republic. These immigrants debated on the role and meaning of the church, the State, and tolerance. But the majority of intellectuals in the Republic were hardly interested in these discussions, for in the Republic these kinds of problems had long been solved (Grijzenhout, Mijnhardt, and Van Sas, 1987). Tolerance, civilian protection by law, and a reasonable penalty were already established in the Republic. But of course scholars in the Republic were interested in the ideas of the early phase of the Enlightenment. The debate on the friction between ratio and religion was a very current one (ibid.).

Figure 1: Dutch localities mentioned in the text.

When the young lawyer Willem Jacob 's-Gravensande returned from England in 1717 and was appointed lecturer of mathematics and astronomy in Leiden, he brought Newton's ideas with him. The text books that 's-Gravensande wrote were based on the Newtonian approach, and spread the new method throughout the Republic. Of great significance was his book, *Physices Elementa Mathematica, Experimentis Confimata. Sive Introductio ad Philosophan Newtonianam (Mathematical Foundations of Physics, Tested by Experiments. With an Introduction to Newtonian Philosophy)*, which was reprinted and translated many times and quickly found its way across mainland Europe (see Zuidervaart, 1999). Together with Jan van Musschenbroek, 's-Gravensande also developed a set of instruments with which to demonstrate Newtonian physics, and by the time that Jan's brother, Petrus van Musschenbroek, returned to Leiden to lecture at Leiden University Newtonianism was well established (ibid.). But the Dutch philosophical climate was eclectic and pragmatic, and so the universities taught Aristotelian views as well as Cartesian and Newtonian ideas (Grijzenhout, Mijnhardt, and Van Sas, 1987). Outside the universities, through publications and lectures by Daniël Gabriël

Fahrenheit, John Theophilus Desaguliers, and others, more and more people became acquainted with the new investigational science. But these were mostly well-to-do people, and only a very small percentage of the overall population heard about the latest scientific developments (ibid.).

However, in the beginning of the eighteenth century books gradually began to appear in Dutch, and in the second half of the century it was quite normal to publish books and brochures in Dutch as well as in Latin. The version in Latin was usually intended for export to foreign countries, where books written in Latin were still widely read (Kloek, and Mijnhardt, 2001). But the use of Dutch as a scientific language was not common to all sciences. Theology, for instance, cherished the old ideal of science as a closed community of scholars, which could be maintained by the use of Latin. But in the natural sciences this concept was completely out of date. The barrier between scientists and laymen rapidly became smaller and smaller, and skilled craftsmen appeared in all kinds of scientific areas (ibid.). Science here was no longer a closed territory, and in the end the boundaries between scientist and layman slowly disappeared.

Figure 2. A view of Eisinga's house from the street (after *Eisinga Planetarium* ..., n.d.: facing 1).

2.2 Astronomy in Friesland

Friesland has been home to many amateur astronomers over the centuries. The oldest report on this topic dates back from the thirteenth century and concerns a certain Valerius Camga, who is said to have been an exceptional astronomer (Louwman, and Terpstra, 1994). Another report dates from 1374 and concerns the monk Hermanus, who taught metaphysics, philosophy, calculation, and mathematics at the Monastery of the Fratres Minores in Bolsward, and was also a gifted astronomer (ibid.).

In the seventeenth and eighteenth centuries the study of astronomy was strongly influenced by the Franeker High School (1585-1811) (ibid.). For more than 250 years, Franeker had an institution for higher education, first a University and later an Athenaeum (see Ekkart, n.d.), and because of this the town was able to play an important role in the Frisian, Dutch, and international scientific and cultural community. With the publication of astronomical books and the education of teachers, surveyors, and other professionals, large transfers of knowledge took place, and the study of astronomy among self-educated men also thrived (ibid.). Friesland had a large number of telescope-makers, and two-thirds of all reflecting telescopes in the Republic in the late eighteenth century were of Frisian manufacture (Zuidervaart, 1999). In addition, many Frisians computed eclipses, and a Franeker University professor, Cornelis Ekama, even stated that Frisians had a special innate talent for mathematics (Kloek, and Mijnhardt, 2001; Zuidervaart, 1999). This led to a 'scientific fiasco' in 1817 when King Willem I gave two self-taught Frisian telescope-makers, Arjen Roelofs and Sieds Johannes Rienks, an order for some large telescopes. Grinding a 550-mm parabolic mirror proved too difficult for them, although they did complete some smaller mirrors. But their finished telescopes, while beautiful works of art, were by no means suited for astronomical observation. The telescope they manufactured for the Leiden Observatory was used just once and was later, in 1850, sold as scrap, while the telescope intended for the Utrecht Observatory was displayed at an exhibition in Haarlem, where it stayed for fifteen years, and when it finally reached Utrecht it was never used. The Utrecht astronomers claimed there were inaccuracies in the mirror that could even be seen with the unaided eye, and shortly afterwards the telescope was abandoned (De Jager, Van Bueren, and Kuperus, 1993; Zuidervaart, 1999).

Even though a lot of amateur astronomers lived in Friesland, the majority of the population had outmoded and peculiar ideas about the orbits of celestial objects, so special celestial events were often cause for concern. Furthermore, religious conscientiousness only intensified people's fear of the horrible consequences that God would bring down in judging the sins of mankind. This would have been the case on 1774 May 8, when Jupiter, Mars, Venus, Mercury, and the Moon were together in Aries at the same time, and an author who called himself 'liefhebber der waarheid' (lover of the truth) wrote a small book with the long and sensational title, *Godgeleerde en Philosophische Bedenkingen over de Conjunctie van de Planeten Jupiter, Mars, Venus, Mercury en de Maan, op den Agsten May Staande te Gebeuren en wel over de Mogelijke en Waarschijnlijke Sterre- en Natuurkundige Gevolgen Deezer Conjunctie, waaruit Opgemaakt kan worden, dat die niet alleen Invloed kan hebben op Onzen Aardbol, maar ook op het Ganze Zonnestelsel, Waartoe Wij Behooren, en eene Voorbereiding of een Beginmaking van de Ontsloping of Vernieling van Hetzelfde, ten Deele of Geheel zou kunnen zijn*. This translates in English as: *Philosophical Considerations about the Conjunction of the Planets Jupiter, Mars, Venus Mercury and the Moon, to Take Place on the Eighth of May 1774, Especially about the Possible and Probable Astronomical and Physical Consequences of this Conjunction from which may be Deduced that they will not only Influence our Earth, but also the Complete Solar System to which We Belong and that they Might be a Preparation or a Commencement of the Demolishing or Destruction of the Same*. The author's real name was Eelco Alta and he was a preacher in Bozum. He stated that this conjunction could have a pernicious influence on not only the Earth but also on the whole solar system, to the point where this could be a preparation for the destruction of the universe (Eekhoff, 1851). He believed that this celestial spectacle most likely foreshadowed the approach of the Day of Judgement. As soon as this booklet was made public all kinds of prophecies were made, among them predictions that the Earth would certainly be destroyed on 1774 May 8. This was, of course, cause for major concern among the population, which was added to by local printers and by travelling bards who sang about the upcoming end of the world (ibid.). Eventually things got so out of hand that the Government had to interfere and confiscate the books and jail the bards. To reassure the population, the Government then had an expert prepare a notice for the provincial newspaper, the *Leeuwarder Courant*, stating that nothing untoward would happen on that day except for the sight before dawn (and only if the weather was clear) of the four planets and the Moon in the same region of the sky. Moreover, this astronomical event would have no effect whatsoever on happenings here on Earth (ibid.).

At this time Eise Eisinga was an amateur astronomer in Franeker, and he was so annoyed and concerned that this kind of superstitious nonsense could thrive among his countrymen that he decided to build a clock-driven planetarium that would clearly demonstrate that planetary conjunctions and close groupings have no supernatural significance but were merely the result of the physical structure of the solar system. This decision was to make him one of Friesland's most famous astronomers.

3 EISE EISINGA: A BRIEF BIOGRAPHY

The following account draws heavily of the book about Eisinga and his planetarium that was published by Eekhoff in 1851. Eise Eisinga (Figure 3) was born on 1744 February 21 in Dronrijp, a small village about 10 km west of Leeuwarden in the province of Friesland. He went to the Dronrijp primary school for a few years and was then educated in his father's

Figure 3. Portrait of Eise Eisinga, painted in 1827 by Willem Bartel van der Kooi (after *Eisinga Planetarium* ..., n.d.:7).

business. Eise's father was a wool-comber by profession, but he had a keen interest in mathematics and astronomy and a knowledge of mechanics, and practised these disciplines for a hobby. Among other things, he built sundials. From an early age Eise also showed an aptitude for mathematics and astronomy, and once a week he went to Franeker where he studied Euclid's first six books and the eleventh and twelfth books with a wool-dyer named Willem Wijtses. Together they also studied spherical trigonometry, the structure of the solar system, the use of astronomical tables, and the computation of eclipses. Apart from this schooling, which was far from flawless, Eise never received any form of higher education.

