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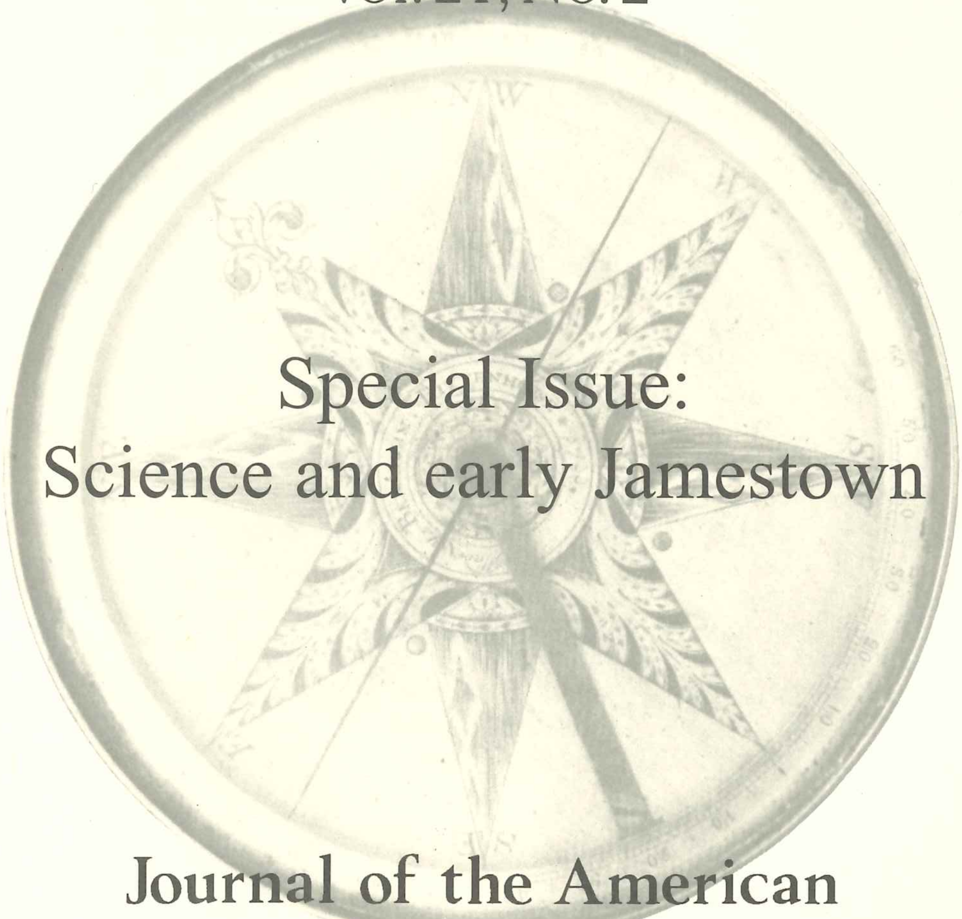

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The Adventures of Captain John Smith Among the Mathematical Practitioners: Cosmology, Mathematics, and Power at the Time of Jamestown

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While exploring the Chickahominy River by canoe in December 1607, Captain John Smith was ambushed by 200 Powhatan Indians and chased into the swamp. Wounded by arrows and mired in the cold mud, Smith surrendered and was led to their chieftain, Opechancanough. Smith played for time. "I presented him with a compasse diall," Smith wrote in his *True Relation*, "describing by my best meanes the use thereof, whereat he so amazedly admired, as he suffered me to proceed in a discourse of the roundnes of the earth, the course of the sunne, moone, starres and plannets."[1] Smith added that the Indians also "marvailed at the playing of the Fly and Needle, which they could see so plainely, and yet not touch it, because of the glasse that covered them."[2] Notwithstanding the fascinating show, his captors had him tied to a tree an hour later and were preparing to shoot when Opechancanough held the instrument aloft and spared his life.

For the next month, Smith was alternately fêted and condemned while being paraded around various Indian villages. At last, he was brought before Opechancanough's father-in-law, the supreme chief, Powhatan. Powhatan questioned Smith about the colonists' intentions and held a trial of his prisoner. After debate among the Indians, Smith was forced to lie down on a large stone slab. Just before a warrior was to bash in his head, the chief's young daughter, Pocahontas, threw herself across Smith and asked that his life be spared. (Fig. 1) Smith was then released on the condition that he pledge loyalty to Powhatan as a subservient chieftain. Although Pocahontas, a mere child of nine or ten years, appears to have played a choreographed role in a shaming ritual (what better way to humiliate a brash soldier than to have him saved by a female child?), Smith was convinced that he owed his life to her.[3]

This mythic tale of Smith's escape by virtue of his pocket sundial and an Indian princess reveals more than Smith's ingenuity and ability to embellish a good story. The compass dial represents the clash of two cosmologies – that of the Indians and European settlers. It embodies the belief that the smallest things mirrored the large, that

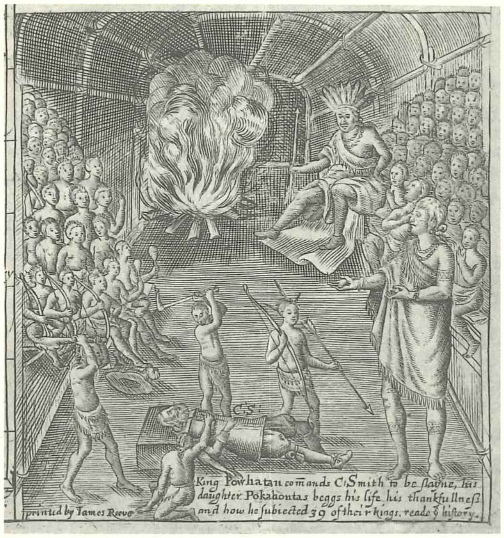

Figure 1. Pocahontas "saves" the life of Captain John Smith, from Smith's *The Generall Historie of Virginia* (1624). Courtesy of Houghton Library, Harvard University (STC 22790).

number was the key to God's creation, and that by means of mathematical instruments, men could dominate that world (or at least extricate themselves from tight spots!).

