ONE

Ferdinand Verbiest

THE EMPEROR'S NEW ASTRONOMY

(1601–1688)

IN 1668, THE "SEVENTH YEAR OF KANGXI," the emperor of China was a powerless teenager, fourteen years old. His father, on his deathbed, had appointed four men to rule as regents until his son came of age. He had made unfortunate choices. Deadly clashes among the four regents had left two survivors—dangerous, ruthless men determined to keep the young heir to the throne under their control as long as possible. The boy was well educated and extremely intelligent. At age thirteen he had been allowed to attend to affairs of state, though ruling only in name. He had nevertheless contrived to acquire a fearfully good grasp of the politics of the Chinese court and the workings of the Empire. The time was approaching when, according to law and tradition, he could dispense with the regency, and he was chomping at the bit. With the advice possibly of his tutor and his mother, the dowager empress, he looked for a way to rid himself of the two surviving regents. His choice of weapon sounds curiously innocuous: the calendar. It was, in fact, an astute choice, and this teenager was about to prove that he, too, could be a

OPPOSITE: *Jesuit astronomers meet with the Kangxi Emperor in an imaginative tapestry from* The Story of the Emperor of China Series, *woven in France, c. 1700.* LEFT: *A Chinese scroll portrait of the Kangxi Emperor at a calligraphy table, c. 1662–1722.*

dangerous man. He was the "Kangxi Emperor," second ruler in the Qing Dynasty and destined to be one of the ablest monarchs in China's history.

While historians and scientists as well as non-experts are familiar with the story of Galileo's trial in Rome in 1633, hardly anyone knows about a trial that took place in the young Kangxi Emperor's court in Beijing thirty-five years later—one that pitted religion against religion, science against science, culture against culture. The outcome depended on clear-cut scientific results that all present could agree upon, though few could understand. Lives and the control of an empire hung in the balance, but it was the calendar that lay at the root of the contest. The earliest first-person description of the event was lost for three hundred years until 1991, when historian of science Efthymios Nicolaidis discovered a manuscript in a collection in the Church of the Holy Sepulchre in Istanbul, referenced sketchily in an old catalogue. He suspected he had found a previously unknown work from the seventeenth-century Jesuit astronomer Ferdinand Verbiest. Noël Golvers, a specialist in the early Christian missions in China at the Ferdinand Verbiest Foundation in Leuven, Belgium, was able to certify that this manuscript was, indeed, unknown. Dating from 1676, it was the earliest Latin text from Verbiest. It described in vivid detail Verbiest's unusual experiences in the imperial court in Beijing.

The story had begun in 1601, a half century before the Kangxi Emperor's birth, when Matteo Ricci, Jesuit missionary and astronomer, settled in the Chinese capital and learned that the reigning Wanli Emperor had a penchant for European mechanical instruments such as clocks and harpsichords. Here was an opportunity to gain access to the highest strata of Chinese mandarins and others who frequented the imperial court, even to the emperor himself. Ricci had a particularly valuable card up his sleeve: Western mathematics and astronomy, and their potential for helping Chinese astronomers produce an accurate calendar. The European *Prutenic Tables* of 1551—based on Copernican sun-centered astronomy and the more advanced computational methods of Europe—were unmatched by anything available to Chinese scholars at the time. At best, these scholars could

come no closer than about a quarter of an hour in predicting an eclipse—an essential step in producing the calendar. Ricci and his associates could do so dependably with a discrepancy of no more than one minute.

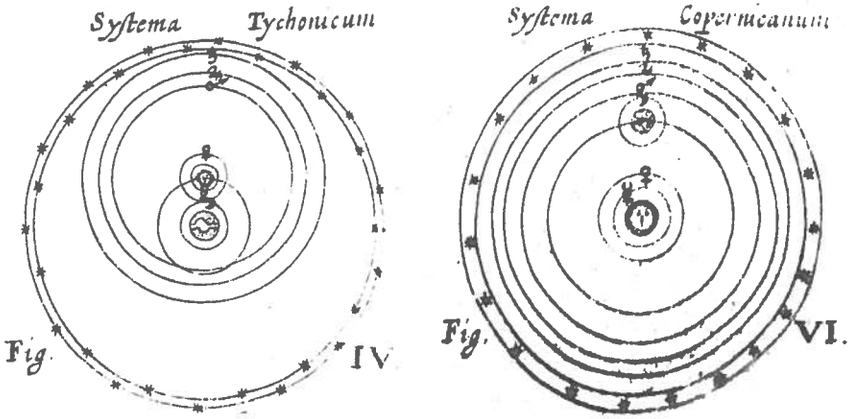
The Jesuits were devout missionaries with a commission to preach the Christian gospel to all nations, and they strategized that if they were to Christianize China, it was at the pinnacle of Chinese society, Beijing's imperial court, that they must sow the seeds of their faith. Wisely, Ricci insisted that candidates for the Chinese mission field possess not only