In the years 1759 and 1760 Eise compiled a 665-page manuscript on computation, even though he was not yet seventeen years of age when he finished it. This contained chapters on the fundamentals of calculation and on geometry, and of special interest was a chapter on decimal fractions, which were not very often used in those days. The manuscript also included many illustrations, including figures of barrels and towers, which were in Eisinga's hand. All this work was done in his spare time, because during the day Eisinga had to work in his father's business.

Then Eisinga met the famous Frisian mathematician, astronomer, and instrument-maker, Wytse Foppes Dongjuma (1707-1778) of Leeuwarden, who was to have an important influence on his further development. Foppes was the son of a humble carpenter, and he, too, had received little serious education, but he applied himself to mathematics and astronomy and became very accomplished at constructing mathematical instruments. In 1761 June there would be a transit of Venus and Foppes had constructed instruments with which he hoped to accurately observe and measure this event. He received permission to make his observations from the abandoned castle Camminghaburg near Leeuwarden, and Eisinga was allowed to be present at the time – which only served to increase his interest for astronomy even more.

Like his father, seventeen year old Eisinga kept devising and manufacturing sundials, and each year he also prepared monthly tables to help him find planets more easily during his observations. He did not know that professional astronomers in Europe did the very same thing in order to popularize astronomy. In 1762 Eisinga wrote two more manuscripts, *Gnomonica of Sonnewijsers alle door Passer en Lijnjaal afgepast Op De Noorder Breete van Dronrijp* (*Gnomonica or Sundials, all Measured out by Compass and Ruler on the North Latitude of Dronrijp*) and *Grondbeginselen der Astronomie of Starre-loopkunde op een Theoretische Wijze Verhandelt* (*Fundamentals of Astronomy Treated in a Theoretical Manner*). At the end of that same year he started working on a fourth manuscript that he finished in 1763. In this new manuscript he computed and drew every solar and lunar eclipse from 1762 to 1800 (*Eisinga Planetarium* ..., n.d.).

In 1768, at the age of 24, Eisinga married Pietje Jacobs, and they moved to Franeker, to the seventeenth century house called 'De Ooijevaar' (The Stork), where he started his own wool-combing business. Franeker was an important university town, but wool-combing then was the main trade and through hard work a lot of money could be made. Eisinga and his wife had their first child in 1773, but the little girl died within a month. The following year a boy, Jelte (1774-1809), was born, and ten years later, on 1784 March 7, another boy was born. His name was Jacobus (1784-1858), and he would later follow in his father's footsteps.

Eisinga led a relatively quiet life and was not involved in any business other than wool-combing, although he was appointed to a number of municipal posts. However, his main love was astronomy, and he devoted every spare moment to his planetarium, yet he made no attempt to contact others in Franeker who shared his astronomical interests. With the passage of time Eise Eisinga's name became well known throughout the Dutch Republic and by the time he died, on 1828 August 27 at the age of 84, he was quite a celebrity. He was buried in Dronrijp, in a family grave.

4 CONSTRUCTION AND USE OF THE PLANETARIUM

The book about Eisinga and his planetarium that was published by Eekhoff in 1851 also gives a lot of information about the construction and use of the planetarium. The following account, therefore, draws heavily on this book.

As the 1774 May 8 quadruple planetary conjunction approached and word on the street was that the world would come to an end panic broke out among Frisians. But Eisinga realized that there was nothing to fear, and he regretted the ignorance and superstition of the local people. He had already rejected Ptolemy's and Brahe's views and accepted the Copernican cosmovision, and was amazed that most people still believed the Earth to be the centre of the solar system with the Sun and the planets revolving around her. He wished to take away the fear among his fellow Frisians and decided to build an instrument that would show the true movement of the planets and the harmlessness of these conjunctions. But the instrument had to be simple, so that everyone could understand it, and he settled on a planetarium, a mechanical scale model of the solar system with the planets revolving around the Sun. At that time most planetariums were table-top models, but instead Eisinga opted for a large-scale moving model of the solar system attached to the ceiling of his living room!

The construction of the planetarium would take about seven years according to Eisinga's calculations, and after convincing his wife of his plan he started work. She insisted that the project should take no more than seven years, and that the drive-clock and all the wheelwork should be hidden from view. Eisinga had never seen a planetarium nor read any of the books about them, but he began making the necessary calculations and drawings (see Figure 4). His father made some shafts and wheels on his lathe and a clockmaker constructed four brass clockworks, based upon Eisinga's plans, but everything else, including the forging of ten thousand iron nails, Eisinga did himself.

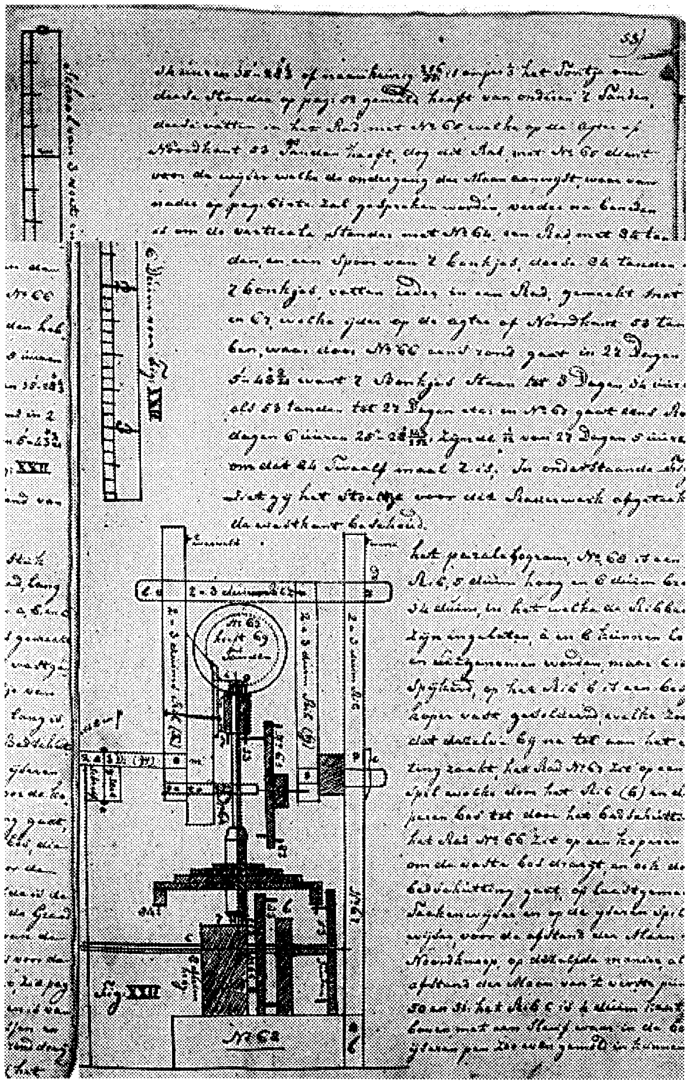

Figure 4. A page from Eisinga's design of the wheelwork, written for his sons (after *Eisinga Planetarium* ..., n.d.:8).

Construction of the planetarium took place entirely in Eisinga's spare time, and despite some unforeseen obstacles it first became operational in 1778. By 1780 February it was finished except for the paintwork, which Eisinga completed by 1781 May. Two months earlier William Herschel had detected a new planet, Uranus, but by the time this discovery was publicized in the Dutch Republic it was too late for this planet to be incorporated into Eisinga's planetarium (nor was his living room large enough to accommodate its orbit).

In 1780 February, before the planetarium was quite finished, Jan Hendrik van Swinden (1746-1823), a Professor of Philosophy at Franeker's University, together with two of his colleagues, visited Eisinga. They had heard of a 'small instrument' he had made and they wanted to see it. Van Swinden (1994) had seen planetariums before and had even made simple sketches of one, but he was touched by the beauty and scale of Eisinga's new instrument – or 'work of art' as he termed it – and examined it for two hours. Once home, he wrote a description of the most important features, read about other planetariums to convince himself of the value of Eisinga's planetarium, and compiled a list of thoughts and questions for further research. On March 13 he again visited Eisinga and brought along a number of professors and other highly-placed persons. After an inspection that lasted several hours, he discovered more qualities of the planetarium that he had missed on his first visit. His appreciation grew and he showed this by sending his brother, a lawyer in The Hague, a short description of the planetarium. He also sent copies to the Academy of Sciences in Brussels, the Prince of Gallitzin, the famous scientists Du Luc in London, Cotte in Montmorenci, and Baussen in Montpellier. Lack of time prevented him from sending copies to his correspondents in Paris, St. Petersburg, Germany, Switzerland, and Italy. As a scholar and fellow citizen, he felt obliged to proclaim the genius of Eise Eisinga. He believed the Frisians had every right to be as proud of Eisinga as the English were of John Harrison whose solution to the longitude problem was the famous marine timepiece H4, or James Ferguson, Britain's leading popularizer of astronomy. For this reason and to inform everybody who would like to visit the planetarium of its true value, but mostly to avoid disdain and misjudgement, he decided to write a detailed description. He did this in 1780, the same year of his visits, and before Eisinga had painted and gilded the planetarium.

