A prototype wetsuit — one of several innovations presented in the 1590s manuscript MS Osborn a8.

TUDOR TECHNOLOGY

Shakespeare and science

To mark the 450th anniversary of the bard's birth, **Jennifer Rampling** probes how mathematics and technology shaped his era.

Like the plots of William Shakespeare's plays, from *The Merchant of Venice* to *Hamlet* and *Othello*, Tudor science took its inspiration from abroad. However, its dramatis personae include few easy analogues of continental stars such as Nicolaus Copernicus, Johannes Kepler, Paracelsus or Galileo. England and Wales undoubtedly had scholars of international calibre, including the mathematician-astronomers John Dee, Thomas Digges and Thomas Harriot. Yet the expansion of its scientific horizons was driven as much by artisanal and mercantile interests as by university learning or royal patronage. Detailed globes, astronomical instruments and translations of French and Spanish navigational texts offered new tools for mastering both England's coastal waters and the ocean voyages required for intercontinental trade and exploration.

Shakespeare's "scepter'd isle" was a late-comer to Europe's scientific renaissance. The upheavals of the English Reformation

diverted energies that might have otherwise been channelled into exploration. By the time of Elizabeth I's accession in 1558 (six years before the playwright's birth on 23 April 1564), her Spanish and Portuguese counterparts had amassed vast New World territories — and with them, knowledge of new plant and animal species, peoples, geographies and commodities. England's rotting fleet and dearth of native pilots and navigational know-how offered dispiriting prospects for the expansion of either territory or natural knowledge.

A quick scene change to almost 40 years later, towards the end of Elizabeth's reign, and we find the port of London booming and England a maritime power, defending its shores from Spanish fleets and establishing fledgling colonies in the Americas. Goods, people and ideas poured in from continental Europe and beyond, bringing new experiences and expertise. London's presses added to the flow of information. Scientific

best-sellers included almanacs, collections of alchemical and household 'secrets' and vernacular mathematical textbooks such as Robert Recorde's oft-reprinted *Arithmetic, or The Grounde of Arts* (1543).

Enter Shakespeare. Born in Stratford-upon-Avon, by 1592 he was in London as both player and playwright. From temporary stages in inn yards to purpose-built theatres, the capital offered increasing scope for companies of players. There, a growing population of 'mechanical' artisans, instrument-makers, engineers, printers and medical practitioners helped to constitute one of the most sophisticated play-going audiences in history, eager for new material and swift to detect topical allusions. Whatever the causes and effects of the English transformation, we might expect to catch some hint of it on the stage.

For both playwrights and audiences, the connection between global ambition and artisanal know-how would have been hard to miss: new technologies simultaneously ►

Elizabeth I rests her hand on a globe — an instance of technology advertising naval prowess.

► enabled expansion and advertised it. In 1592, the Lambeth-based mathematician and instrument-maker Emery Molyneux presented Elizabeth I with intricate, 65-centimetre globes that tracked the voyages of the English explorers Francis Drake and Thomas Cavendish. The globes' fame helped to promote the use of smaller versions as navigation aids, and even reached the stage: playwright Thomas Dekker referenced "Molyneux his globe". In 1599, Shakespeare's company, the Lord Chamberlain's Men, named their new theatre the Globe — a fitting symbol of Elizabethan aspirations. The unexpected richness of New World discoveries, and the challenges they posed to ancient authorities, forced Europeans to expand their world views even as their voyages put a girdle round the Earth.

Shakespeare's famously sparse biography offers few clues to his own views on the sciences. Young Will may have witnessed the blazing Stella Nova: the supernova spotted by Danish astronomer Tycho Brahe and others in 1572. Unlike comets, the new star had no apparent parallax or proper motion, suggesting that it lay at a great distance from Earth — a novelty where none should have existed, according to the generally accepted Aristotelian model of the cosmos. For Digges, the star offered a potential confirmation of the Copernican system, and an opportunity to advance his reputation through timely publication of his own work on stellar parallax.

Not all observers read the star in that way. For astrologically literate Londoners, stellar novelties might also presage warfare and dynastic change. Shakespeare well

understood the analogy between heavenly and political stability, and the anxieties triggered by inauspicious stars, comets and sunspots (the "disasters in the sun" mentioned by Horatio in *Hamlet*). The playwright's dramatic use of celestial portents does not stretch to promoting a Copernican model, although we may detect a glancing reference to heliocentrism in Hamlet's love letter to Ophelia — "Doubt thou the stars are fire; Doubt that the sun doth move ... But never doubt I love". Only after Shakespeare's death and Galileo's energetic interventions would Copernican ideas take centre stage.

Few Elizabethan scholars pursued astronomy on the scale of Brahe or Galileo, both recipients of princely patronage. (An exception was Harriot — the protégé of Walter Raleigh and Henry Percy, Earl of Northumberland — who mapped the Moon by telescope before Galileo.) Elizabethan science, like Elizabethan dramaturgy, responded to funding priorities, and theoretical advances carried less weight with Elizabeth's government than pragmatic and potentially high-profit schemes to improve navigation, exploit mineral resources or alchemically transmute metals on an industrial scale.

Petitioners to the queen often sought monopoly grants for such projects. Others hoped for financial investment. Apart from utility and personal expertise, proposals

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drew on classical precedents and the latest knowledge from abroad. Grenades, printing presses and fireworks attached to the backs of cats (intended to "raise a tumult" in enemy camps) appear in one manuscript collection of Elizabethan inventions. The anonymous compiler (possibly the engineer and alchemist Ralph Rabbards) combined practical experience of Italian military campaigns with fanciful ideas for adapting ancient inventions — among them, an ingenious design for a wetsuit with adjustable snorkel, for covert attacks on enemy shipping.

The tension between learning and experience, speculation and utility, can also be detected in scholarly works. When John Dee famously surveyed the "Artes Mathematicall" in his preface to Henry Billingsley's 1570 English translation of Euclid, he stressed the value of mathematics in studying both natural phenomena and practical problems — from arranging artillery to compounding medicines. The utilitarian ethos helps to explain why Digges, for all his astronomical skill, served Elizabeth primarily by consulting on the construction of Dover Harbour. Dee, who coined the term "Brytish Empire", eventually left England to pursue his dream of a court-philosopher post abroad.

Only in *The Tempest* does Shakespeare evoke the kind of philosopher that Dee sought to embody: the magus Prospero, whose expertise in natural and occult philosophy grants him the upper hand over the unschooled Caliban and the shipwrecked royal party. Dee, who tried and failed to persuade Elizabeth to sponsor a 'research institute' under his direction, might well have envied Prospero the freedom to experiment without the constraints of patronage. On the whole, the "brave new world" of Tudor knowledge-making lay elsewhere — between the commercially minded Antonio, the eponymous merchant of Venice, and the "rude mechanicals" of *A Midsummer Night's Dream*.

This is the world of Shakespeare's plays, populated with ideas and technologies that his audience would have recognized from contemporary life: clocks, globes, compasses, the distorting 'perspective glass'. Even his famous evocation of England, a "precious stone set in the silver sea", suggests the technique of foiling to create brilliant reflective backings for jewels and mirrors. If Shakespeare declined to furnish later ages with a convenient narrative of Elizabethan science, he surely succeeded in holding up a mirror to the technological and commercial vibrancy of his own age. ■

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