# Forums of Validation and Forms of Knowledge: The Magical Rhetoric of Otto von Guericke's Sulfur Globe

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Controversies over the premature public release of scientific findings concerning such issues as AIDS, cold fusion, and superconductivity have focused attention on the contemporary scientific norm that novel results should first be announced within professional forums for the judgment of peers, before the wider public, governmental agencies, or other public groups are informed. The assumption is that the professional community will first be able to judge the validity of the claim in camera and will then disseminate only reliable findings. It is felt that the authority of science might be undermined by the dissemination of dubious results as well as by revelations of internal uncertainty, argument, and contradiction—apparent concomitants of esoteric science (as noted by Ludwik Fleck over half a century ago[1]), where knowledge only gets stabilized and simplified as one moves to the exoteric circles of the public.

But science was not always organized as it currently is, and in other times communication flowed in different channels with different social meanings. Our current system of science developed through evolving practices and institutions that first began taking shape in the seventeenth, eighteenth, and nineteenth centuries. The inventions of scientific societies, journals, editorial and review procedures, the genres of modern experimental articles and reviews

1. Ludwik Fleck, *Genesis and Development of a Scientific Fact* (Chicago: University of Chicago Press, 1979), pp. 120–122.

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of the literature, grants and awards, the contemporary university, and many other now-taken-for-granted innovations have helped create the social field within which new findings are announced.[2] But how were findings announced before the emergence and solidification of our current forums? And what would the announcement of findings mean within those other social arrangements?

The history of electricity poses this issue sharply, for there we find many curious presentations of what we now consider discoveries, presented in forums and manners that we would not at all consider appropriate for scientific communication and consideration. These public displays and the published accounts of them clearly belong to other traditions and sets of social arrangements. These displays and their accounts are different from social actions that we would now consider scientific. Even as late as the eighteenth century we have such oddities as Stephen Gray's use of a young boy to demonstrate conduction, and the great popularity of the Leyden jar in giving shocks and felling long rows of soldiers. Although we may now simply dismiss these as parlor games and children's amusements (every high-school physics class still keeps such tricks popular), these events brought phenomena into a public space where they might be recognized and accepted as fact by relevant audiences.

## Von Guericke's Curious Sulfur Globe Demonstration

Perhaps the most unusual electrical display is that of Otto von Guericke's sulfur globe, the earliest record of which dates from 1663. After molding a ball out of sulfur and rubbing it with his dry hand, von Guericke would levitate a feather above the ball. As he carried the ball raised on a stick about the room, the feather would float as it followed the ball beneath. To modern eyes, the event might seem more of a magic trick, aimed at our wonder rather than our understanding and critical thought. This odd bit of early science remained out of the main line of the emerging scientific community, and its retrospectively labeled discoveries had to be rediscovered later in the eighteenth century. Yet von Guericke believed he was pursuing natural philosophy in the best way open to him,

2. As a number of scholars—such as Margaret Jacob, in *The Newtonians and the English Revolution, 1689–1720* (Ithaca, N.Y.: Cornell University Press, 1976); Steve Shapin and Simon Schaffer, in *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton: Princeton University Press, 1985); and Tom Gieryn, in "Boundary Work and the Demarcation of Science from Non-Science," *American Sociological Review* 48 (1983): 781–795—have pointed out, these various enclosures have had political, philosophical, and social intentions and consequences.



and he saw himself as part of an emerging new philosophic understanding of the world. This essay will be an exploration of the rhetoric of his account of the display to see what kind of event he thought he was creating and the rhetorical world his account was part of. Particular attention will be given to the socio-political-intellectual world of magic, of which the display seems so much a part.

From the perspective of modern science, Otto von Guericke is known more for his invention of the air pump than for the discovery of electrical repulsion, attributed to the sulfur globe demonstration.[3] Some commentators have also attributed to this demonstration the discovery of conduction, luminescence, and even induction, as well as the invention of the static electricity generator. A modern description of his demonstration would be that he produced a static electrical charge on a sulfur globe, which then attracted certain light materials to it. Upon contact with the globe the light materials (particularly feathers) became charged and were then repelled. The repulsion overcame gravity sufficiently to allow a feather to hover, suspended above the globe. This repulsive force was shown, as well, to be transmitted through a linen thread hanging from the globe. However, while von Guericke did describe this event in his magnum opus *Experimenta nova Magdeburgica* he presented it neither as discovery, nor as electrical—even though electrical attraction had been well known since William Gilbert's publication of *De magnete* in 1600.