A portrait engraving of Verbiest from Description de la Chine *(*The General History of China*), 1736, by French Jesuit and historian Jean-Baptiste Du Halde.*

Thus things stood in 1658, when thirty-four-year-old Ferdinand Verbiest sailed from Lisbon to Macao with a fleet that made the long, treacherous voyage once a year. His credentials as an astronomer were not impressive: one semester under the tutelage of the mathematician André Tacquet at the University of Leuven in Belgium; ten undocumented years in Rome, where he *might* have undertaken private study with the polymath Athanasius Kircher; and a year teaching mathematics at a Jesuit school in Coimbra, Portugal (where, by his own admission, he "learned mathematics more than I taught"), were scant preparation for the challenges lying ahead of him. Once the fleet had embarked, however, Verbiest found it possible to ignore the perils of this two-year voyage, which had a history of fatal disease and shipwrecks, and concentrate on his beloved astronomy. Fellow passenger Martino Martini, an Italian Jesuit astronomer, was returning to the mission field. Verbiest commented in a letter to Kircher, "Often, in the sublunary night, we learnt from Father M. Martini not superstitious astrology, but the rules of astronomy and the rise of the stars."

Before making too hasty an assumption that the astronomy of Ricci, Schall, Martini, and Verbiest was state-of-the-art Copernican sun-centered astronomy, it is best to examine more closely what "state-of-the-art" meant back in Europe at the time. "Physics" at the University of Leuven, where Verbiest spent the one semester studying with the mathematician Tacquet, meant the ancient physics of Aristotle. Astronomy was almost entirely medieval astronomy based on the first-millennium work of Arabic-Ptolemaic astronomers al-Farghānī and al-Battānī. A century had passed since Copernicus had written his book *De revolutionibus orbium coelestium* (*On the Revolutions of the Heavenly Spheres*), and Verbiest may have heard some professors at Leuven discussing the systems of Copernicus and Tycho, but only as interesting hypotheses. That was the only nod given to emerging ideas.

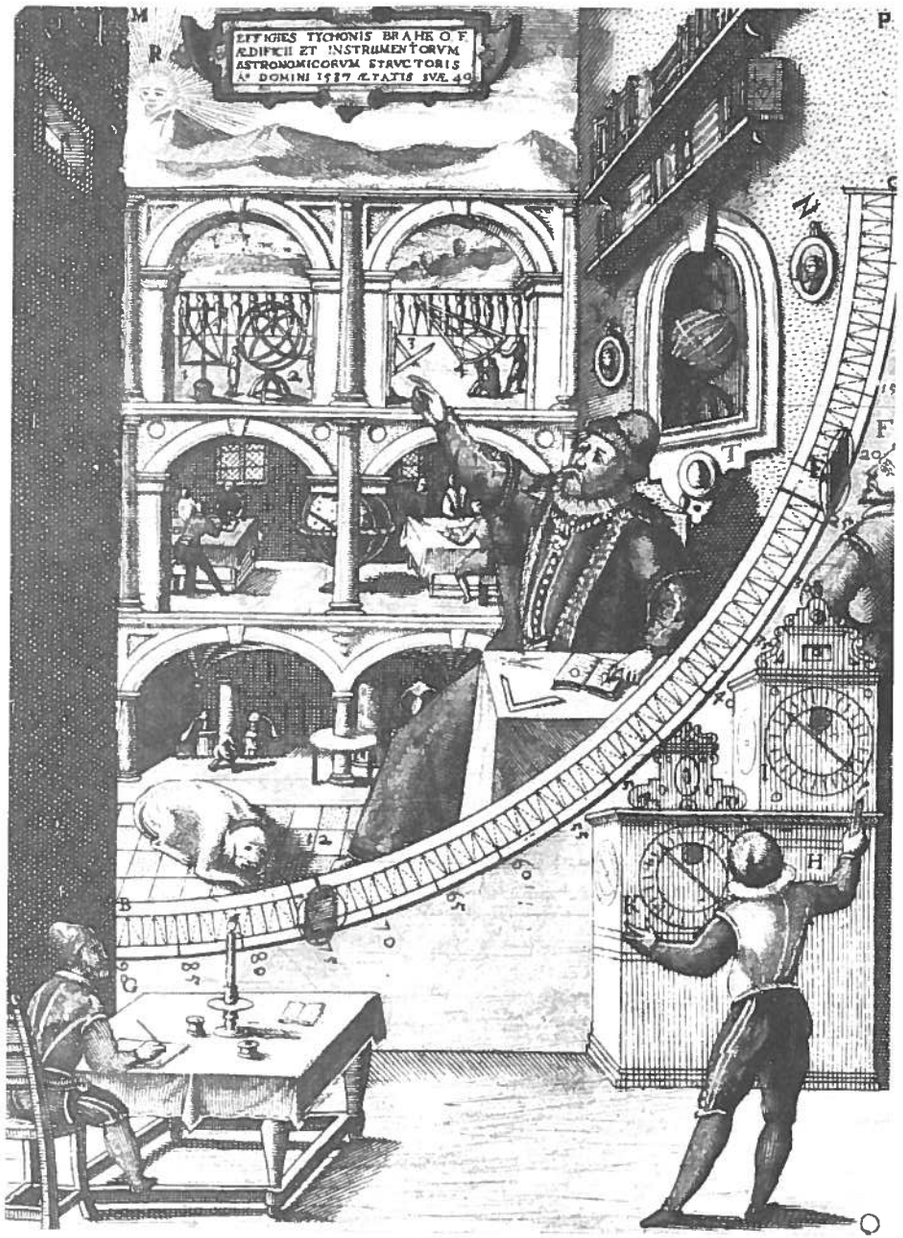
These were the decades during which Copernican astronomy, after three quarters of a century's peaceful coexistence with Catholic authority, increasingly ran into difficulty as Galileo insisted on a showdown. Jesuit scholars