Soon after the publication of Van Swinden's description of the planetarium, Eisinga's house was visited almost daily by people whose curiosity and interest had been aroused. Even though Eisinga enjoyed the attention, the planetarium was still not painted and gilded, and after a while he had to deny access to anyone other than a few friends and scholars. But when the planetarium was finally finished, in 1781 May, Eisinga opened his doors to the public and the run was enormous. From all over the country people came to visit, and special group outings to Franeker were organized in order to see this remarkable work of art.

But Eisinga did not consider the completion of the planetarium the end of his labour, and he continued working on improvements. It seemed, for instance, better to move the pointers of the Moon phases from the bottom of the pillars of the frame around the built-in bed up to the ceiling, where there was more space for an accurate representation. The wheels had to be relocated and rearranged, so this took a lot of time and effort.

In 1784 November Eisinga wrote a manuscript titled *Naaukeurege Afteekeningen en Beschrijving van de Uitwendege Vertoning en Inwendege Samenstelling van het Alom Geroemde Beweeglijk Franeker Planeetarium Hemelsplein Zon en Maanwijsers (Accurate Record and Description of the External View and Internal Composition of the Generally Renowned Moving Franeker Planetarium Hemisphaerium Sun and Moon Pointers)*. This consisted of ninety-two folio pages with twenty-seven illustrations, and was dedicated to his two sons, Jelte and Jacobus, so that they and their offspring could maintain the planetarium and keep it operating. Later in life he made an exact copy of the manuscript, probably as a spare if the original should be lost or to give each son a personal copy (see Figure 4).

From 1780 The Netherlands experienced political disputes and civil discord, and these conflicts reached their peak in 1787. Franeker then became the centre where armed discontented people, calling themselves patriots, fought the authority of Stadholder Willem V of Orange. Eisinga had been a member of the City Council and was, against his will, involved in these conflicts, but soon Prussian troops restored the authority of the Stadholder and Franeker was recaptured (*Eisinga Planetarium* ..., n.d.). Thousands of Frisians had to flee to safety, and Eisinga was among them. He had to leave his wife and children and his beloved planetarium behind and he escaped to Steinfurt and later from there to Gronau, both of which were just across the German border (Louwman, and Terpstra, 1994). It was there, a few months later, that he received the news of his wife's death, but he could not return home at this time. His house was then let and the furnishings were sold, the planetarium came to a standstill, and the upbringing of his children was left to relatives.

During his stay in Gronau Eisinga thought about the construction of a new, larger planetarium, an idea given to him years before by Professor Van Swinden. In letters to his family Eisinga even described ideas for the new instrument: it should be housed in a cylindrical building with a roof in the shape of a hemisphere, and the building had to be at least 8.5 m (28 ft) in diameter, or if possible even larger (Noordmans, 1997). Though Eisinga must have known about the discovery of the new planet, Uranus, by Sir William Herschel, he never mentioned it in his plans for this second planetarium. Nor did he fully develop the concept, although he did work out design details of the building and of the wheelwork, but lack of money prevented him from constructing it. If Eisinga had actually built this planetarium, it would have been even more accurate than the planetarium in his living room (ibid.).

In 1790 Eisinga took the risk of returning to the Frisian border and settled in Visvliet (in the province of Groningen), but a year later he was taken prisoner by Frisians who operated on behalf of the *Hof van Friesland* (Frisian Court) outside the borders and jurisdiction. He was transferred to *Het Blokhuis*, a prison in Leeuwarden, and after a year of imprisonment and an extensive tribunal in 1792, he was sentenced to five years exile outside the province of Friesland. He returned to Visvliet where he met Trijntje Sikkema, who became his second wife. Together they had three daughters, Eelke (1793-1795), Hittje (1796-1843) and Minke (1798-1870).

In 1795 a political revolution took place, the Stadholder fled to England, and the French revolutionary army occupied the Dutch Republic which became the Batavian Republic (see Israel, 1995). Eisinga was then able to return to Franeker, but his former home was still let and he had to find another place to live. However about a year later, he was able to return to his old dwelling, but it took almost nine years of repairs before his planetarium was operational again. Soon it was open to the public and attracting large numbers of visitors.

Eisinga spent all his spare time working on the planetarium and had aspirations to constantly improve it. He also worked on his plans for the construction of the second, larger, much improved planetarium again, but as his prestige in the community rose he was offered a number of administrative positions which took up more and more of his time. In 1797 he was appointed a Curator of the Franeker Academy, and in 1802 he once again became a member of the Council of Franeker, a post he held until his death in 1828 (Louwman, and Terpstra, 1994).

5 DESCRIPTION OF THE PLANETARIUM

The following account is based on the description Eisinga prepared for his two sons, as rewritten and edited by Noordmans (1997), plus a synthesis of the following sources: Eekhoff (1851); *Eisinga Planetarium* ... (n.d.); Havinga, Van Wijk and Dáumerie (1928), and Van Swinden (1994).

In the Dutch Republic, the prime use of planetariums as a means of demonstrating the movements of the planets around the Sun in accordance with the prevailing Copernican view began in the second decade of the eighteenth century (Dekker, 1985; King, 1978; Zuidervaart, 1999), but Eisinga was not familiar with these planetariums.

The key characteristic of his planetarium is the large overhead model of the Copernican solar system, constructed between 1774 and 1781. The model has a scale of roughly $1{:}10^{12}$, so one millimetre equals one million kilometres. It consists of a series of seven eccentric circular slots of which the seventh represents a zodiac/calendar scale. The first six slots represent the orbits of the planets Mercury to Saturn. Each planet is represented by a metal ball that is gilded on its sunward hemisphere. These balls are attached to short metal rods and orbit a painted Sun. Only the Earth has a revolving and rotating satellite; all the other moons shown – four for Jupiter and five for Saturn – are suspended by metal wires from their respective planets. Added to each planet's orbit is a painted zodiac scale and a somewhat eccentric circle with markings that refer to the planet's latitude, and the positions of its aphelion, perihelion, and nodes. Eisinga also constructed additional dials and clocks to show the times of sunrise, sunset, Moon rise and Moon set, lunar phases and distances, days of the week, and more. The impressive clockwork that drives this planetarium is mounted between a false wooden ceiling and the ceiling proper and consists of dozens of wooden disks and wheels and some ten thousand iron nails (e.g. see Figure 5). Everything is kept in motion by one weight-driven clock. The planetarium only works in real time, and cannot be sped up or slowed down. Visitors, therefore, will hardly see any signs of motion, but this planetarium has been kept operational for over two hundred and twenty years without interruption. This makes it the oldest, still functioning mechanical planetarium in the world, and during this interval nothing of importance has ever been replaced. The accuracy of this planetarium is such that to this day the current position of the stars and planets, and the current day, date and rising and setting of the Sun and Moon are given. Nor does this planetarium ever fail to recognize a solar or a lunar eclipse.

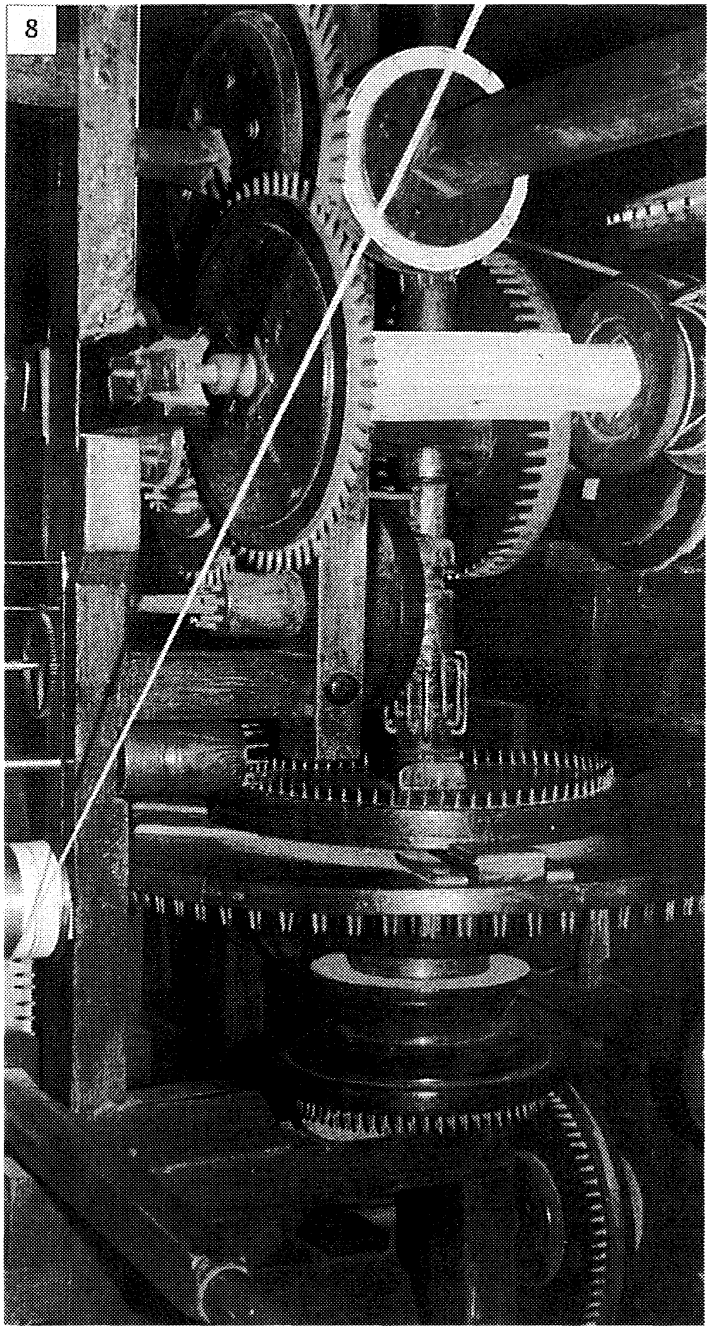

Figure 5. Some of the impressive wheelwork between the two ceilings (after *Eisinga Planetarium* ..., n.d.:6).