This lack of explicit connection with the developing investigation into electricity has led at least one modern commentator to deny von Guericke credit for any electrical discovery: N. H. Heathcote correctly points out that von Guericke was engaged with an entirely different set of problems and mode of thinking, so that what he found and invented and did cannot be properly measured in modern, after-the-fact terms.[4] Whether this disqualifies von Guericke from any credit for his work in displaying previously

3. John Heilbron, in *Electricity in the 17th and 18th Centuries: A Study of Early Modern Physics* (Berkeley: University of California Press, 1979), catalogues a number of near-discoveries of repulsion throughout the seventeenth century, including those of Cabeo (p. 183), Browne (p. 194), Boyle (p. 204), and Huygens (p. 225) as well as that of von Guericke. Not until the observations of Francis Hauksbee published in *Physico-Mechanical Experiments* (London, 1719) was repulsion definitively and robustly identified as a regular phenomenon. Similarly, conduction was not definitively established and communally recognized until the 1731 work of Stephen Gray, "Several Experiments Concerning Electricity," *Philosophical Transactions* 37 (1731): 18–44.

4. N. H. Heathcote, "Guericke's Sulfur Globe," *Annals of Science* 6:3 (1950): 293–304.

unobserved phenomena is perhaps a nicety of moral judgment that we will pass by here, except to comment that Professor Heathcote of University College London published his attack on von Guericke in 1950, following prewar and wartime German nationalistic use of von Guericke's reputation.[5]

Leaving aside issues of national pride, it is clear that von Guericke was operating in a mode of discourse and investigation quite different from that which was gaining dominance over European science in the latter half of the seventeenth century. As John L. Heilbron explains in the standard history of electricity in the seventeenth and eighteenth centuries, to von Guericke the ball was a microcosm of the terrestrial sphere, and the hovering of a feather was an exhibition of one of the eight terrestrial virtues.[6] What we consider the essential feature of the event, the repulsion of the feather, was to von Guericke only a secondary token of inner mysteries or virtues of the universe that he had understood through his deep learning. What he was communicating was an understanding of the constitution and forces of the universe. The feather's hovering was a glimpse into his system and even more a revelation of the power of his learning, establishing his authority to speak for the mysteries of the macrocosm.

Heilbron's account makes von Guericke's work appear as much magical as scientific, although von Guericke never explicitly refers to magic. Nonetheless, his contemporaries and closest philosophical allies Athanasius Kircher and Gaspar Schott gave their publications such names as *Mundus subterraneus* (The subterranean world), *Prodromus Coptus sive Aegypticus* (Messenger of Coptic or Egyptian [wisdom]), and *Thaumaturgus physicus sive magiae universalis naturae* (The miraculous workings of the physical world or the universal magic of nature).[7] Von Guericke was clearly operating within the remnants of the Renaissance revival of magic. Charles Webster points out that although among educated classes during the sixteenth and seventeenth centuries

5. See, for example, Fuchs's catalogue of a 1936 von Guericke exhibit at the Deutsches Museum in Munich (Franz Fuchs, *Guericke Ausstellung* [Munich: Deutsches Museum, 1936]), and Pohl's scientific biography of von Guericke published the same year in conjunction with the exhibit (R. W. Pohl, *Otto von Guericke als Physiker* [Berlin: VDI Verlag, 1936]).

6. Heilbron, *Electricity* (above, n. 3).

7. Athanasius Kircher, *Prodromus Coptus sive Aegypticus* (Rome, 1636); Athanasius Kircher, *Mundus subterraneus* (Amsterdam, 1665); Gaspar Schott, *Thaumaturgus physicus sive magiae universalis naturae* (Wurzburg, 1659).