The Tychonic and Copernican cosmological systems from Athanasius Kircher's Iter Exstaticum (Ecstatic Journey) *(1655), which he wrote in the form of a celestial dream. In Tycho's model, Earth remains in the center of the system. The sun orbits Earth, and all the planets orbit the sun. In Copernicus's model, the sun is at the center of the system. All the planets, including Earth, orbit the sun. Although it is not clear in these early drawings, the Tychonic and Copernican systems are geometrically equivalent.*

in Europe found themselves between a rock and a hard place. Being fine mathematicians with a superb scholarly tradition and a passion for advancing technology, they could not deny the validity of the discoveries Galileo was making with a new instrument, the telescope—discoveries that supported Copernican sun-centered astronomy. On the other hand, they could not throw aside the theological traditions of their faith—extrapolated not directly from the Bible but from long-accepted interpretations of it and the authority of St. Augustine and other church fathers—which followed Aristotle in insisting that the cosmos was centered on an unmoving earth. Surprising to the many of us who are taught that, after a few glitches, Copernican astronomy quickly supplanted Ptolemaic and Tychonic astronomy, it in fact took many decades for the change to take place in Europe. In China, Copernican astronomy didn't gain a firm footing until Protestant missionaries arrived in the early 1800s.

Meanwhile, the great, eccentric Danish astronomer Tycho Brahe had thrown scholars like the Jesuits a lifeline by proposing an ingenious model that kept the earth as the unmoving center of everything, with the sun



An engraving from Tycho Brahe's book Astronomiae instauratae mechanica (Instruments for the Restoration of Astronomy), *1598, showing Brahe and his Great Mural Quadrant. The engraving is a reproduction of a wall painting—a scientific and artistic masterpiece—in his palace observatory in Uraniborg, Isle of Hven (now part of Sweden).*

orbiting the earth and all the other planets orbiting the sun. It was a brilliant compromise—the exact geometric equivalent of the Copernican system. Until Isaac Newton's discoveries about gravity in the late seventeenth century, there was little to argue the validity of one system over the other, except that one was decidedly simpler and more economical. Johannes Kepler had made adjustments when compiling his *Rudolphine Tables* in the light of his own reliance on Copernicus and his discovery that planetary orbits are elliptical, but those subtleties went largely undetected by those who used the tables and were not important for astronomers of the Chinese Astronomical Bureau in the day-to-day practice of computing and predicting eclipses. Thus, the *new* European astronomy that the Jesuits brought to China was not, in fact, sun-centered Copernican astronomy. It was the compromise astronomy of Tycho Brahe—a system more in accord with Jesuit teaching.