5.1 The Sun and the Ecliptic

In the centre of the living room ceiling a stationary Sun is painted (see Figure 6). In the centre of this Sun a gilded ball dangles from a string. Twenty-four sunbeams leave the painted Sun and every second sunbeam reaches to the outer circle of the planetarium, which represents the ecliptic. Because of these twelve sunbeams, twelve equal parts are identified on the ecliptic, and these carry the names of the signs of the zodiac.

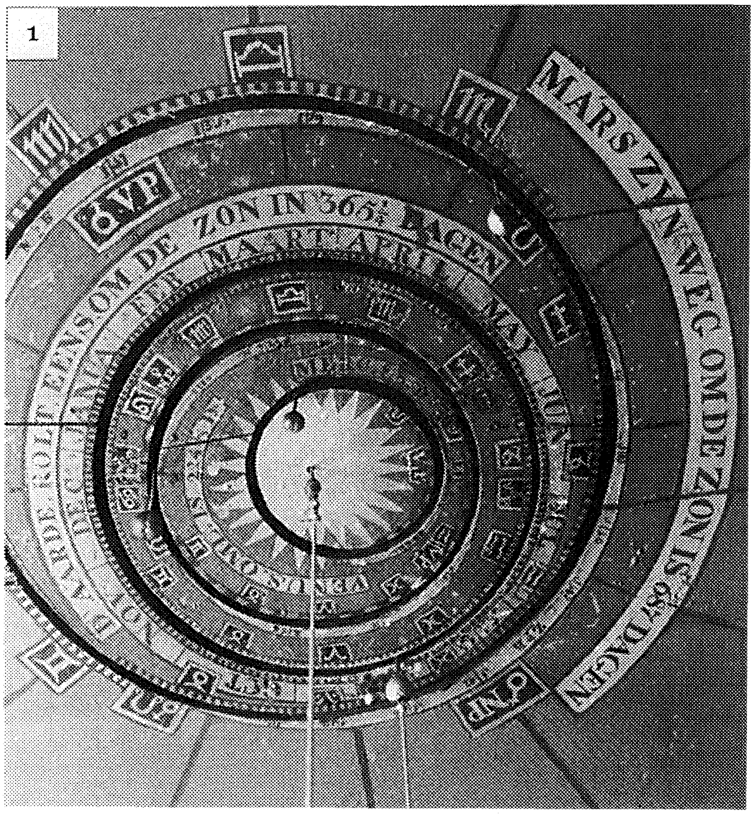

Figure 6. The four planets in orbit around the Sun on the ceiling of Eisinga's living room (after *Eisinga Planetarium* ..., n.d.:1).

5.2 Mercury and Venus

The first slot around the painted Sun is Mercury's orbit (Figure 6). The slot's diameter is 139.7 mm, and the ball representing Mercury moves round this slot in 88 days. It is half gilded and half black, the gilded side standing for day and the black side corresponding to night. Mercury moves in an orbit that does not have the Sun in its centre. The second circle from the Sun is for the orbit of Venus (Figure 6). The diameter of the slot in which this planet moves is 234.95 mm, and the ball representing the planet orbits once every 225 days.

5.3 The Earth and Moon

The third circle is for the Earth (Figure 6), and is divided in months and days. The diameter of the slot is 330.2 mm, and the ball representing the Earth circles once every 365 days. At a distance of 25 mm from the Earth there is a smaller ball symbolizing the Moon, which revolves around the Earth once every $27^d\ 7^h\ 43^m$. Together with the Earth, it orbits the Sun in 365 days. The ball representing the Moon is half gilded and half black, with the gilded side always turned towards the Sun. When observed from the Earth, this construction shows the phases of the Moon.

5.4 Determining the Geocentric Position of a Planet

The ball representing the Earth dangles on a string of the same length as the previously-mentioned rod from which the Sun hangs. At the end of this string there is a small gilded ball.

Both balls serve to keep the rod taut. This way it is possible with the aid of the two strings to determine the geocentric position of a planet. One picks a location in the room where the planet is behind the rod from which the Earth dangles, and then distinguishes what part of the ecliptic is behind the rod from which the Sun hangs. This is exactly the position of the planet as seen from Earth.

5.5 Mars, Jupiter and Saturn

The fourth slot from the Sun is the orbit of the planet Mars (Figure 6). The diameter of this slot is 456.2 mm, and the ball that represents Mars orbits the Sun in 687 days. The fifth slot is the planet Jupiter's orbit. The slot has a diameter of 1562.1 mm, and the ball representing the planet orbits the Sun in 4335 days. To the ball representing Jupiter four smaller balls are attached representing the four Galilean moons, Io, Europa, Ganymede, and Callisto. These four little balls do not move separately. The sixth slot is for the Saturn's orbit, and has a diameter of 2908.3 mm. Attached to the ball which represents Saturn is a flat ring and five smaller balls. The latter represent Saturn's moons, Thethys, Dione, Rhea, Titan, and Iapetus. Saturn needs 10760 days in order to complete an orbit around the Sun.

5.6 Sun and Date Pointer

The seventh slot (the slot outside Saturn's orbit) is the apparent route of the Sun in a year. This slot has a diameter of 3544.3 mm. The hand that goes through this slot takes 365 days for one orbit. On the inside of the slot, the hand points to the sign of the zodiac in which the Sun is in, and to the number of degrees in that sign. Each sign is divided into thirty degrees. On the other side of the slot the hand points to the month and the day of the year. In addition, the declination of the Sun is shown. From the circle representing the date, perpendicular lines are drawn to equal scale divisions on the baseboards of the ceiling. Every scale is divided into twice times 23½°, and gives the northern and southern declination of the Sun. The seventh slot is divided into 365 days. That is the time the hand needs for one orbit. In the case of a leap year, on February 29 the hand needs to be set back one day, so that it will point to the right day on March 1.

5.7 Pointers of the Day and Year

Along the southern side on the ceiling there are five dials, and the middle one (Figure 7) is divided into seven parts, the days of the week. Every day in its turn is divided into twenty-four hours. The hand goes around in one week and points towards the day and the hour according to solar time. A painted sign referring to the original name of the day accompanies each day. There is a rectangular opening in the ceiling between the centre of the dial and its periphery, which reveals the year. On December 31 at about 4pm the year sign starts moving. Slowly the new year appears, and it is completely visible by next morning. Every twenty-two years the board with the years painted on it has to be repainted with twenty-two new years.

5.8 The Pointers of the Moon

To the right of the pointers of the day and year there are two dials on the ceiling, the pointers of the Moon. On the first dial the position of the ascending node of the Moon's orbit is indicated in the signs of the zodiac. On the dial next to it the Moon's phases are shown. Beneath these two dials, on wooden boards above the built-in bed and the cupboards, there are another two dials. One indicates the time the Moon sets and the other the Moon's distance to the ascending node. The pointer on the ceiling that indicates the position of the ascending node in the zodiac therefore has the same rotation period. Because of the monthly revolution of the Moon around the Earth, the Earth will be in a node twice a month. The pointers of the dial in the pillars indicate the distance from the Moon to the ascending node. This distance is expressed in signs of the zodiac by the small pointer and in degrees by the large pointer. When both pointers indicate zero, the Moon is at the ascending node. When the small pointer indicates six and the large one zero, the Moon is exactly six zodiac signs away from the ascending node and is thus located at the descending node. If the Moon is located at one of the nodes at the moment the pointer of the phases of the Moon indicates New Moon, then there will be a solar eclipse visible from somewhere on Earth on that day. However, if the pointer indicates Full Moon, there will be a lunar eclipse.