Who Was John Smith?

When John Smith (1580–1631) arrived on American shores at the age of twenty-seven, he was a seasoned adventurer who had served Lord Willoughby in Europe, had sailed the Mediterranean in a merchant vessel, and had fought for the Dutch against Spain and the Austrians against the Turks.[4] In Transylvania, he had been captured and sold as a slave to a Turk. The Turk had sent Smith as a gift to his girlfriend in Istanbul, but Smith escaped and fled through Russia and Poland. In the midst of these adventures, Smith was shipwrecked, enriched by piracy, and thrown into the sea as a human sacrifice to a storm. After further escapades–real or embellished–in Europe and North Africa, he returned to England around 1604.

In London, Smith signed up with the Virginia Company to plant a settlement on the Chesapeake. He set sail in late December 1606. After the forgoing ordeals, the prospect of four hard months at sea might have seemed a piece of cake to Captain Smith, but he took part in a mutiny and arrived at Jamestown in chains. He was held prisoner until the letter of instruction of the Virginia Company – sealed until the colonists had landed – announced him to be one of the colony's governing counselors. So it was that in June 1607, Smith began his embattled leadership of the colony.

Jamestown was fraught with problems, including a shortage of food, water, and supplies and an abundance of dissent, laziness, and efforts to desert. Smith was reviled and revered. In the midst of the chaos, he left Jamestown to explore the Chesapeake Bay area not only in search of food and water, but also in search of navigable passages to the Pacific and marketable commodities. This brings us to the episode at the heart of this paper. Our analysis of what Smith's sundial meant to him will show him to be not only a swashbuckling soldier-adventurer, leader of the Jamestown colony, and explorer, but also a mathematical practitioner, a cartographer of North America, and the author of seamen's manuals.

Smith's Cosmology

Captain John Smith described his instrument as a "round Ivory double compass Dyall...[a] Globe-like Jewell, [that demonstrated] the roundness of the earth, and skies, the spheare of the Sunne, Moone, and Starres, and how the Sunne did chase the night round about the world continually; the greatnesse of the Land and Sea, the diversitie of Nations, varietie of complexions, and how we were to them Antipodes, and many other such like matters."[5] Although recent movies have misrepresented Smith's device as a pocket compass, it was a type of pocket sundial made in Europe and contained in a hollow ivory sphere.[6] (Fig. 2) When opened, one hemisphere contained a magnetic compass whose wire needle was glued to the underside of a card painted with a wind rose. The card – or fly – spun on a pivot and indicated north. The fly was protected by glass held down by a brass sundial that stretched across the opening. Inside the other hemisphere, there typically was a brass volvelle that showed the phases of the moon and could be used to determine the times of tides or to convert the sundial into a moon dial. The exterior of the ivory sphere was often ornamented with delicate patterns, or, as in Smith's example, could be inscribed with the great celestial circles – i.e., the ecliptic, the Equator, the Tropics of Cancer and Capricorn, Arctic and Antarctic circles, and the colures – demarcating the path of the sun and planets in the heavens.

Figure 2. Ivory globe compass sundial, French, 17th century, similar to the sundial mentioned by Smith. Courtesy of the Trustees of the British Museum (inv. 1926,1016.3).

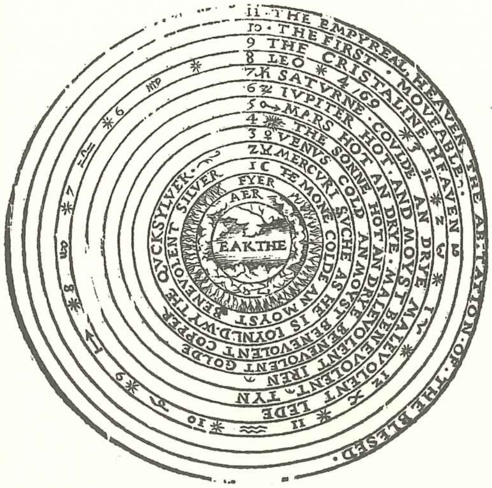

Figure 3. Ptolemaic system of the world from Thomas Blundeville, *His exercises* (1594).

Smith's sundial was a powerful token, a model of the universe he could hold in the palm of his hand. In shape and inscribed detail, it mirrored the cosmic sphere of Aristotle and Ptolemy. According to this view, the earth was located at the center of a finite universe and encircled by the moon, sun, planets, and fixed stars (each generally thought to be carried in its own sphere). (Fig. 3) Although some astronomers advocated the new theory proposed by Copernicus of a sun-centered system of the world, they were the minority, and there was no concrete evidence at this time to prove that it was better. In any case, a navigator need not choose between one cosmology or the other in order to find his way across the seas. All his instruments worked on the premise that the earth was fixed and the celestial bodies revolved around it.

Just as the heavenly sphere was represented in miniature on the ivory globe, the magnetic virtues of the earth were mirrored in the tiny compass needle. Smith might have subscribed to William Gilbert's view that magnetism was a mysterious, animistic power flowing through the world, which caused the earth to rotate, held the moon in its orbit, and controlled the tides.[7] He likely endorsed the common view that stars and planets exerted heavenly influences on the earth.[8]

This sort of interconnectedness was typical of the Renaissance belief in the unity of nature, the great chain of being, and the correspondences between macrocosm and microcosm.[9] All parts of the sublunary world, including the political sphere or human body, were mirrors of the celestial world and heavenly order. Almanacs containing astronomical tables of use to navigators also offered astrological forecasts on politics and weather, as well as medical images of the "man of signs" relating parts of the human body to their ruling signs of the zodiac.[10] Political pamphlets compared the spheres of state to the heavenly spheres, while physiological tracts compared human anatomy to the body politic.[11] (Figs. 4 & 5) A disturbance in one sphere could cause a disturbance in a corresponding sphere. These beliefs traveled to the New World, as seen in Samuel Purchas's analysis of the hardships faced by Jamestown's first settlers:

> True it is, that some emulations did even then becloude that morning Starre, and some disastrous Comets did arise in that Hemisphere, in place of better Starres, shining rather with combustion in civill broiles, and bralls, then comfortable illumination and influence to the common good: these disorders were attended with idlenesse of the most, sicknesse of many, and some dyed. A cleare skie did afterwards appeare in their agreement on the choise of Captaine *Smith* for their President, who having before fallen into the hands of the Virginians, had beene presented Prisoner to *Powhatan*, where he tooke advantage by that disadvantage, to acquaint himselfe with the State and condition of the Countrie and Inhabitants.[12]

To the Renaissance mind, such disparate things like stars, weather, illness, and civil disorder went together. This is why John Smith could use his pocket sundial as inspiration for his lecture to the Powhatans on astronomy (heavens), geography (earth), nations (politics) and ethnography (man). He saw in his ivory, compass sundial a microcosm of the universe.