> there emerged a degree of skepticism concerning the cruder forms of manipulative magic, [there remained] a continuing appeal of such ideas as divine plenitude, metaphysical hierarchies, or the existence of fundamental harmonies and correspondences between the celestial and the terrestrial world. . . . At the least the magus might unlock the potential of occult qualities through exploiting natural magic. . . . It is therefore important not to assume that the decline of popular operative magic entailed the wholesale abandonment of the magical world view.[8]

Indeed, in recent years an extensive literature has argued that many roots of modern science were to be found in magic, and that many of the early scientists perceived themselves as directly part of or indirectly transforming the magical tradition.[9] An examination of von Guericke's text reveals rhetorical features deeply embedded in assumptions coming out of the system of magic. In this paper I hope to show that the magical worldview is not just an explanatory system, but entails a discourse universe with implied social relations, relations to the material and spiritual worlds, political consequences, and a use of language that respects all these contextual particulars. These elements make von Guericke's text a particular kind of rhetorical event not directly equivalent to or translatable into the emerging discourse of the Royal Society.

However, there are other rhetorical elements in the text as well, and the situation is not so easily categorized as an unmixed outgrowth of the magical tradition. The work contains many of the impulses we associate with modern science—mathematization, emphasis on experience, respect for the discoveries of prior natural philosophers, and humility in being part of a long communal effort. These impulses are most clearly expressed in the preface to the reader and are then carried out in various places in the text. In the text there also appear a kind of abstract reasoning, respect for ancient authorities, and the kinds of explanatory systems that are usually associated with scholastic discourse. Nonetheless, in this text, which comes during a time of major transition in science, when science was starting to close in upon itself as an esoteric discourse system, we can see the socio-intellectual world of magical accounting as a

8. Charles Webster, *From Paracelsus to Newton* (Cambridge: Cambridge University Press, 1982), p. 11.

9. For example, Francis Yates, "The Hermetic Tradition in Renaissance Science," in *Art, Science, and History in the Renaissance*, ed. Charles Singleton (Baltimore: Johns Hopkins University Press, 1967), pp. 255–274; Paolo Rossi, *Francis Bacon: From Magic to Science* (Chicago: University of Chicago Press, 1968); Webster, *From Paracelsus to Newton*.

dominant discursive force, perhaps all the more striking as it is set against these other conflicting discursive impulses.

## The Demonstration of Mundane Virtues

We will begin our examination of what has since been taken as von Guericke's announcement of electrical repulsion and will then move outwards to an examination of the larger text and the social context. In chapter 15 of book 4 of *Experimenta nova Magdeburgica de vacuo spatio*, von Guericke describes "The Experiment wherein These Aforementioned [Mundane] Virtues Can be Excited through Rubbing on a Sulphur Globe" (p. 147). He gives instructions for casting a sulfur globe "about the size of a child's head" within a glass sphere, breaking the glass to release the sulfur, then carrying out with this globe various experiments that reveal six of the eight mundane (or terrestrial) virtues (see Fig. 1, right side).[10]

In the second experiment he suggests placing a rod through the axis of the globe, then rubbing it with a dry hand, whereupon it will attract various shreds or light particles. This he calls a demonstration of the conserving force of the earth (we would now say he was conflating electrical attraction with gravity). Gilbert over half a century previously had pointed to classical precedents of the attraction of light particles by rubbed amber; he labeled the phenomenon "electrical" after the Greek name for amber, *elektrum*, and had identified several other materials as electricals, sharing this property. Throughout the century others had added to the list of electricals. Thus although such designation had to have been known to von Guericke,[11] he describes the event not in electrical terms, but

10. Page references are to the original Latin text: Otto von Guericke, *Experimenta nova (ut vocantur) Magdeburgica de vacuo spatio* (Amsterdam, 1672). This and all following translations from this work are based on the unpublished English translation by Margaret Ames Foley (Otto von Guericke, *New Magdeburg Experiments*, trans. Margaret Ames Foley, n.d., Burndy Library, Cambridge, Mass.). In consultation with the original and the German translation of 1968 (Otto von Guericke, *Neue (sogenannte) Magdeburger Versuche ueber den leeren Raum: Nebst Briefen, Urkunden und anderen Zeugnissen*, trans and ed. Hans Schimank [Düsseldorf: VDI Verlag, 1968]), I have amended the English translation for greater historical accuracy, particularly to retain the term "virtue" instead of the misleadingly modern use of "force." Unfortunately, there exists no published English translation of von Guericke's monumental work. Only a few short passages appear in translation in William Francis Magie, ed., *A Source Book in Physics* (Cambridge, Mass.: Harvard University Press, 1965).

11. Von Guericke at various points cites Gilbert as well as Cabeo, who added to the list of electricals. Moreover, electrical phenomena and theoretical explanations of them appear in the works of Kircher and Schott, with whose work von Guericke was very familiar.