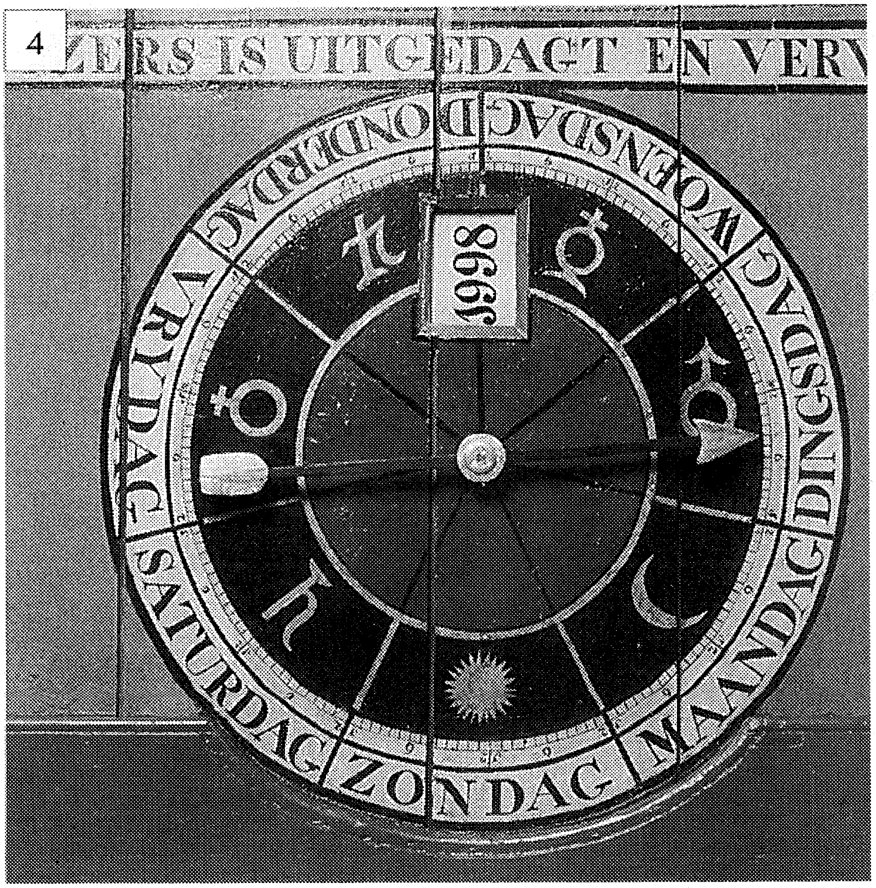

Figure 7. The day and year pointers, on the ceiling (after *Eisinga Planetarium* ..., n.d.:2).

To the left of the pointer of the day, there are also four Moon dials. One of these indicates the apogee of the Moon in the signs of the zodiac. The positions of the aphelion and perihelion of the Moon revolve in eight years and three hundred and eleven days, and this is also the time the pointer on the ceiling takes to rotate. The pointer of the dial on the pillar gives the distance from the Moon to the perihelion, just like the indication of the distance to the ascending node in signs of the zodiac and in degrees. On the ceiling is another pointer indicating the distance covered by the Moon on the ecliptic. It shows the location of the Moon in the zodiac sign and in degrees. Above the cupboard there is another dial that indicates the time of moonrise.

5.9 The Planisphere

Over the built-in bed there is a nearly circular opening of almost 500 mm radius in a panel. The border of the opening represents Franeker's horizon, and is divided into hours. Behind the opening is a planisphere of 700 mm radius which rotates in one day (see Figure 8). The part of the planisphere that is visible shows those stars and star signs that are actually visible at that moment above the horizon in Franeker. Furthermore, the equator, both tropics and the arctic circle are drawn on this planisphere. The ecliptic is represented by means of a slot cut through the planisphere. This slot is eccentric, and cuts the tropic of Cancer in the zodiac sign Cancer and the tropic of Capricorn in the zodiac sign of Capricorn. The planisphere rotates in twenty-four hours. The wheel has a pivot attached it which runs through a slot to a metal disc representing the Sun. So the Sun also rotates in twenty-four hours along with the wheel, and runs three minutes and fifty-six seconds behind on the rotation of the planisphere each day. The planisphere therefore shows the apparent rotation of the stars, the rising and setting of the Sun, and the lengthening and shortening of the days.

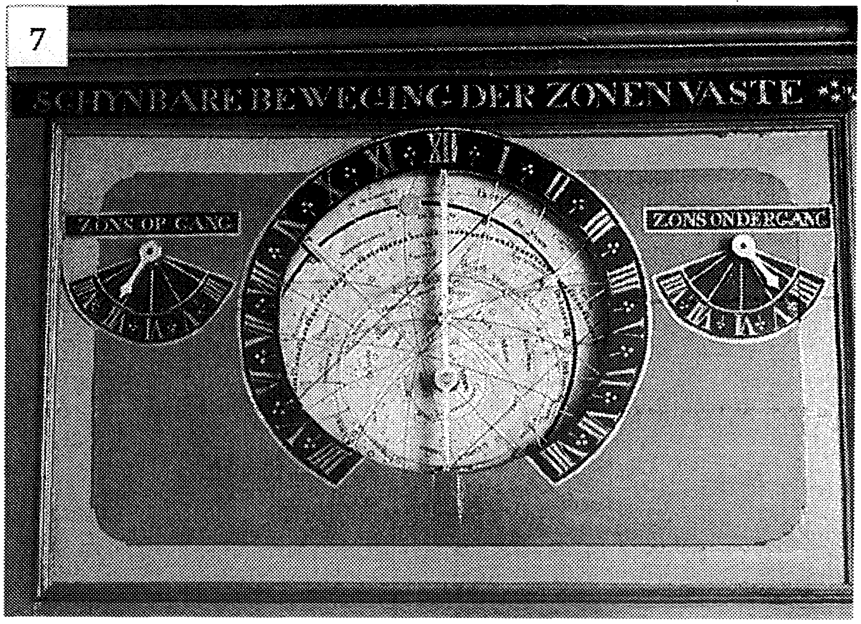

Figure 8. The planisphere, on the central wall panel above the built-in bed (after *Eisinga Planetarium* ..., n.d.:5).

5.10 The Wheelwork

The living room has a false ceiling, which supports the day, year, and various Moon pointers, and the orbits of the planets. These orbits divide the ceiling into seven separate discs, and these hang from the joists of the original ceiling and are connected by iron hooks. By unscrewing the nuts from the bolts it is possible to lower parts of the ceiling. Access to the wheelwork that is between the original and the false ceiling can be obtained by entering the attic and lifting hatches in the original ceiling. The cogwheels were made from oak wooden discs and hoops, with handmade iron pins that serve as cogs (see Figure 5). Only the central clock above the built-in bed has metal wheels. Eisinga had this clock manufactured by a clockmaker, and its sole function is to regulate the pace of the wheelwork.

The wheelwork is driven by eight weights that are located in the cupboards on either side of the built-in bed. Every main shaft has its own weight, in order to spread the driving force evenly over the whole wheelwork. The clockwork is also driven by a weight. Its pendulum swings eighty times per minute.

6 ACCURACY OF THE PLANETARIUM

In order for the planetarium to operate properly, with the passage of time various adjustments have to be made. These were documented by Eise Eisinga for his sons (see Noordmans, 1997), and are summarized below.

6.1 The Inner Planets Mercury and Venus

In Eisinga's planetarium the inner planet Mercury orbits the Sun in 88 days. The true orbital period however is $87^d\ 23^h\ 14^m\ 26^s$, so the planet moves a little too slowly. In 88 days this amounts to $45^m\ 34^s$. During this period, 44 cogs are moved, so only after 15 years is a correction of one cog necessary. Venus orbits the Sun in 225 days in the planetarium, and this, too, is a little slow as its true orbital period is $224^d\ 16^h\ 41^m\ 32^s$. In these 225 days Venus falls $7^h\ 18^m\ 28^s$ behind. The wheel for Venus has 60 cogs and one cog moves in $3^d\ 18^h$, so after $7^y\ 210^d\ 14^h$ a correction of one cog is needed.

6.2 Earth and Moon

At first the cogwheel belonging to the Earth moved around in 365 days. The Earth's average orbital period however is $365^d\ 5^h\ 48^m\ 45^s$. Because of this, the wheel went $5^h\ 48^m\ 45^s$ too fast every year and therefore caused a lead of almost one day in four years and needed a correction of one cog after twenty years. For this reason, in 1782 Eisinga decided to keep the Earth in motion by a separate shaft which would be connected to another shaft that went around in 365 days and was corrected by a day every leap year. This construction made the average orbital period of the Earth in the planetarium about the same as the planet's true orbital period. But the correction made the Moon revolve around the Earth in $29^d\ 12^h\ 21^m\ 49^s.09$, which is a little too fast (it should be $29^d\ 12^h\ 44^m\ 3^s$). However, it takes more than 19 years before a correction of one cog on the wheel has to be made.

6.3 The Outer Planets

In Eisinga's planetarium Mars orbits the Sun in $686^d\ 22^h\ 18^m$ and therefore moves $6^h\ 18^m$ too fast. The Martian wheel has 103 cogs. It takes $6^d\ 16^h$ to move one cog, thus it will take 47¾ years before a correction of one cog must be made. Jupiter has a wheel with 289 cogs and revolves round the Sun in 4335^d. Since its true orbital period is $4330^d.373611$, it moves $4^d\ 15^h\ 2^m$ too slowly. One cog of Jupiter's wheel moves in fifteen days and it therefore will take more than 38 years before the wheel needs a correction of one cog. Saturn orbits the Sun in 10760 days and its wheel has 538 cogs. Saturn's true orbital period is $10749^d.6347222$, so it will take more than 56 years before a correction of one cog is needed.