Number as the Key to Knowledge

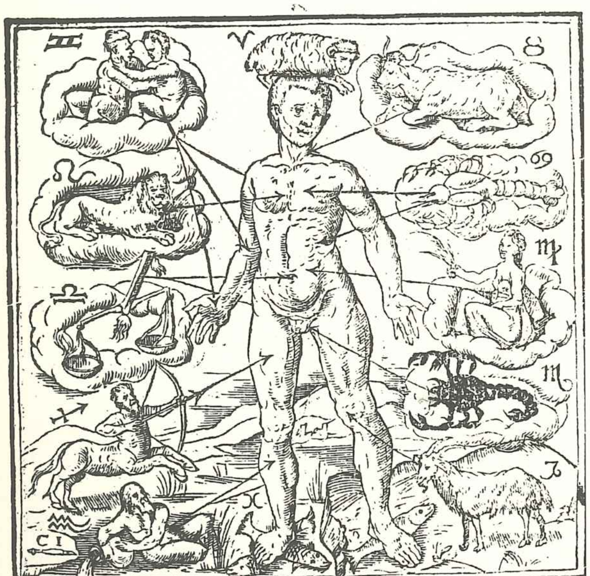

Figure 4. Man of Signs from Leonard Digges, *A Prognostication everlasting* (1586).

Smith's sundial embodied mathematical projections of the sun's path through the sky and motions of shadows on a horizontal surface, and as such was as much a mathematical instrument as an astronomical one. For those Renaissance scholars influenced by Neo-Platonic and Pythagorean writings, mathematics was the key to unlock Nature's secrets. It was second only to theology as a path to divine, hidden truths. Nicholas of Cusa, John Dee, and others

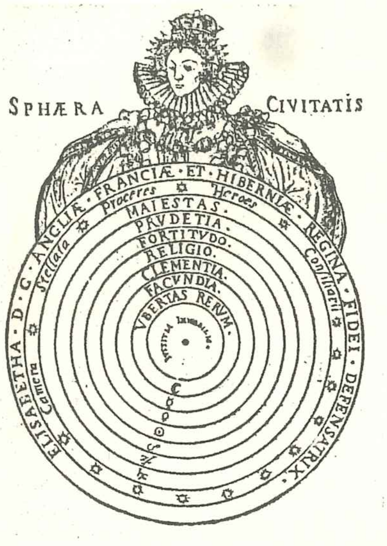

Figure 5. Image of Queen Elizabeth as the Prime Mover of the cosmic spheres, from John Case, *Sphaera civitatis* (1588).

maintained that God "created all things in *Number*, *Waight*, and *Measure*."[13] Indeed, the act of creation had been a mathematical process:

> *All thinges...do appeare to be Formed by the reason of Numbers. For this was the principall example or patterne in the minde of the Creator*....In God the Creator,...his *Numbryng*, then, was his Creatyng of all thinges. And his Continuall *Numbryng*, of all thinges, is the Conservation of them in being.[14]

This suggested, on one hand, that a mathematical study of Nature would lead to a better understanding of God; and on the other hand, that the scholar had God's assurance that mathematics was a valid approach. Analysis of mathematical relationships and harmonies, however, was not restricted to an idealized world within the investigator's mind. Experiments were welcomed. The authority of the senses replaced that of ancient texts, and scholars began to build up museum study collections. Since the microcosm was a faithful reflection of the macrocosm, numerical methods could be applied successfully at all corresponding levels of nature. Dee went so far as to quote Pico de Mirandola, "By Numbers, a way is had, to the searchyng out, and understanding of every thyng, hable to be knowen."[15]

Although a neo-Platonic emphasis on number certainly could and did become the foundation of natural magic and mysticism,[16] it also encouraged a new, mathematical approach to natural philosophy. It has been argued, for instance, that Galileo drew upon such tenets when he treated motion in abstract mathematical terms rather than with the Aristotelian four causes.[17]

The revival and printing of ancient texts also enabled mathematics to take a more practical or Vitruvian turn in the mid-16th century. In *De architectura*, Vitruvius gave mathematics a central and applied role in architecture, surveying, fortification, simple machines, astronomy, optics, and sundials. In England, the Vitruvian approach found impetus in the wave of economic and social changes that took place during the Tudor period. The transfer of monastic property into private hands, the enclosure of farms, and the growth of urban centers demanded skilled surveyors to establish boundaries.[18] Overseas trade and exploration of new worlds required new navigational methods to set a course through open water.[19] A relatively new sense of time pressure among men of business augmented the consumer market for portable sundials.[20]

Unfortunately, the mathematical fundamentals of surveying, navigation, and time finding were, until the 16th century, taught only through Latin and Greek texts, whereas the necessary surveyors, navigators, and sundial artisans were unskilled in those languages and untrained in mathematics. So how were the ranks of these practitioners augmented, and how were practitioners trained in the latest techniques?