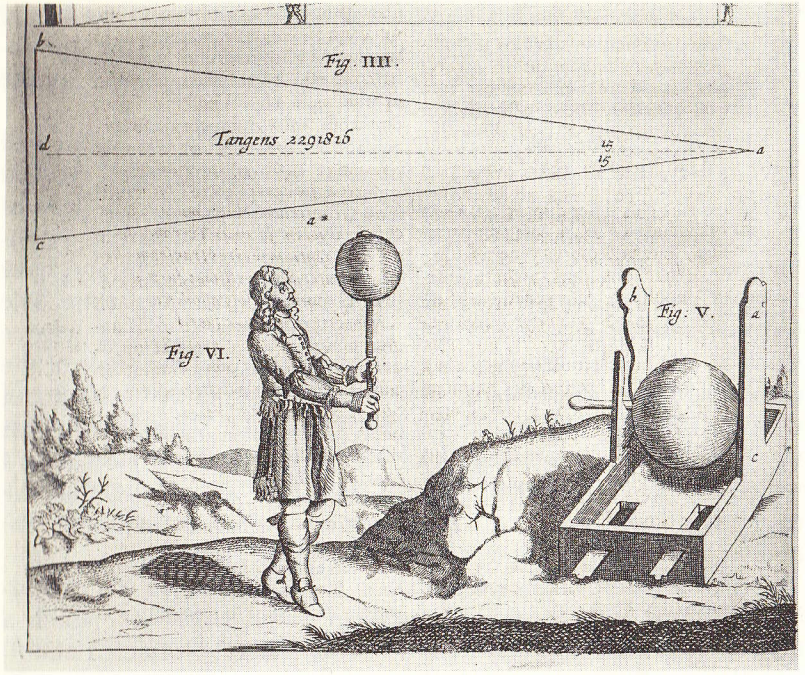


Figure 1. Von Guericke's sulfur globe and floating feather experiment. From Otto von Guericke, *Experimenta nova (ut vocantur) Magdeburgica de vacuo spatio* (Amsterdam, 1672), p. 129. Courtesy of the Burndy Library, Cambridge, Mass.

in terms of the conserving force, which he sees as a terrestrial phenomenon.

In the third experiment von Guericke provides a demonstration of the expulsive virtue, using the same apparatus. He comments that once the shreds or particles (and particularly light feathers) touch the globe, they are no longer attracted to it, but are propelled away until they touch some other object. Thus a feather can be propelled upward and remain suspended above the globe, within the globe's sphere of influence, even as the globe is carried about the room (see Fig. 1, left side). Moreover, he notes that this feather has its own attractive power, maintains the same face toward the globe, and if touched will oscillate back and forth between the globe and the other object. He describes further details and variations in which the fronds of the feather stretch out to the attracting globe and then spread apart from each other as it is ejected, and he points out that the expulsive virtue seems to be carried along a linen thread (what we would now label conductivity).

Other experiments with this sulfur globe (experiments we would not now consider electrical) demonstrate how it contains the impulsive virtue (similar to the modern momentum) as well as the virtues of sound, heat-making, and light-giving.

Previous commentary on the experiments with the sulfur ball have fallen largely into two groups. One group, interested most in telling the progress of electrical knowledge (following the lead of the eighteenth-century Charles-François Dufay and Joseph Priestley) have translated the experiments into electrical terms and have pointed out the phenomena observed here for the first time. The second group, composed largely of modern historians of science (such as Heathcote and Heilbron), have focused on the place of the experiment within the larger intellectual explanatory system put forth in the text. These commentators note that the experiment is not described as presenting a discrete phenomenon in electricity. I would like to explore both sides of this observation: first, that the experiment was not aimed at displaying a discrete phenomenon; and second, that the event was not considered electrical.

First, the point of the presentation is not to observe the curiosities of nature or to assemble Baconian natural histories. Nor is a discrete phenomenon displayed to be identified, wondered about, or explored. The event is in a sense not even a phenomenon—it is a token, or a representative occurrence, of deeper forces. As von Guericke tells the reader in the preface, experience is important not as an end in itself, but only as revealing the powers and orders that the investigator finds in the universe.