By the 1660s, Adam Schall von Bell was growing old in the happy knowledge that his time in China had been fruitful for him and his order. He began to consider who might succeed him in the high-ranking positions he had achieved. Ferdinand Verbiest was serving in a missionary post in a western province, but he already enjoyed high regard as a mathematician. Schall chose him as successor. In a letter supporting his choice, he wrote "according to his reputation, [Verbiest] is well versed in all kind of virtues and letters, but especially in mathematics." The Shunzhi Emperor summoned Verbiest to Beijing.

Verbiest's grooming by Schall was meticulous and anything but hasty. The elderly astronomer introduced him to the routine, practical duties he would have to perform, and Verbiest made an arduous effort to master the Chinese language. By 1663 he may have surpassed the expertise of his mentor. When a bell weighing 120,000 pounds was about to be hoisted into a tower, Verbiest calculated a way to increase the power and efficiency of the tackles. Schall heeded his advice and averted a disastrous failure. In the following year, Verbiest received the emperor's permission to construct six astronomical instruments, in the style of Tycho Brahe's magnificent pre-telescope instruments, for the Beijing Observatory. Everything seemed to be moving ahead toward a smooth transition.

the seventeen districts of China, and all had to be calculated six months in advance so that the proper rites could be planned. These rites, with hardly less ceremony than the calendar presentation, included the beating of drums and cymbals and the playing of other instruments to create a din that echoed through the city. According to ancient tradition, the noise supported the sun and moon in their "time of trouble," although Verbiest pointed out that Chinese astronomers understood eclipses very well and knew that this pandemonium could not in the slightest affect the destiny of the sun or moon.

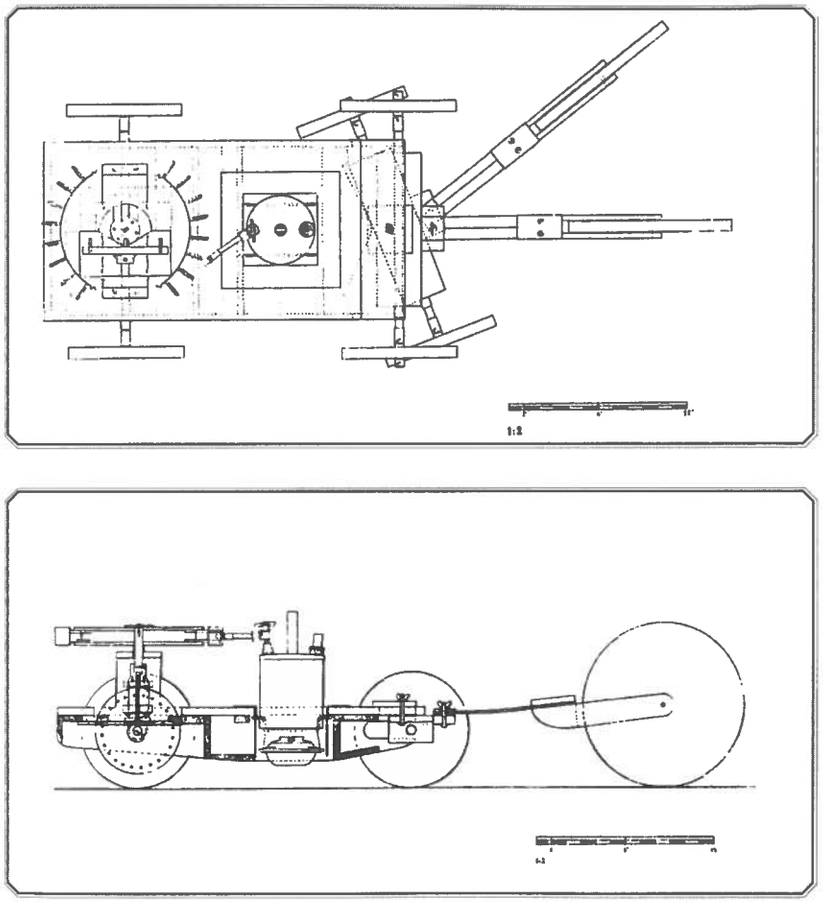
The Kangxi Emperor grew up to be an exceptionally effective ruler, defeating or immobilizing enemies and potential enemies, and securing Qing dominion over all of China. By both military and diplomatic maneuvers he won back his dynasty's Manchu homeland, and Manchuria became part of his empire. In 1696, after Verbiest's death, he personally led an extremely dangerous military expedition across the hostile, scorching Gobi Desert to add Outer Mongolia. Cannons designed by Verbiest played an essential role in these campaigns.