A number of college-affiliated men led the way in developing new mathematical methods and instruments to simplify the required work and, even more critically, they offered instruction in the vernacular to the new mathematical practitioners. A fellow of All Souls College, Oxford, Robert Recorde published *The Ground of Artes* (1543) and *The Whetstone of Witte* (1557) on arithmetic and *The Pathway to Knowledg* (1551) on geometry. Recorde's enthusiastic endorsement of mathematics is clear from his titles. Leonard Digges of University College, Oxford, and his son, Thomas Digges, educated at Cambridge, wrote two surveying textbooks, *A Boke named Tectonicon* (1556) and *A Geometrical Practise, named Pantometria* (1571). These introduced angle-measuring instruments such as the theodolite and were addressed not to the learned, but to "Surveyors, Landmeters, Joyners, Carpe[n]ters, and Masons."[21]

The man, however, who perhaps best endorsed both the Neo-Platonic and Vitruvian approaches was John Dee, the polymath of Trinity College, Cambridge, and astrologer to Edward VI, Mary, and Elizabeth. In his "Mathematicall Praeface" to Henry Billingsley's English translation of Euclid (1570), Dee showed not only his Neo-Platonic inclinations (as discussed above), but also his Vitruvian side when he included among the mathematical sciences perspective optics, astronomy, music, cosmography, astrology, statics, architecture, simple machines, time finding, plumbing, warfare and gunnery, surveying, geography, and navigation (the most relevant for our understanding of Jamestown).

The Mathematical Art of Navigation

John Dee offered the first, original English definition of navigation:

> The Arte of Navigation, demonstrateth how, by the shortest good way, by the aptest Directio[n], & in the shortest time, a sufficient Ship, betwene any two places (in passage Navigable,)...may be co[n]ducted.[22]

However, the shortest and safest paths were not always one and the same. In coastal waters and seas like the Mediterranean, mariners found their way by means of landmarks, tide tables, magnetic compass, and rutters, which showed the compass bearings (or rhumb lines) to their desired destinations. In mid-ocean there were no landmarks and rutters to guide seamen. On a globe, rhumb lines ceased to be straight lines and became spirals. Moreover, sailing by compass bearings was unreliable over large distances, because the magnetized needle was found to point east or west of true north at different places on the globe. Therefore, oceanic voyages required different navigational methods than sailing in coastal waters.

Once the Portuguese crossed the Equator in 1471 and explorers set out across the seas, it became necessary for navigators to use the stars and sun as guides and have a rudimentary understanding of astronomy and geometry. To get from Europe to the Americas, the mariner followed a method known as running down the latitude. He sailed north or south to the latitude of his destination, and then west or east along that line until he made landfall. Latitude was found readily by observation of the altitude of the sun and key stars with instruments borrowed from the astronomer or newly invented for the purpose, and then making particular mathematical corrections. Longitude was an extremely difficult problem and one not sufficiently solved until the mid-18th century. Although in the first half of the 16th century, scholars proposed new methods involving the observation of eclipses, lunar distances, or time measurements, mariners had to rely on dead-reckoning based on estimates of the speed of their ship and the course made good.[23]

In England, the belief that mathematical knowledge was essential to mariners was promoted by John Dee and advanced by Sir Walter Raleigh. Dee put the point most sharply: "What nede, the *Master Pilote*, hath of other Artes, here before recited, it is easie to know: as, of *Hydrographie*, *Astronomie*, *Astrologie*, and *Horometrie*. Presupposing continually, the common Base, and foundacion of all: namely *Arithmetike* and *Geometrie*."[24] To that end, Dee took it upon himself to train navigators in the use of new methods and mathematical instruments. In the late 1540s, Dee had traveled to the Flemish Low Countries where he studied with Gemma Frisius, the mathematician and cosmographer, and Gerard Mercator, the geographer, and befriended Pedro Nunes, the chief royal cartographer of Portugal. Dee returned to England in 1551 bearing new astronomical instruments – a cross-staff and astronomical ring of Gemma Frisius's design and a pair of Mercator's globes. He became a consultant to the Muscovy Company (formed in 1555 by Sebastian Cabot to find the Northwest Passage). Dee prepared nautical charts and instructed crew members in cosmography before they set sail for North America in 1576 with Martin Frobisher or 1583 with Sir Humphrey Gilbert.[25]

Around 1582, Raleigh hired the Oxford astronomer, Thomas Harriot, to tutor his sea captains in London. With the death of Sir Humphrey Gilbert, Raleigh inherited his half-brother's interest in colonizing North America. Harriot drew up navigational instructions for Philip Amadas and Arthur Barlowe whom Raleigh dispatched to explore the coast from Florida to New England in 1584 to select a place for a settlement. The following year, Harriot accompanied Sir Richard Grenville on his voyage to Roanoke Island on the Outer Banks of North Carolina.[26] Harriot spent about nine months at Roanoke, and established a metallurgical and alchemical laboratory there.[27]

The cause of training navigators was also taken up by Robert Recorde. Recorde dedicated his *Whetstone of Witte* to the governors of the Muscovy Company, and he wrote an astronomy textbook, *The Castle of Knowledge* (1556) for the use of the Company's navigators.[28] Five years later, Richard Eden translated Martin Cortés's *Arte de navegar* into English. The last quarter of the sixteenth and first quarter of the seventeenth centuries saw an explosion in the number of new English tracts written to instruct unlettered seaman on better ways to do their jobs. Thomas Digges, for instance, appended "Errors in the Arte of Navigation commonly practized" to the 1576 edition of his father Leonard's almanac, *A Prognostication everlastinge*. William Cuningham offered mariners the first English book on cosmography, *The Cosmographical Glasse* (1579).