Secondly, the demonstration was not presented as electrical. At that time electricity was a curious and discrete phenomenon. Some, such as Gilbert, tried to incorporate it into a magnetic theory of the universe, but its primary presence was as an unusual phenomenon. However, von Guericke was not interested in calling attention to some oddity. Rather, he was giving a full account of the universe, a kind of Protestant cosmology that would place all the events of the world into a coherent natural account which also mirrored the divine order. In particular in book 4, he was presenting the fundamental properties of the terrestrial world. The majority of the chapters of this book are devoted to defining and discussing the mundane virtues in general terms, relying partially on general reasoning and assertion, and partially on the authority of the ancients. Some demonstration experiments are also described, and experiments elsewhere in the volume are cross-referenced. For example, the chapter on the expulsive virtue (which is demonstrated by the floating feather experiment) begins:



The Expulsive Virtue of the Earth

> Aristarchus, who for many reasons was of the opinion that the earth is endowed with a perceptive spirit, examined the opinions of those who think that among the many other virtues in which it abounds, the earth particularly delights in attraction and expulsion and exercises this virtue to the limits of its influence, etc.
>
> It seems reasonable that since the earth has the power to attract those bodies which are congenial to it, it should also be able to expel those things which are harmful or are not agreeable to it.
>
> This faculty will likewise be seen in the sulfur globe experiment in Chapter 15 which follows . . . . (pp. 133–134)

The final chapters of the book, including chapter 15 on the sulfur globe, are directly linked to the exposition of the terrestrial virtues, as is indicated by the title of book 4: "De virtutibus mundanis & aliis rebus inde dependentibus" (Virtues of the earth and other allied subjects).

## The System of the Universe

Book 4 is only part of the seven-book volume, which presents an overall system of the universe, beginning with a history of the theories of the system of the heavens in book 1 and proceeding in later books to discussions of the moon, the planets, and the fixed stars. Von Guericke accounts not only for everything in his universe, but for the nothing as well, so that book 2 is devoted to a general discussion of the vacuum and book 3 to his experiments with the air pump in producing vacuum. He presents the entire universe as an ordered system, and the feather floating above the sulfur globe is just a local manifestation of the largest principles that float throughout.

Von Guericke's universe is alive, flowing with a great undercurrent of powers. In the opening of book 4, he links the topic of the terrestrial virtues directly with the larger harmonies of the universe:

Chapter 1

A General Discussion of the Earthly Virtues

> In our preceding book II, Chapter 7, we stated that everything that is created—and earth-like bodies in particular—consist of their own matter, life, and innate virtues.
>
> These virtues are neither substances nor accidents but are effluvia of earth-like bodies which are inherent in them and flow out from them. . . . (p. 125)

Thus the floating feather is in the most fundamental sense just a manifestation of the inner life of the universe; it is an object for

awe and wonder, an object of the most divine mysteries, displayed by the magus who understands those mysteries and is our intermediary with them. Such a concept of a universe moved by powerful virtues is at the heart of the magical endeavor, which attempts to locate and tap into those virtues by whatever means available. As many commentators have pointed out, such an impulse was very evident among many early scientists—and we still see its remnant within modern science, removed from direct concepts as innate forces of the universe and filtered through objectifying mathematized frameworks and structures of quantified empirical verification. In other parts of von Guericke's exposition, particularly concerning the size and distances of heavenly bodies, we see some of that move toward mathematizing and quantifying relationships; yet we still see the impulse to identify a simple set of directly observable qualities that inhabit and animate the universe.

### An Engineered Microcosm

But what makes the sulfur globe particularly the carrier of these underlying animating virtues is not just that it is a part of the universe—as is every other object, every fork and spoon and piece of amber—but that it is crafted to be a microcosmic model of the macrocosmic terrestrial globe. Indeed, the micro-macrocosmic analogy is an important element in many of von Guericke's demonstrations. For example, earlier in the fourth book, in chapter 4, he cites an experiment first performed by Kircher and reported by Schott in *Magiae universalis naturae* in which a sphere is suspended between two liquids. He cites Schott's explicit comparison between the experiment and the macrocosmic world:

> The sphere will rest immobile in the midst of waters as the earth rests immobile in the center of the universe. (p. 131)

Then when the container is rotated, the sphere extends to the outer reaches of the container, held in circular orbit by the rotation and the limits of the container, modeling the orbit of the planets. Von Guericke then himself makes the comparison:

> in the same way (if the small may be compared to the large), are the planets in the sphere of the sun's force (where all hang freely in pure space without weight) made to revolve through the continual turning of the sun which controls the whole sphere of its force. (p. 132)

Equally, the air pump is described as an attempt to create a microcosmic equivalent of the macrocosmic emptiness of space.