6.4 The Wheel Belonging to the Pointer of the Date

The wheel belonging to the pointer of the date, just outside Saturn's orbit, has 584 cogs plus one cog for the motion of the year pointer. This is the largest wheel of the planetarium. Once every four years, on February 29, the wheel has to be moved back one day, so that year it will be February 28 twice. But the next day the orbital period of the pointer of the day will exactly correspond to reality.

6.5 The Hemisphaerium

The hands for the Sun and the night revolve in twenty-four hours. The Sun moves around the ecliptic in 365 days, but its true speed should be $365^d.25$. The difference amounts to twenty-four hours in four years, which equals about one degree on the ecliptic. One cog represents $4°.9$, so it will take about twenty years before a correction by one cog is required.

6.6 Sunrise and Sunset

The pointers for sunrise and sunset are set to motion by a wheel so accurate that the difference is only $1^m\ 51^s$ per year. The shaft has 31 cogs and only moves by one cog each twelve days. This is why it takes 9300 years before a correction of one cog is necessary.

6.7 Pointer for the Distance from the Aphelion to the Spring Equinox

This pointer revolves in $8^y\ 312^d$ but the true orbital period is $8^y\ 311^d\ 8^h\ 34^m\ 58^s$, so the pointer is $15^h\ 25^m\ 2^s$ too slow. The wheel has 101 cogs and moves by one cog every thirty-two days. Each cog represents 3° 33′ 52″. Therefore it takes 441 years before the difference amounts to one cog.

6.8 Pointer for the Distance from the Ascending Node to the Spring Equinox

This pointer revolves in 6800 days but its true orbital period should be $6798^d\ 4^h\ 52^m\ 3^s$, so the pointer is $1^d\ 19^h\ 7^m\ 57^s$ too slow in one revolution. The wheel has 68 cogs and moves one cog every hundred days. Each cog represents 5° 17′ 39″. It therefore takes 1035 years before the difference amounts to one cog.

6.9 The Eastern-aphelion Shaft

This shaft revolves in $27^d\ 13^h\ 18^m\ 36^s.97$, but the actual time the Moon needs to get to the same orbital position is on average $27^d\ 13^h\ 18^m\ 34^s$. The difference is almost three seconds, and it takes about 1678 years before a correction of one cog is required.

6.10 The Moon's Distance to the Aphelion

This pointer revolves in the same time as the above-mentioned eastern-aphelion shaft, in $27^d\ 13^h\ 18^m\ 36^s.97$. The sign pointer and the degree pointer have the same irregular speed as the eastern-aphelion shaft. The pointer for the degrees revolves twelve times while the pointer for the signs revolves once. The pointer has exactly the same small inaccuracy as the eastern-aphelion shaft.

6.11 The Moon on the Ecliptic

This pointer revolves in $27^d\ 7^h\ 43^m\ 4^s.06$, which is slightly faster than the sidereal month. However, it takes 841 years before a correction of one cog is necessary.

6.12 The Western-aphelion Shaft and the Node Wheels

The western- aphelion shaft revolves in the same time as the eastern-aphelion shaft, and so it takes about 1678 years before a correction of one cog is required.

6.13 The Node Wheels

The node wheels drive the pointers for 'Moon Rise' and 'Moon Set'. These wheels rotate in $27^d\ 5^h\ 5^m\ 43^s.1$, instead of $27^d\ 5^h\ 5^m\ 39^s$. Only after 642 years does this four second delay cause a difference of one cog.

6.14 The Pointer for the Distance from the Moon to the Ascending Node

This pointer revolves in exactly the time the Moon needs to regain the same position in relation to nodes, so no correction is required.

6.15 The Pointer for the Phases of the Moon

The pointer for the phases of the Moon revolves in an average $29^d\ 12^h\ 43^m\ 13^s.37$. This should be $29^d\ 12^h\ 44^m\ 3^s$, so the pointer is 50^s too fast. One cog moves in $1^d\ 5^h\ 31^m\ 50^s$ and the wheel has 24 cogs, so it takes almost 172 years before a correction of one cog must be made.

6.16 The Pointer for 'Moon Rise'

The pointer for 'Moon Rise' revolves in $14^d\ 18^h\ 22^m\ 0^s.51$. This is exactly the time the Moon requires in order to reach the same phase again. The time for the rising of the Moon indicated by the pointer is nearly the same as in reality, so no correction needs to be made.

6.17 The Pointer for 'Moon Set'

The pointer for the wheel 'Moon Set' revolves in $14^d\ 18^h\ 22^m\ 0^s.51$. This, too, barely differs from the real value, and again a correction is not required.

7 THE PURCHASE OF THE PLANETARIUM BY THE STATE

With the passing of the years, many visitors to Eisinga's house must have worried about what would eventually happen to the planetarium after his death, for there was the very real danger that the house would be sold and that the new owner, having little interest in astronomy, would remove this annoying obstacle.

This possibility is mentioned in the diary of Jacob van Lennep who visited Franeker and the planetarium on 1823 June 9. The son of a professor, Van Lennep was from Amsterdam, and during the summer he and a university friend from Leiden, Dirk van Hogendorp (also a member of a prominent and well-to-do family), travelled on foot through The Netherlands instead of taking the usual *Grand Tour* of Europe. From the diary account, it is clear that both students felt superior to Eisinga, who after all was a simple working man of modest descent, without a university education (Mak, and Mathijsen, 2000). Van Lennep even suggests that Eisinga did not seem to know all that much about his own creation, but it is more likely that the Frisian was so annoyed by the arrogance and behaviour of the two young men that he simply kept quiet (ibid.). Here is an English translation of Van Lennep's description of the visit:

> A few canals further on we entered the modest home of wool comber Eise Eisinga. He came to us wearing an apron and he lead us to a small room, in which we saw the entire solar system above our heads. All planets visualized here, really move as in nature and complete their orbits in the same time, just like their moons. Four other plates show the rise and set of the Sun and the Moon. On others one can see the apparent movement of the Sun, the phases of the

> Moon, the distance from Earth to the Sun, from the Moon to the North and South Poles, the days of the month, the week, the hour, the minutes and seconds, also the year, the north and south declination etc.. This all is put into motion by a clock. The wheels and pins are all made from wood and take no more place than there is in the attic, which is a foot and a half high, above the small room. The maker showed all this to me as if it were some sort of fairground attraction, seemingly lacking all knowledge about it. (see Mak, and Mathijsen, 2000:68-69).

Van Lennep (ibid.) continues his account with the observation that both he and Van Hogendorp did not exactly know what to appreciate more, the planetarium itself, which was constructed with such precision, or the incomprehensible simplicity of its maker! He ends with the important statement that it was really sad that this remarkable construction is not transportable and that it and the house are doomed to come to an end some day.

Concern about the survival of this unique planetarium was cause enough for some of Eisinga's contemporaries to be moved to action, and three individuals, in particular, were largely responsible for the fact the house and its work of art survived and can still be visited today. They were Idsert Aebinga van Humalda, Daniel Jacob van Ewijck, and King Willem I. Van Humalda (1754-1834) was born into nobility, and was a fellow villager and school friend of Eisinga. He completed his academic education in Franeker and throughout his life was very interested in the arts and the sciences, including astronomy. In 1813, the year the French were driven out of the country and the House of Orange was restored, King Willem I appointed him Governor of Friesland. Van Ewijck (1786-1858) was also interested in astronomy, and after being appointed to a post in the Ministry of the Interior became Administrator for Education, Arts and Sciences, a post that was to prove crucial to the survival of the planetarium.

In 1824, a second edition of Van Swinden description of Eisinga's planetarium was published. Actually, it was Eisinga who suggested this new volume, for the original was no longer available, and a new printing also allowed for some minor additions to the text. For example, three illustrations of the planetarium by Klaas Johannes Sannes (a friend and fellow citizen of Eisinga) were added so that readers of the book who could not come to Friesland to see the planetarium with their own eyes would still have a good idea of what it looked like. These illustrations showed the planetarium as it appeared in 1820. Eisinga provided some text to support the three illustrations, and he also indicated the changes and improvements that had been made since the publication of Van Swinden's original edition in 1780. The 1824 edition included a portrait of an ageing Eisinga, also drawn by Sannes, and Reverend Brouwer from Leeuwarden provided a caption in poetic form. Brouwer also wrote a Foreword for this edition, and in this he alludes to the possible loss of the planetarium for Friesland and the Netherlands, and hopes that the interest shown by King Willem I will guarantee its survival. Brouwer was undoubtedly referring to the fact that the King visited the planetarium in 1818 June.