As scholars, educators, and reformers, the authors aimed to improve English navigation and promote settlement of the New World. That the principal sea captains took them seriously is known by the fact that Frobisher took the *Castle of Knowledge*, *Cosmographical Glasse*, and *Arte de navegar* on his first voyage in 1576.[29] John Smith was himself schooled in the Vitruvian works of like-minded reformers, including Thomas Digges, William Bourne, Robert Norton, Thomas

Smith, Edward Wright, John Tapp, Martin Cortés, John Davis, Lucas Janssen Wagenaer, Edmund Gunter, John Aspley, Robert Norman, William Borough, and Robert Hues. William Barlow spoke for many when he said in *The Navigators Supply*:

> A great helpe also would it be for the furtherance of skill, if those that are practisers in that Arte [of navigation], and such as are Students of the Mathematikes, might often conferre together. For except there be a uniting of knowledge with practise, there can be nothing excellent: Idle knowledge without practise, & ignorant practise without knowledge, serve unto small purpose.[30]

Smith as Teacher and Practitioner

Smith left Jamestown for England in 1609, but was soon after dispatched by London merchants to explore and chart the waters of New England in 1614 and 1615. It was in the spirit of the English mathematical reformers, that Smith published accounts of his Virginia and New England expeditions that were notable in cartography and scientific detail.[31] He also published the first English manual for seamen, *An Accidence or The Path-way to Experience. Necessary for all Young Sea-men, or those that are desirous to goe to Sea* (1626). The book offered practical advice on various duties aboard ship and explained terms related to rigging, types of vessels, and ordnance. It also explained the navigational instruments and skills required of a seaman. An enlarged version appeared a year later with a new title, *A Sea Grammar,* and it was followed by *Advertisements for the unexperienced planters of New England or anywhere* (1631). These were aimed at would-be colonists. Smith said that he did not write them "as an instruction to Marriners nor Sailors...But as an intraduction for such as wants experience, and are desirous to learne what belongs to a Sea-man." [32]

Even so, Smith's books provide a good summary of what the navigator must know and the books that would train him in his art. Smith advised:

> For to learne to observe the Altitude, Latitude, Longitude, Amplitude, the variation of the Compasse, the Sunnes Azimuth and Almicanter, to shift the Sunne and Moone, and to know the tydes, your roomes [rhumbs], pricke your card, and say your Compasse, get some of those bookes, but practise is the best.
>
> *Master Wrights* errors of Navigation.

Master Taps Sea-mans Kallender.
The Art of Navigation.
The Sea Regiment.
The Sea-mans secrets.
Wagganour.
Master Gunters workes.
The Sea-mans glasse for the skale.
The new attracter for variation.
Master Wright for the use of the Globe.
Master Hewes for the same.[33]

Although some such how-to books were written by weathered sea captains, many were penned by mathematicians who preferred to keep the salty sea air at some distance. The scholars were interested to learn from the experience of sea-going practitioners, but the reverse was not always true. As parties to high and low culture, there was not

Figure 6. "Experience" and "Art" share information on the frontispiece of John Seller's *Practical Navigation* (1669). Courtesy of Adler Planetarium & Astronomy Museum, Chicago, Illinois.

mutual respect. Sailors resented the efforts to reform them and distrusted the instructions of mathematicians. They were suspicious of "these tap-room pilots, these men with their great mappemondes who always carry their spheres with them, these men who from always looking at the sun and the moon and the stars and the heavens while they are sailing run the ship aground." The sailors would rather trust in:

> sea-going pilots, who go from pages to cabinboys and from cabinboys to sailors, and from there they push their way upward until they become mate or pilot, because the experience of these men is a living knowledge, not a painted one, of the land, of the sea, of the birds, of the sea weed, of the seals, of the Cape of Good Hope, and of the depths where they throw their lead, of the parts of the sea that are charted, and of the coast; even the fish that follow the ship they catch for information about their voyage, and about the latitude where they are.[34]

Captain Smith was the first to agree that practice was best, a point he reinforced repeatedly in his manuals for those that would go to sea. On ordnance and gunnery, for example, he referred readers to texts by Thomas Digges, William Bourne, Robert Norton, and Thomas Smith, but hastened to add, "Any of these will shew you the Theoricke; but to be a good Gunner, you must learne it by practise."[35]

Scientific Instruments Taken to Virginia

The trick, then, for the would-be reformers was to incorporate theory and practice in the design of simple instruments and methods that acknowledged the seaman's, surveyor's, or gunner's preference for rules-of-thumb and disdain of mathematical dainties. What were these new instruments and which ones found their way to the shores of North America?

Again, Captain John Smith offers us a ready list in his books, as does John Dee and Thomas Harriot in their instructions to the earlier explorers. As "Instruments fitting for a Sea-man," Smith recommended "Good Sea Cards" – i.e., good nautical charts – and "compasses so many paire and sorts as you will" to prick off distances on charts and scales. For guiding the ship, the fundamental instrument was to be a magnetic compass mounted in gimbals and protected in a bittacle in the steerage room. Its fly was painted with a polychrome, thirty-two-point wind rose. A "dark compass" with a black-and-white wind rose was best for easy reading at night, and an azimuth compass was the means to determine the variation of the needle from true north and the sun's position east or west of south. According to Smith, the ship's pilot kept a lodestone in his sea chest to remagnetize the needles when necessary. He kept track of the time elapsed and ship's direction with a half-hour sand glass and pegs on a traverse board.[36] A log line and minute glass could be used to estimate the speed of the ship in knots, but Smith observed "that [dead reckoning] is so uncertaine, it is not worth the labour to trie it." In order to plumb the depth of water beneath his keel, the seaman dropped a weighty lead on a dipsie line in deep water, or a lighter lead on a sounding line in shallow. The leads had tallow tucked in their bottoms in order to draw up samples of the sea floor.[37]

These were the tools of coastal navigation and loxodromic sailing, but to venture across the Atlantic a pilot needed more. Smith acknowledged the three primary methods for finding latitude – observations of the altitude of the sun at noon; of the azimuth and almucantar (elevation) of the sun before or after noon; or of the altitude of the Pole Star at night.[38] Angle-measuring instruments best suited for these tasks included the cross staff, backstaff, mariner's astrolabe, or quadrant.[39] For finding the local time by day, Smith employed a sundial or astrolabe quadrant; time at night was found by means of a nocturnal. If Smith ever had onboard a planispheric astrolabe with star pointers, it could have been used for all of these measurements and more, but such a complex instrument would have been a luxury.