The analogy between the microcosmic and the macrocosmic is a major trope of magical reasoning.[12] Smaller things are seen to mimic the forces and qualities of larger, and we can have access to the mysteries of the greater through our mastery of the smaller. Interestingly (with major implications concerning the transition to modern science, where, as Derek Price, Allen Franklin, and others have argued, the instrumentalities of made experiments and apparatus are crucial[13]), von Guericke finds his microcosm in engineered, made apparatus rather than in naturally found objects or purely symbolic representations (such as a map of the heavens, which then instantiates the powers of the heavens). Further, he designs his made apparatus to display concretely the appearances analogous with the macrocosm.

Von Guericke's first career was as an engineer, and through this craft he first rose to civic prominence. Now in his natural philosophic work he substitutes the mastery of the engineer for the mystical genius of the magus. As will be discussed below, magic rests on assumptions about the magus's spiritual power to bridge between the divine order and the everyday world of apparent disorder. Von Guericke (as did a number of his contemporaries) located that power in the ability to manipulate and reconstruct nature through engineered models. Thus in a sense he turns the microcosmic/macrocosmic analogy into a technological accomplishment, but one that allows the engineer to display the harmonious operation of the universal scheme.

The remnants of this transformed microcosmic/macrocosmic analogy can still be seen in the modern experiment. The modern experiment may not have any apparent or physical resemblances to the larger operations of the universe, nor does it posit harmonious operations of an animate universe, but the analogy to the natural order is its primary underlying motive and justification. In some way, through some set of warranted correspondences, it serves to reveal some aspect of the larger world that operates outside the laboratory. Much of the argumentative work of the experimental account is in fact to warrant that connection, and to per-

12. See, for example, Wayne Shumaker, *The Occult Sciences in the Renaissance* (Berkeley: University of California Press, 1972), p. 119; and Marcel Mauss, *A General Theory of Magic*, trans. Robert Brain (London: Routledge and Kegan Paul, 1972), pp. 68–71.

13. Derek de Solla Price, "The Science/Technology Relationship," *Research Policy* 13 (1984): 3–20; Allen Franklin, *The Neglect of Experiment* (Cambridge: Cambridge University Press, 1986).

suade that the experimental events are not purely artifactual or local, but are somehow representative of a larger class of naturally occurring events.

Von Guericke did not reside in a world where those correspondences might be kept indirect and abstract. To him they must be displayed graphically and concretely by direct physical analogues. Thus, although Gilbert and others had already identified electrical attraction in a variety of materials and had pointed to no restriction of shape, von Guericke made a point of shaping his material into a sphere, and of using sulfur. The symbolism of the sphere, we have already discussed; sulfur, in Paracelsian alchemy and in the general belief of the time, was a very special substance, associated with the celestial soul, fire, and energy. Indeed, when von Guericke was demonstrating this apparatus to the passing traveler Balthasar Monconys in 1663, he was not content with the soulful fiery analogy of sulfur to the universal forces of the earth: to make the analogy with the earth even more concrete, he stated that the globe was composed of nine minerals that comprised the essential composition of the earth.[14] It may be that von Guericke used a different recipe at that time, and then later simplified it; or perhaps he was engaged in some willful mystification (as on other occasions, which we will note below). In any event, whatever he did, or said, was clearly motivated by the desire to maintain the micro-macrocosmic analogy.

## The Magus as Showman

In presenting this system of the innate life of the universe, revealed in the analogies that he both points us to and accomplishes through demonstration, von Guericke establishes himself as an authority on the cosmic mysteries. The overall tone of the work, and particularly this book, is authoritative, despite some gestures toward exploratoriness and provisionality. Von Guericke presents great abstractions as assertions of truth, with little question as to their accuracy, nor much effort devoted to proof. The demonstrations are not used in argumentation, but rather as concrete manifestations of that which has already been authoritatively asserted. Thus von Guericke places himself in the role of the magus, the one

14. Monconys's account originally appeared in the journal of his voyages published in three volumes (Balthasar Monconys, *Voyages* [Lyon, 1665–66]); a German translation was published in Leipzig in 1697. The passages from the German translation related to von Guericke are reprinted on pp. 46–49 of the addenda to the full edition of Hans Schimank's 1968 translation of von Guericke's book (above, n. 10).



who knows the secrets of the universe and can exhibit them for the less enlightened. The magus is necessarily highly visible as the interpreter of the heavens, unlike the modern scientist who takes the guise of stepping back to allow nature to reveal itself.