The emperor's skill in management within his empire was no less effective. His love of knowledge in many fields, including a passion for European art and painting, never waned. Verbiest was a trusted friend and mentor who knew that this powerful man was still something of a child at heart, so he presented him with a truly remarkable toy.

In a memoir of his scientific and technological work during twenty-five years in China, Verbiest mentioned an invention that, though he evidently considered it of no great significance, seems especially impressive to us today: the first automobile. It was, in fact, this little steam-driven device that first called Verbiest to my personal attention. Its design came to light in Europe in the late 1680s, when a Bavarian publisher, Johann Kaspar Bencard, published a beautiful edition of Verbiest's *Astronomia Europaea*.

Verbiest reported that he was experimenting with an "aeolipyle," a device dating from ancient times in the West. Basically, an aeolipyle is a closed vessel

in which water is heated until it creates steam that escapes through small nozzles. If the aeolipyle is placed on a pivot, two nozzles faced in opposite directions can turn it. Verbiest's aeolipyle was cylindrical, heated by burning coal beneath it, and fixed in place so that it could not rotate. He used only one nozzle for steam to escape, and he positioned in front of the aeolipyle a horizontal wheel one foot in diameter, with small, wing-like double bars on its outer rim. The steam expelled from the nozzle of the aeolipyle blew against these wings at an angle, causing the wheel to turn, something like the way falling water causes a waterwheel to turn.



Line drawings illustrating Verbiest's "automotive machine," drawn by Ditlev Scheel, 1994.

Verbiest constructed his two-foot-long, four-wheeled vehicle out of light wood. The wheels were probably the delicate, spoked wheels popular in China at the time. Verbiest fixed a vertical wheel (which didn't touch the ground) to the front axle of his little vehicle in order to turn the front wheels. The teeth of that vertical wheel engaged the teeth of a horizontal wheel above it, which was fixed below the "winged" horizontal wheel. When steam from the aeolipyle caused the upper horizontal wheel to turn, the second horizontal wheel, having teeth rather than wings, moved with it and engaged the teeth of the vertical wheel fixed to the axle. Verbiest recorded that the vehicle could go for an hour or more at a considerable speed as long as the coal burned and the aeolipyle continued to produce steam.

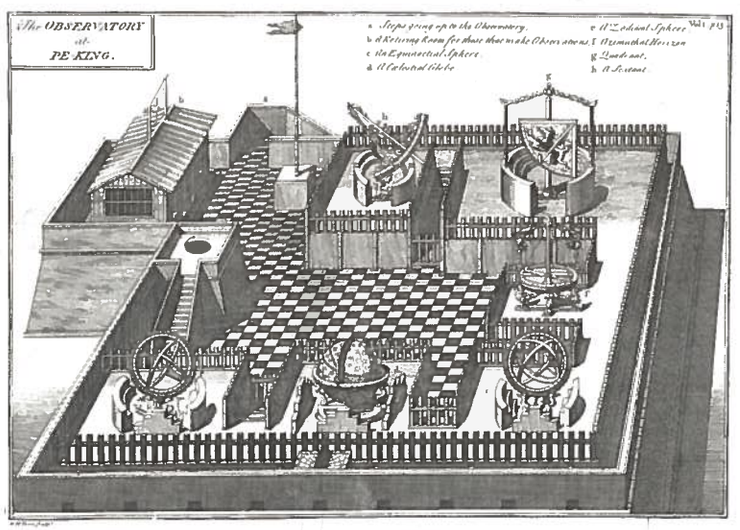
In order to control its direction, Verbiest modified the vehicle so that the rear axle could pivot and attached a tiller to the center of that axle. At the end of the tiller he attached a large, freely moving wheel. By turning the tiller to the right or left and fixing the position with a screw, he could cause the vehicle to move in larger or smaller circles, depending on the angle of the tiller and rear axle. Now he could adjust his "automotive machine" to run within the dimensions of a room or courtyard. Verbiest then added a whimsical refinement: a second nozzle on the aeolipyle, with a whistle, which produced the song of a nightingale. He also fashioned a set of bells into a miniature carillon that played melodies.

Verbiest's inventiveness was not yet exhausted. Employing a similar "method of movement," he caused a little paper boat to sail in circles with bellying sails, and he hid the mechanism so that it seemed the faint hiss of the steam was the sound of the water rushing around the boat. One cannot doubt the delight of the emperor (and, in the case of the boat, the emperor's brother) when Verbiest presented and demonstrated these marvelous toys. However, Verbiest's automobile was too small to carry a human passenger, and a twentieth-century writer's report that Verbiest rode his automotive machine through the streets of Beijing is definitely a flight of imagination.