As advised by Dee, Martin Frobisher's kit for 1576 was more extravagant than Smith's. In addition to the essential astrolabe and cross staff, Frobisher took a surveyor's theodolite, a blank metal globe on which to inscribe newly charted regions, an armillary sphere, a nautical sphere for solving astronomical problems useful for navigation, an azimuth compass, a universal sundial, an astronomical ring, a level (perhaps for artillery), eighteen sand glasses (identified as hour glasses, but more likely of different running times for the watches and log, with duplicates to insure against breakage), and twenty diverse compasses (most likely assorted mariner's compasses as well as dividers, drawing compasses, and Dee's new "paradoxall" compass). Most of the instruments were made by master craftsman, Humphrey Cole, of London.[40]

If these were representative of the sea-going instruments, what might we expect to find on land? Sir Humphrey Gilbert's ill-fated expedition in 1583 included a land surveyor, Thomas Bavin, to whom instructions survive. In order to sketch maps, Bavin was told to take parchment, paper, quills, ink, colored powders, pensyll brushes, black lead, a pair of brass compasses and other drawing instruments, a plane table, and a magnetic compass. To find latitude, Bavin had a cross staff. To determine magnetic declination and dip, he had the latest inventions: a universal, self-orienting sundial (which would show true north), a variation compass, and a dip needle. The sundial was also to be used to find the time and to regulate three good, spring-driven clocks. Longitude was to be found by comparison of the local time of a solar eclipse (given by the clocks) with that predicted for London.[41] Harriot, too, had spring-driven clocks with him in Roanoke, along with the most modern mathematical and navigational apparatus, burning glasses, and his chemical equipment.[42] Remnants of such instruments have been recovered from excavations at Jamestown and the sites of other early Virginia settlements. These include dividers, pocket sundials, a magnetic compass, and chemical apparatus. More finds are to be expected as the digs continue.[43]

It is worth noting how "modern" the instruments taken by Frobisher, Gilbert, Harriot, and Smith were. Although the mariner's compass and planispheric astrolabe were used for navigation in the Middle Ages, the other instruments were borrowed from astronomers in the late 15th and 16th centuries and modified greatly to accommodate seamen's needs. The earliest known nautical use of a quadrant was 1460; a mariner's astrolabe, 1481; a cross-staff, 1515. The log for measuring the speed of a ship was first described in 1574 and not widely used at sea until the 1590s. The backstaff for observing the sun's altitude without looking at it directly was not invented until 1595. Variation compasses and dip needles were first described in 1581, just two years before Bavin set out.[44]

Captain John Smith understood well how bold action and new mathematical tools and technologies could be joined to explore, subdue, and shape the world. Smith included a portrait of himself on his important map of New England, published in 1616 and 1624 in his *Generall Historie*. (Fig. 7) In the corners we see troops, a globe and dividers, soldier on horseback, and a ship – symbols of Smith as a man of action. Below the portrait, poet John Davies of Hereford praised Smith:

> These are the Lines that shew thy Face; but those
> That shew thy Grace and Glory, brighter bee:
> Thy Faire-Discoveries and Fowle-Overthrowes
> Of Salvages, much Civilliz'd by thee
> Best shew thy Spirit; and to it Glory Wyn;
> So thou are Brasse without, but Golde within.
> If so; in Brasse, (too soft smiths Acts to beare)
> I fix thy Fame, to make Brasse Steele out weare.[45]

Figure 7. Smith as Admiral of New England, from his map of the same in his *Generall Historie* (1624). Courtesy of Houghton Library, Harvard University (STC 22790).

Davies compared Smith to a finely engraved brass instrument magically tempered to be stronger than steel, and indeed, the swashbuckling and intrepid Smith was a robust mathematical practitioner. He felt invincible. But the English cosmology represented by Smith's sundial was on a collision course with the world of the Native Americans. Thomas Harriot, the scientist-explorer, who tutored Raleigh's sea captains on navigation and spent nine months at Roanoke Island in 1585, wrote that the Indians did not know what to make of "Most thinges they sawe with us."

> Mathematicall instruments, sea compasses, the vertue of the loadstone in drawing yron, a perspective glasse [mirror] whereby was shewed manie strange sightes, burning glasses, wildefire woorkes, gunnes, bookes, writing and reading, spring clocks that seeme to goe of themselves, and manie other thinges that wee had, were so straunge unto them...that they thought they were rather the works of gods then of men.[46]

And so we come full circle to the clash of cosmologies represented by Captain Smith's sundial. Harriot observed what Smith would note twenty years later: that knowledge of mathematics and its worldly applications – in navigation, surveying, optics, chemistry, fortification, gunnery, time keeping, and more – gave the European settlers powers that seemed magical to the Indians. For better or for ill, the explorers would use these powers to dominate the New World landscape.

7. Smith as Admiral of New
l, from his map of the same in
erall Historie (1624). Courtesy
oughton Library, Harvard
ity (STC 22790).

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Notes:

1. John Smith, *A True Relation of such occurrences and accidents of noate as hath hapned in Virginia* (London: 1608), sig. B4r. See also *The Complete Works of Captain John Smith (1560-1631)*, ed. Philip L. Barbour, 3 vols. (Williamsburg: Institute of Early American History and Culture, 1986), 1: 47. Cf. Samuel Purchas, *Purchas his Pilgrimage* (London: 1613), 634.
2. John Smith, *The Generall Historie of Virginia, New-England, and the Summer Isles* (London: 1624), 47; Smith, *Complete Works*, 2: 147.
3. For analysis of multiple versions of the tale and the shaming ritual involving Pocahontas, see Ivor Noël Hume, *The Virginia Adventure: Roanoke to James Towne* (New York: Alfred A. Knopf, 1994), 171-181.
4. P. L. Barbour, *The Three Worlds of Captain John Smith* (Boston: Houghton Mifflin, 1964).
5. Smith, *Generall Historie*, 47.
6. Cf. French spherical, ivory compass sundials, 1624 and circa 1675-1685, British Museum, inv. 1894,1211.9 and 1926,1016.3; German ivory compass dials, circa 1600-1650, Adler Planetarium and Astronomy Museum, Chicago, inv. W-26, M-254; and an ivory globe sundial, Seville, 1626, Collection of Historical Scientific Instruments, Harvard University, inv. HO81Z-17. Smith's dial was different from the fragments of German sundials recovered in archaeological sites in Virginia. See, Nicholas Luccketti and Beverly Straube, *1998 Interim Report on the APVA Excavations at Jamestown, Virginia* (Richmond: The Association for the Preservation of Virginia Antiquities, 1999), 23-25 (ivory dipytch); Alain Outlaw, *Governor's Land* (Charlottesville: University Press of Virginia, 1990), item 219 (pocket compass or compass sundial).
7. William Gilbert, *De magnete...physiologia nova* (London: 1600); William Gilbert, *De mundo nostro sublunari philosophia nova* (posthumously published, Amsterdam: 1651).
8. See Eugenio Garin, *Astrology in the Renaissance* (London: Routledge and Kegan Paul, 1983); Francis R. Johnson, *Astronomical Thought in Renaissance England* (New York: Octagon Books, 1968); Wayne Shumaker, *The Occult Sciences in the Renaissance* (Berkeley: University of California Press, 1972).
9. A good summary is found in E. M. W. Tillyard, *The Elizabethan World Picture* (New York: Vintage Books, 1960).
10. See for instance, Leonard Digges, *A Prognostication everlastinge of right good effect*, rev. Thomas Digges (London: 1585), or issues of this almanac from other years. On medicine at Jamestown, see William Kelso and Beverly Straube, *1996 Interim Report on the APVA Excavations at Jamestown, Virginia* (Richmond: Association for the Preservation of Virginia Antiquities, 1997), 19-22.
11. See William Harvey, *Exercitatio anatomica de motu cordis et sanguinis in animalibus* (Frankfurt: 1628), epistle dedicatory in which Harvey compares the heart to the king and the sun; John Case, *Sphaera ciuitatis* (Oxford: 1588), identifies Queen Elizabeth with the cosmic sphere. Tillyard, *Elizabethan World Picture*, 88-99.
12. Purchas, *Purchas his Pilgrimage*, 632. On Renaissance and early modern beliefs

about comets, see Sara J. Schechner, *Comets, Popular Culture, and the Birth of Modern Cosmology* (Princeton: Princeton University Press, 1997).

13. John Dee, *The Mathematicall Praeface to the Elements of Geometrie of Euclid of Megara (1570)*, ed. Allen G. Debus (New York: Science History Publications, 1975), sig. biiiiv; Nicholas of Cusa, *De docta ignorantia*, book 2, chap. 13; Jasper Hopkins, ed. and trans., *Nicholas of Cusa on Learned Ignorance* (Minneapolis: Arthur J. Banning Press, 1981), 122.

14. Dee, *Mathematicall Praeface*, sig. *.i, the italicized sentences are a quotation from Boethius. See also Allen G. Debus, *Man and Nature in the Renaissance* (Cambridge: Cambridge University Press, 1978).

15. Dee, *Mathematicall Praeface*, sig. *.iv. For more on Renaissance mathematical themes, see Allen Debus, "Mathematics and Nature in the Chemical Texts of the Renaissance," *Ambix* 15 (1968): 1-28; and his introduction to Dee's work.

16. See examples in Shumaker, *Occult Sciences*; Frances A. Yates, *Giordano Bruno and the Hermetic Tradition* (Chicago: University of Chicago Press, 1964); Keith Thomas, *Religion and the Decline of Magic* (New York: Charles Scribner's Sons, 1971).

17. Alexandre Koyré, *Galileo Studies* (Atlantic Highlands, NJ: Humanities Press, 1978); E. A. Burtt, *The Metaphysical Foundations of Modern Physical Science* (London: Routledge and Kegan Paul, 1932).

18. A. W. Richeson, *English Land Measuring to 1800: Instruments and Practice* (Cambridge: MIT Press, 1966), chap. 3.

19. David W. Waters, *The Science and Techniques of Navigation in the Renaissance* (London: Trustees of the National Maritime Museum, 1976).

20. Sara J. Schechner, "The Material Culture of Astronomy in Daily Life: Sundials, Science, and Social Change," *Journal for the History of Astronomy* 32 (2001): 189-222.

21. Leonard Digges, *A Boke named Tectonicon* (London: 1556). For more on mathematical practitioners, see E. G. R. Taylor, *The Mathematical Practitioners of Tudor and Stuart England* (Cambridge: Cambridge University Press, 1968); J. A. Bennett, *The Mathematical Science of Christopher Wren* (Cambridge: Cambridge University Press, 1982); Gerard L'E. Turner, *Elizabethan Instrument Makers* (Oxford: Oxford University Press, 2000).

22. Dee, *Mathematicall Praeface*, sig. D.iiijv.

23. On the history of navigation and its instruments, see E.G. R. Taylor, *The Haven-Finding Art* (New York: Abelard-Schuman, 1957); David W. Waters, *The Art of Navigation in England in Elizabethan and Early Stuart Times*, rev. 2nd ed. (London: National Maritime Museum, 1978); J. A. Bennett, *The Divided Circle* (Oxford: Phaidon-Christie's, 1987); William J. H. Andrewes, ed., *The Quest for Longitude* (Cambridge: Collection of Historical Scientific Instruments, Harvard University, 1996).

24. Dee, *Mathematicall Praeface*, sig. d.iiij.r.

25. Ibid.; John Dee, *The Compendious Rehearsall* (1592) and other autobiographical sources quoted by Allen Debus in his introduction to John Dee, *Mathematicall Praeface*, 2-5.

26. Helen Hill Miller, *Passage to America: Ralegh's Colonists Take Ship for Roanoke*

(Raleigh: North Carolina Department of Cultural Resources, 1983); Waters, *Art of Navigation*, 194, 546, 584-591.

27. On the archaeological excavation of Harriot's laboratory, see Ivor Noël Hume, "Roanoke Island: America's First Science Center," *Colonial Williamsburg*, Spring, 1994. Thomas Harriot, *A briefe and true report of the new found land of Virginia* (Frankfurt: Theodor de Bry, 1590; reprinted, New York: Dover Publications, 1972).

28. Robert Recorde, *The Whetstone of Witte* (London: 1557), sig. a.ii.r; Waters, *Art of Navigation*, 94-95.

29. Invoice for charts, instruments, and books for Frobisher's voyage, 1576, taken from public records, and printed in Waters, *Art of Navigation*, 530-531.