The central position of von Guericke as magus is graphically illustrated in the figure that accompanies the account of the floating feather experiment (Fig. 1, left side). A human, presumably von Guericke, carries the sulfur globe held above his head on a stick with the feather floating above it. The human who can achieve this wondrous demonstration is given a prominent role as, literally, the carrier of the mystery.[15]

The demonstrations as well are presented in an authoritative voice, as generalized experimental recipes, as though the procedures were fixed and stable. For example:

> In order to demonstrate the conserving virtue in this globe, one should set it up with a rod through its axis on two supports, *ab*, in the device labeled *abcd*. This should be a palm in height from the base and all kinds of shreds or bits of leaves, gold, silver, paper, hop plants and other tiny particles should be strewn beneath it. Then one should touch the sphere with a dry hand and rub or stroke it two or three times. (p. 147)

Moreover, the procedure is presented very much as a performance. This is evident not only in the diagram and the account of the traveler, but in the description of the procedures themselves. The description is easily visualized as a performance, and not abstractly as an apparatus, a series of actions, and separate results, which then must be reconstructed mentally in order to be visualized. The generalized narrative of the demonstration-recipe describes a complete vicarious demonstration for us to witness as we read. The experiment cited just above continues:

> At this point it will attract the fragments to it. If the globe is rotated on its axis, it carries these bits along with it. Now we can visually perceive how the sphere of our earth holds and maintains all animals and other bodies on its surface and carries them about with it in its daily twenty-four-hour motion. (p. 147)

15. Shapin and Schaffer (*Leviathan and the Air-Pump* [above, n. 2], p. 335) similarly comment on an illustration of von Guericke's demonstration of the air pump. For their purposes they emphasize the public space of the demonstration with the audience looking on. But they also, in passing, note the figure (aided by angels) carrying out the experiment. That figure is equal in prominence to the apparatus. This is quite contrary to modern standards, where the performer seems to vanish behind the scenes. Here, the person of the intermediary retains a prominent part.

The concrete visualization now carries across the micro-macrocosmic analogy to a visual representation of the grand show of the earth itself.

We can also see the dramatic character of experiments for von Guericke when he describes the reactions to his replication of Kircher's floating earth demonstration:

> When I first carried out this experiment, I cannot describe the amazement which this produced even among those who wished to be regarded as philosophers. They could not understand how the small sphere could be suspended in the center of the container with such stability since they could not distinguish between the different liquids in it, identical in color as they were. They kept on asking, "How do you produce this stability? Have you fitted a magnet to the bottom or opening of the container in such a way that the poles of the magnet are equidistant horizontally? And then does the sphere that has been magnetized by this come to rest in the middle of the container so that the magnetic poles of each become oriented to one another? Is this the reason why it does not shift position no matter how vigorously the sphere may be shaken from the center? (p. 131)

Notice here how the demonstration itself is presented as an object for amazement, with no explanation given beforehand to the witnesses, who are left to come up with their own explanations—much like modern audiences at a magic show who are left to explain away the magician's illusions. Even when we are given the mechanical means for the production of the effect, as the text explains that the sphere is floated in liquids of different densities, the production of the effect remains the key element in the demonstration and in making the link to the macrocosmic account of how the planets float in space and maintain their orbits. Mechanically producing an icon is immediately taken as a sign of mastery over the powers that produce the macrocosmic effect as well as the smaller demonstration.

Again in this light we may consider von Guericke's ignoring the electrical vocabulary others had attached to attraction experiments similar to those of his sulfur globe. In demonstrating the terrestrial virtues in microcosmic icon, any other account of the effect would be extraneous. He can even obscure other accounts if they detract from the firmness of the micro-macro connection.