Such mechanical marvels—and the Kangxi Emperor's seemingly insatiable curiosity about such things—sealed even further the relationship between the two men as the years passed. As Verbiest described in the language of allegory,

> *After Astronomy, marching like a venerable queen between the Mathematical Sciences and rising above all of them, had made her entry among the Chinese and had ever since been received by the Emperor with such an amiable face, all the Mathematical Sciences also gradually entered the imperial Court as her most beautiful companions . . . as if they were gold and precious stones, to find more favour in the eyes of such a great majesty.*

Verbiest's output in the way of astronomical studies, inventions, and magnificent astronomical instruments was prodigious. He sent some of his books, in Latin, to Europe, but most of his writings were only in Chinese and, in his own time, never went beyond the borders of China. In 1669, under his supervision, the old instruments of the Yuan and Ming eras were taken down from their platform on Beijing's eastern wall and replaced by at least nine new instruments, six of them exquisitely made, elaborately decorated, and designed by Verbiest himself in the style of Tycho Brahe.



An engraving of the platform observatory in Beijing (today known as the Beijing Ancient Observatory) from Du Halde's The General History of China. *The astronomical instruments depicted are (clockwise from top left) a sextant, a quadrant, an azimuthal horizon, an equinoctial sphere, a celestial globe, and a zodiacal sphere.*

However, Verbiest's difficulties were not over. The emperor's insistence on showering him with exalted titles conflicted with the Jesuit vow not to aspire to high dignities outside the Jesuit order. At one point even his faithful colleagues Buglio and de Magalhães became openly hostile. They were no doubt inspired in part by justifiable envy: The emperor was giving Verbiest credit for all the best work of the Jesuit astronomers with complete disregard for the substantial and essential contributions of his two associates. But their opposition was also motivated by a sincere and reasonable fear that a foreigner's holding such exalted positions would bring reprisals within the slippery, xenophobic imperial court.

But there was another side to the argument, with which an overwhelming majority of Jesuits and other Christian leaders all over China agreed wholeheartedly: To refuse or renounce honors conferred by the Kangxi Emperor would have been taken as a gross insult, ending Verbiest's valuable relationship with him and probably resonating far beyond Beijing and the Jesuit order to jeopardize the success of the entire Christian enterprise in China. Eventually the Vatican declared Verbiest innocent of any wrongdoing and instructed him to continue his official dignities "without further molestation." Researchers who have delved most extensively into the correspondence and reports having to do with this difficulty, which lasted many years, have been awed to find that "in all the sources we possess, Verbiest's pen does not produce even one word of bitterness, anger, or recrimination." Clearly, he was an extraordinarily focused, self-assured, patient man.

It was on the occasion of an inspection of a set of cannons Verbiest had designed and cast that the Kangxi Emperor turned aside and asked to see Verbiest's church and residence. After a two-hour visit, the emperor "by his own hand" created two large Chinese characters and sealed them with the imperial stamp as a gift to the church, where "they render[ed] us great prestige and respect."

Verbiest worked at the Beijing Observatory until his death at age sixty-five on January 28, 1688. In his final communication with the emperor, he wrote,

Sire, I die content, since I have used almost all the moments of my life in the service of Your Majesty. But I very humbly beg Your Majesty to remember after my death that in all I have done, I have had no other view than to procure, in the person of the grandest king of the Orient, a protector for the holiest religion in the universe.

His dying hope temporarily became a reality in the Chinese Edict of Toleration in 1692, which officially permitted the preaching of Christianity in China. Sadly for his legacy, controversies involving the papacy and the Jesuits over such matters as whether a Chinese who became a Jesuit could administer the Catholic sacraments, whether it was right to have Christianity accepted as one of four religions tolerated in China, and disputes among missionaries of different orders, would plague the Christian church in China for many years.

With the eventual failure of the Jesuit Chinese mission, and the triumph of Copernican over Tychonic astronomy in the West and eventually in China, Verbiest's earnest endeavors essentially came to little. His beautiful instruments still stand in Beijing, but they are artifacts, and his name has been almost entirely forgotten. The Kangxi Emperor's has not.

A 2009 photograph of the Beijing Ancient Observatory. Instruments from left to right are the azimuth theodolite (1715), altazimuth (1673), ecliptic armillary sphere (1673), celestial globe (1673), and "new" armillary sphere (1744).