30. William Barlow, *The Navigators Supply* (London: 1597), sig. Lv.

31. John Smith, *A Map of Virginia. With a Description of the Countrey, the Commodities, People, Government and Religion* (Oxford, 1612); John Smith, *A Description of New England: or The Observations, and discoveries, of Captain John Smith* (London, 1616).

32. John Smith, *An Accidence or The Path-way to Experience* (London: 1626), sig. A2. See also Smith, *Complete Works,* 3: 11.

33. Smith, *An Accidence*, 36. Cf. John Smith, *A Sea Grammar* (London: 1627), 83; Smith, *Complete Works*, 3: 27, 111 (full texts of both the *Accidence* and *Sea Grammar* are 3: 5-121). The books Smith recommended were Edward Wright, *Certaine Errors in Navigation* (London: 1610), John Tapp, *The Seamans Kalendar* (London: 1602), Martin Cortés, *The Arte of Navigation*, translated by Richard Eden (London: 1651), William Bourne, *A Regiment for the Sea* (London: 1574), John Davis, *The Seamans Secrets* (London: 1595), Lucas Janssen Wagenaer, *The Mariners Mirrour*, translated by Anthony Ashley (London: 1588), Edmund Gunter, *De sectore et radio* (London: 1623), John Aspley, *Speculum Nauticum: A Looking Glasse, for Sea-Men* (London: 1624), Robert Norman, *The newe Attractive* (London: 1581), William Borough, *A Discours of the Variation of the Cumpas* (London: 1581), Edward Wright, *The Description and use of the Sphere* (London: 1613), and Robert Hues, *Tractatus de globis et eorum usu* (London: 1594).

34. Diogo do Couto's account of the shipwrecks of the Portuguese East Indiamen *Aguia* and *Garça* (1559); reprinted in *História Trágico-Marítima,* ed. Bernardo Gomes de Brito, 2 vols. (Lisbon: 1735-1736); and quoted in Miller, *Passage to America*, 24. Cf. C. R. Boxer, ed. and trans., *Further Selections from the Tragic History of the Sea, 1559-1565*, The Hakluyt Society, 2nd ser., no. 132 (Cambridge: Hakluyt Society, 1968).

35. Smith, *An Accidence*, 33; Smith, *A Sea Grammar*, 69.

36. Smith, *An Accidence*, 11; Smith, *A Sea Grammar*, 11-12.

37. Smith, *A Sea Grammar*, 43-44.

38. Smith, *A Sea Grammar*, 42.

39. Smith, *An Accidence*, 37; Smith, *A Sea Grammar*, 83.

40. Excerpts from the account books for Frobisher's voyage are reproduced in Jane McDermott, "Humphrey Cole and the Frobisher Voyages," pp. 15-19 in *Humphrey Cole: Mint, Measurement and Maps in Elizabethan England*, ed. Silke Ackermann (London: British Museum, 1998). See also Waters, *Art of Navigation*, 530-531. Cf. Dee, *Mathematical Praeface*, sig. D.iiij.r, who recommends to master pilots

"Quadrantes, The Astronomers Ryng, The Astronomers staffe, The Astrolabe universall. An Hydrographicall Globe. Charts Hydrographicall, true, (not with parallel Meridians). The Common Sea Compas: The Compas of variacion: The Proportionall, and Paradoxall Compasses (of me Invented [1559], for our two Moscovy Master Pilotes, at the request of the Company) Clockes with spryng: houre, halfe houre, and three houre Sandglasses: & sundry other Instrume[n]tes."

41. British Museum Add. MS 38823, fols. 3v-5v; printed in Waters, *Art of Navigation*, 538-540.

42. Harriot, *Briefe and true report*, 27. On Harriot's navigational instruments, see Waters, *Art of Navigation*, 584-591.

43. Nicholas Luccketti and Beverly Straube, *1998 Interim Report on the APVA Excavations at Jamestown, Virginia* (Richmond: The Association for the Preservation of Virginia Antiquities, 1999), 23-25 (ivory dipytch); Alain Outlaw, *Governor's Land* (Charlottesville: University Press of Virginia, 1990), item 219 (pocket compass or compass sundial); Beverly Straube and Nicholas Luccketti, *1995 Interim Report, Jamestown Rediscovery* (Richmond: etc., 1996), 25-26, 49-51 (crucibles used for assaying and trials of glassmaking, pitch, tar, and potash); Ivor Noël Hume and Audrey Noël Hume, *The Archaeology of Martin's Hundred* (Williamsburg: Colonial Williamsburg Foundation, 2001), 170, figure 1, item 8, and fig. 20, item 12 (possible cucurbits), fig. 28, item 6 (alembic), fig. 44, items 15, 16, fig. 66, item 11 (dividers); Noël Hume, "Roanoke Island" (artifacts from Harriot's chemical laboratory).

44. On the history of navigational instruments, consult Bennett, *Divided Circle*; W. F. J. Mörzer Bruyns, *The Cross-Staff* (Amsterdam: Vereeniging Nederlandsch Historisch Scheepvaart Museum, Rijksmuseum Nederlands Scheepvaartmuseum Amsterdam, and Walburg Instituut, 1994); Sara Schechner Genuth, "Astrolabes: A Cross-Cultural and Social Perspective," in Roderick and Marjorie Webster, Western Astrolabes, ed. Sara Schechner Genuth and Bruce Chandler (Chicago: Adler Planetarium and Astronomy Museum, 1998); and other sources listed in the Scientific Instrument Commission, "SIC Cumulative Bibliography," http://www.sic.iuhps.org/in_bibrm.htm.

45. Smith, *Generall Historie*, foldout map between 202-203.

46. Harriot, *Briefe and true report*, 27.

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I wish to thank Robert Hicks for leading me to unpublished or little-known archaeological finds of a scientific nature in Virginia.

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Luckketti, *1995 Interim Report,*
25-26, 49-51 (crucibles used for
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15, 16, fig. 66, item 11 (dividers);
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