Van Humalda made sure that a copy of Van Swinden's new edition was send to the King as soon as it was published, and in a covering letter (Van Humalda, 1824) he mentioned the King's visit in 1818 and the fact that he had earlier appointed Eisinga a 'Broeder van de Orde des Nederlandse Leeuw' (Brother of the Order of the Dutch Lion). For the benefit of this highly meritorious old man, the Governor dared to include a request which, if granted, would bring Eisinga enormous satisfaction and delight. Van Humalda stated that although he was not exactly poor, the wool-comber was in a difficult situation financially, and several times had mentioned his fear that the house and planetarium would be sold after his death. Van Humalda noted that the planetarium could not be transferred to another building (as the King himself had observed during his visit), and as a result it would probably end up being destroyed. Van Humalda pointed out that the future of the planetarium would be assured if the King approved the purchase of the house by the State. Furthermore, Van Humalda suggested that Eisinga's sole surviving son, who had been educated by his father for quite some time now, could live in the house and be responsible for the continued operation of the planetarium. In this way, the famous work of art would not only be preserved, but would also be immediately available for the education of young students. In concluding his letter, the Van Humalda urged the King to consider this proposition seriously

The King wanted to obtain extensive advice on this matter, so Van Humalda's letter was handed to Van Ewijck, and he in turn corresponded on the matter with the Governor. In his first letter, dated 1825 January, Van Ewijck asked how much money would be required for the purchase of the house and planetarium. Van Humalda (1825a) then had to estimate the financial value of the planetarium, and he found this to be a considerable challenge. He took into consideration the fact that Eisinga had spent seven years building the planetarium and that it had cost him a considerable sum of money. There had also been the expense of keeping the whole planetarium, including the clockwork, functioning for many years. On this basis, the Governor concluded that Eisinga should be paid an amount of ten thousand Dutch guilders (about US$4,800), but that this would only take into account the manual labour. If one were to note the ingenuity of the invention (despite the fact that Eisinga had no scientific education), and if one were also to note his domestic situation and his not very ample financial circumstances, then Van Humalda believed that the King should be advised to not only pay the calculated ten thousand Dutch guilders, but to raise this amount considerably – and the final amount should be considered a homage to the special merits of the this remarkable eighty-years old man. Van Humalda then repeated the suggestion he had earlier put directly to the King, namely that the State should let Eisinga's son Jacobus, continue to live in the house. Jacobus, who was 41 years old, also had no formal scientific education, but was already very familiar with the planetarium and had the competence to maintain it and keep it functioning. In return for doing this, he should be allowed to occupy the house free of rent, and he should also receive a considerable annual fee. The Governor ended with the assertion that through Van Swinden's book, Van Ewijck would realize that it is no overstatement to say that Eisinga's planetarium is truly one of a kind, and must be considered a national 'jewel'.

Shortly after receiving this letter, Van Ewijck presented Van Humalda with some more questions. Among other things he wanted to know whether it would be possible to pay the purchase price in instalments over four to five years. He also wanted to know what sort of annual fee Jacobus Eisinga should be paid. Van Humalda (1825b) rejected the idea of payment by instalments, and recommended a single payment. Meanwhile, he thought that Jacobus Eisinga should be given the use of the house rent free, that he should receive an annual fee of two hundred Dutch guilders, and that the maintenance of the planetarium should be carried out under the observation of a professor from the Athenaeum.

Van Ewijck (1825a) now had all the information he required, and in 1825 May he assembled his recommendations. He agreed with all of Governor Van Humalda's suggestions, with the exception of the payment of an extra amount on top of the purchase price of ten thousand Dutch guilders. But there was one problem: he could not identify funds from which the ten thousand Dutch guilders should be paid, as all funds that qualified for this in the budget were already being used. Despite this, the Minister of the Interior approved Van Ewijck's recommendations, and they were presented to the King. As far as they were concerned, it would be up to the King to designate the funds to be assigned for this expenditure, although the annual payment to Jacob Eisinga could come from the Ministry of Interior's budget.

After receiving Van Ewijck's recommendations, the King advised the Minister that because funding was not available the purchase of the planetarium could not go ahead. His suggestion was to see whether the State could still obtain the planetarium, but by making annual payments to Eisinga, which would then be transferred Jacobus after his death. The King asked Van Ewijck to prepare a new proposal along these lines.

Van Ewijck then put this scenario to Van Humalda, and the Governor found it very difficult to react to this new proposal, especially in that another total amount for the purchase of the planetarium had to determined before the annual payments could be computed. Van Humalda (1825c) subsequently suggested a minimum annual fee of one thousand Dutch guilders, with the proviso that after Jacobus Eisinga's death the State would become the new owner of the house and planetarium. Upon reflecting on this and taking account of Jacobus's age, Van Ewijck concluded that this was not a viable alternative as it would most likely cost the State three times as much money as the figure of ten thousand Dutch guilders originally mentioned by Van Humalda. Certainly, spending all this extra money would not have been the intention of the King!

Van Ewijck took all of these factors into consideration when preparing a new proposal for the King in 1825 December. In this document (Van Ewijck, 1825b), he suggested that it would be better to make the payment for the purchase of the house and planetarium in instalments, over a period of ten years. Meanwhile, the State would also agree to pay Eisinga the sun of one thousand Dutch guilders each year, and this arrangement should start on 1826 January 1 on which day the planetarium would become the property of the State. For the maintenance of the planetarium, Eisinga would also receive an annual fee of two hundred Dutch guilders, and upon his death this arrangement would be transferred to his son, Jacobus. Furthermore, father and son could occupy the house free of rent, so long as they fulfilled their obligation to maintain the planetarium. Finally, the Minister of the Interior should include this expenditure in his Departmental budget. The Minister approved this new proposal, and it was passed to the King for his consideration. This time the King agreed to the terms, and one year after Van Humalda had put forward his original proposal Willem I signed the document approving the purchase of the planetarium by the State (Koning Willem I, 1825). This actually occurred on December 20, and not on December 28 as some authors have erroneously written (e.g. see Eekhoff, 1851; *Eisinga Planetarium* ..., n.d.).

The Minister of the Interior was now responsible for the execution of the Royal Decree, and informed van Humalda of this excellent progress (see Van Humalda, 1826a). In order to officially formalize the arrangement a notary act for the purchase had to be drawn up which Eise Eisinga would then be required to sign, as would Governor Van Humalda acting on behalf of the Dutch State. Notary Kutsch in Leeuwarden received the assignment, but it was only on 1826 September 2 that the Minister of the Interior approved the final manuscript of the notary act and signing it in Friesland was possible. Finally, on October 4, in the *Heerenlogement* in Franeker, the purchase was made official and Eisinga transferred his possessions to the State. Witnesses to this transaction were Professor ll.m. Jan Willem Crane (a friend of Eisinga) and the Frisian nobleman and lawyer Carel Salomon van de Poll. In November the governor sent a copy of the signed notary act to Van Ewijck (Van Humalda, 1826b), and on the last day of 1826 he forwarded a copy to the King. Willem I approved the notary act on 1827 January 4 (Koning Willem I, 1827a), and although Eisinga had yet to receive a single Dutch guilder he must have been somewhat relieved.

Now that the King's signature was on the notary act, payments of the first thousand Dutch guilders for the purchase of the planetarium and the first two hundred Dutch guilders for its maintenance could commence, albeit retrospectively for the year 1826. Van Ewijck reported this welcome news to the newly-appointed Governor of Friesland, Van Zuylen van Nijevelt, who in turn advised Eise Eisinga (see Van Humalda, 1827). For his part, 83 year old Eisinga was pleased with this progress as he was still receiving tax forms as the official owner of the house. Later in the year Eisinga received his first payment, and at about the same time he was specially honoured when his old friend, Van Humalda, arranged for Willem Bartel van der Kooi to paint his portrait (see Figure 3). It was also the former Governor who, in the presence of Eise Eisinga, delivered the speech on 1827 November 13 when the painting was presented to the municipality of Franeker and was hung in the Council Chamber (Eekhoff, 1851).

In 1827 January Van Ewijck (1827a) found time to inform the Curators of the Franeker Athenaeum of the King's decision of 1825 December 20 and the allocation of two hundred Dutch guilders a year to Eisinga for the maintenance of his planetarium under the supervision of a professor from the Athenaeum. The Professor in question was J W Ermerins, and he was assigned the task of reporting each year to the Curators on the condition of the planetarium. The Curators would then incorporate this account into their annual report on the state of the Athenaeum, which would subsequently be presented to the Minister.

In March, Van Ewijck (1827b) wrote to the Curators of the Athenaeum about maintenance of the planetarium and possible repairs to Eisinga's house, noting that these should be paid for from the funds that the State provided to the Athenaeum. The following month, the Athenaeum's caretaker inspected Eisinga's house and estimated the budget for necessary maintenance and repairs. He noticed that the house was not in a good condition, and that it had not been renovated for quite some time. He reported that the living room floor had almost completely decayed and urgently needed to be replaced, and that it also would do no harm to paint the planetarium while Eisinga was still alive (Wijbrandus, 1827). In 1827 June the King agreed to add the sum of four hundred and fifty Dutch guilders annually to the Athenaeum's budget, specifically for the maintenance of the planetarium (see Koning Willem I, 1827b). As a result of these decisions, the planetarium was indeed painted in 1828, and in this same year Van

Humalda joined the board of Curators of the Franeker Athenaeum. This was a fitting reward for a man who had worked so long and so hard to ensure the survival and preservation of Eisinga's planetarium.

After Eise Eisinga died in 1828 Jacobus continued to maintain the planetarium, and the flow of visitors was undiminished. One of those who visited in 1841 was King Willem II (Eekhoff, 1851). Jacobus also lived to see a new edition of Van Swinden's book about the planetarium, which was published in 1851 (ibid.). This third edition began with an extensive history of the planetarium written by W Eekhoff, keeper of the archives of the city of Leeuwarden. He pointed out that although the Athenaeum had closed in 1843, many people still visited Franeker in order to see Eise Eisinga's planetarium with their own eyes. Given that the second edition was long out of print, this description alone should have been sufficient grounds to justify a reprinting. To round it off, this new edition also included a biography of Eisinga's life contributed by his son.

In 1859 February Willem III and the State handed the planetarium over to the municipality of Franeker, and Eisinga's descendants continued to live in the house until 1922, looking after the planetarium and serving as guides for the visitors (King, 1978). The municipality is now responsible for the care and maintenance of this facility, and to this day many people still find their way to Franeker so that they, too, can witness Eise Eisinga's remarkable creation.

8 DISCUSSION

When we think of a planetarium today, we think of a dome-shaped building with a special projector to simulate the night sky. In Eisinga's day the term 'planetarium', or orrery, was used for a mechanical model of the solar system. The English language makes a distinction between a planetarium, an instrument that represents the orbital motions of the planets but ignores the rotation of the Earth, and an orrery, in which the Earth has diurnal motion. In fact, there are further distinctions. When the orrery has the lunar portion absent it is called a tellurian and when present it is called a lunarium. Eisinga's construction is a planetarium in the true original sense of the word.

It was probably Desaguliers who boosted the success of the planetarium in the Dutch Republic by using his orrery as a demonstration model for lessons in astronomy. He had it specially constructed for his lectures just before he left for the Dutch Republic in 1731. Many people attended these lectures, and they were considered highly successful. But planetariums were not new to The Netherlands at this time for the first ones had been built soon after publication of Copernicus's *De Revolutionibus*. However, often they were not an accurate reflection of this new view of the solar system, being no more than simplistic arrangements of the Sun and the planets. This changed when Kepler disclosed the true elliptical orbits of the planets (Zuidervaart, 1999).

Although the first mechanical devices built in The Netherlands to demonstrate the motions of the planets were created in the seventeenth century, few have survived through to the present day. In fact only two are known, and both are on display at the *Museum Boerhaave* in Leiden. One is a planetarium designed by Christiaan Huygens and built by Johannes van Ceulen in 1682 (Dekker, 1985). The other is the *Leidsche Sphaera* (Sphere of Leiden), constructed by Steven Tracy, a clockmaker from Rotterdam (ibid.). This Copernican orrery has a pendulum clock, which indicates that it was not made before 1665 because that is the year in which Huygens was granted the patent on this invention. Furthermore, since the newly-discovered Jovian moons were not included on the *Sphaera*, it must have been constructed before 1672. This makes it the oldest Copernican orrery in The Netherlands.

The eighteenth century marked the heyday of the planetarium in The Netherlands, and many of the models that were built have survived through to the present day in both Dutch and foreign museums. One of the most famous planetary machines of the eighteenth century was built by Pieter Eijsenbroek of Haarlem (King, 1978; Zuidervaart, 1999). A spinner by profession, he probably was more interested in physics and astronomy, and he constructed his planetarium in 1738. It had the form of a grand orrery with a hemisphere and was supplied with an armillary hemisphere. This planetarium was improved by Jan Peres in 1793, and is now on display in the Adler Planetarium in Chicago (see Stephenson *et al.*, 2000:133). Eijsenbroek also fabricated a brass tellurian for educational purposes. Other machines were built by Jan van den

Dam of Amsterdam. Originally a cobbler and later a mathematician, this workman designed a planetarium that was similar to the one made by Tracy, only smaller, and it is still on display in *Het Scheepvaart Museum* in Amsterdam (King, 1978). Johannes Regter of Delft built a double cone planetarium that is now on display at the *Museum Boerhaave* in Leiden (King, 1978; Zuidervaart, 1999). In 1782-1788, a clockmaker named Joseph van den Eeckhout constructed a clock-driven planetarium with help from I F Robert. This planetarium was designed by Johan Adriaen van de Perre who also supervized the work, and after its completion kept the planetarium for his own personal use. After his death it was donated to the *Zeeuws Museum* in Middelburg, where it still forms part of the collection (Zuidervaart, 1999). Hartog von Laun was a member of a family of scientific instrument-makers in Amsterdam, and he constructed a number of demonstration planetariums that were originally designed by D Stoopendaal (King, 1978; Zuidervaart, 1999). Van Swinden, who documented Eisinga's planetarium, was also interested in von Laun's work, and in 1803 he wrote an illustrated description of a tellurian/lunarium/planetarium which served to increase public interest in these planetary devices (see King, 1978).

Most of the above planetariums were table instruments, but Eise Eisinga built one that could only just fit into his living room. Yet as we have seen, he planned to construct an even larger one, in a building specially designed for it, but this dream was never realised – and in The Netherlands it would take until the twentieth century before such a special building was constructed (and by then the word 'planetarium' had acquired a new meaning). Instead Eisinga turned to small instruments and in 1818 he designed a manual planetarium which was constructed by W Jans Jansen, a farmer from Dongjum. This small planetarium, known affectionately as 'The Appendix', is on display in Eisinga's house in Franeker (ibid.).

Unfortunately, little is known of other planetary machines that were built in the nineteenth century, but from those that have survived we may conclude that the momentum established in the previous century continued. Two nineteenth century devices that achieved fame regrettably were destroyed in a large fire at Enschede in 1862. One of them was a planetarium constructed by Lambertus Nieuwenhuis. Eisinga knew Nieuwenhuis well, and during the years of his exile stayed with him in Enschede for a while. Inspired by Eisinga's work, Nieuwenhuis also built a large planetarium, but it was completely destroyed in the great fire (Zuidervaart, 1999). The other device that was lost at this time was a tellurian/lunarium that was built by Coenraad ter Kuile in 1824 (see King, 1978; Zuidervaart, 1999).

Among other planetary devices constructed in the nineteenth century was the *Sneeker Planetarium*, which derived its name from the city of Sneek (in Friesland) where it remained in obscurity for over fifty years (Louwman, and Terpstra, 1994). A bailiff named Cornelis Jacobs van der Meulen completed this device in 1842, but it is not a planetarium in the strict sense of the word since it displays no other planets than the Earth. It is a type of elaborate astronomical clock carrying the names Tellurium, Lunarium, and Planisphaerium, and when constructed generated a lot of interest, but after Van der Meulen's death was quickly forgotten. However it has now been restored, and is on display in Eisinga's house in Franeker (*Eisinga Planetarium* ..., n.d.).

Petrus Verhaar built an electrically-operated planetarium, and before it was put on display in 1921 in The Hague it underwent some alterations by the Kipp firm from Delft (King, 1978). Soon though, the word 'planetarium' would acquire a completely new meaning. It saw its origin in Germany, and the world's first projection planetarium was invented by Walter Bauersfeld of the Carl Zeiss Optical Company in 1923. That same year it was demonstrated at the *Deutsches Museum* in Munich, and it was permanently installed there in 1925 (see Werner, 1957). The first projection planetarium in The Netherlands was the Zeiss Planetarium in The Hague (see Raimond, 1948), which was constructed in 1934 and was operational through until 1976 when it was damaged in a fire. Fortunately the Zeiss projector could be restored, and it is now on display at the *Omniversum* theatre in The Hague. During the second half of the twentieth century, more of these projection planetariums appeared in The Netherlands, and millions of people have enjoyed a planetarium show since these instruments first arrived in this country.

9 CONCLUSION

Eise Eisinga was an extraordinary man. A wool-comber by profession, between 1774 and 1781 he succeeded in constructing a unique scale model of the solar system in the living room of his home in the Dutch city of Franeker. Given that he had little formal education and hardly any knowledge of planetariums, the way in which he constructed this mechanical planetarium demands our respect.

Eisinga's planetarium has been kept in continuous operation for over two hundred and twenty years, making it the oldest functioning mechanical planetarium in the world, and during this period nothing of importance has been replaced. The precision of this planetarium is such that to this day the current day and date, the positions of stars and planets, and the rising and setting times of the Sun and Moon are accurately given. In addition, this planetarium never misses a solar or a lunar eclipse.

Although Eisinga constructed his planetarium in order to educate his superstitious and ignorant countrymen about the orbits of celestial objects, his legacy has been visited by people from all around the world. Planetariums may have changed dramatically in design since Eisinga's day, but their educational goal has not, and nor has the delight that people derive from observing the heavens.

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Jolander Mulder de Ridder received a B.A. degree in History and English in 1991 from Hogeschool Gelderland, Nijmegen. Her main astronomical interests are in planetary sciences, and she is currently enrolled in a Masters degree in Astronomy at the University of Western Sydney, Australia, through their graduate internet programme.