### Natural Wonder and Political Power

Von Guericke's demonstration of mastery of the animating forces of the universe creates a large distance of wonder between him and his audience. As we have already seen in the case of the flotation experiment, he was not always quick to explain to his audiences the mechanisms of his demonstrations, but rather he seemed to consider their wonder and amazement at his production as evidence of the power of his knowledge.[16] Indeed, in his life as a leading figure in the town of Magdeburg, von Guericke created devices to arouse public wonder. He had, for example, a giant barometer placed on the fourth story of his house, with a small mannikin resting on top of the column of liquid, so that when the weather was fair and the barometer high the mannikin would come out to sun himself above the roof, but when the barometer dropped, the mannikin would vanish indoors (pp. 98–99). Apparently von Guericke never explained this mystery to the nonphilosophic citizens of the town, who were left to wonder at the amazing powers of their burghermeister.[17]

His most famous demonstration of the vacuum had that same quality of showmanship that filled his audience with wonder. His air pump gave him the ability to confound those who could not anticipate that air pressure could make ordinary tasks very difficult. In 1654 in Regensburg at a meeting of the Diet and Emperor, where von Guericke was sent as an emissary, he arranged a demonstration on an open field. He placed together two copper hemispheres and evacuated the air from them; it then took sixteen horses to pull the spheres apart. This exhibition spread the fame of von Guericke and his air pump widely as the many politically powerful persons gathered there carried word throughout the ruling classes of Germany, and the educated of the world. In particular, word got back to Gaspar Schott, who then began a correspondence with von Guericke. Schott published an account of the Regensburg demonstration as an appendix to *Mechanica hydraulico-pneumatica* in 1657, and later in *Technica curiosa sive mirabilia artis*.[18]

16. Von Guericke's attitude toward wonder as an adequate demonstration in itself may be seen as a striking contrast to the attitude displayed by Christopher Wren concerning the display of Boyle's air pump. In a letter to Lord Brounker, Wren suggests that the raising of wonders in itself (as he accuses Kircher and Schott of doing) is merely a form of jugglery, not befitting the gravity of the situation, which requires that the spectacle be accompanied by edification. In the ethos of the natural philosophy of the Royal Society, the experiment should serve to reveal the principles by which it is produced, and thus should be open to full inspection; von Guericke's concern for the emblematic meaning of the effect, to the contrary, supports a practice of secrecy, by which the effect becomes more significant than the means by which it was produced (Shapin and Schaffer, *Leviathan and the Air-Pump*, p. 31).

17. Mauss (*General Theory* [above, n. 12], pp. 29–31) as well has pointed out the frequent association between magicians and those with political or social power.

18. Gaspar Schott, *Mechanica hydraulico-pneumatica* (Wurzburg, 1657); Gaspar Schott, *Technica curiosa sive mirabilia artis* (Wurzburg, 1664).

As his biographer Alfons Kauffeldt points out, the impression created by this public display in a primarily political forum also aided von Guericke's political credibility. During the decade after the end of the Thirty Years' War, he was often sent as an emissary to plead the case for the independence of his city Magdeburg. Since, however, his city had been the most devastated of all during the conflict, particularly suffering from a siege and sacking by the Catholic forces under Tilly, von Guericke had few means such as military force or economic strength to help plead his case. His city could not even provide the funding for the usual gifts that would grease the wheels of political settlement. So at this particular meeting the demonstration served as his offering, much as a lavish entertainment might serve the case of others—and at the same time, it exhibited the powers he had mastered.[19] It was a kind of exploitation of the charisma associated with the magus, who is the privileged knower of divine mysteries.[20]

It is not difficult to imagine that the charisma that attached to von Guericke through this and other demonstrations was of use in his continuing political career. Through his patriotism and efficiency as an engineer during the war and afterward in Magdeburg's reconstruction, he had achieved civic prominence: he was elected burghermeister in 1645 and was later reappointed, to retire only in 1676. For such a man, continuing demonstrations of his power over material forces would serve as constant reminder to others of his deepening power and wisdom, and in fact he continued to give demonstrations of his experiments at his home, throughout the middle of the century. He even had a hidden apparatus, below the floor of his chambers, where workers stood ready to produce vacuum behind the scenes, on command for any visitor.[21] We have seen

19. Alfons Kauffeldt, *Otto von Guericke* (Leipzig: BSB B.G. Teubner Verlagsgesellschaft, 1975), p. 23.

20. Simon Schaffer in a private communication has pointed out to me that von Guericke seems to have been engaging in a more general practice of showing a prince a wonder for some worldly gain. Richard Westfall, "Scientific Patronage: Galileo and the Telescope," *Isis* 76 (1985): 11–30, for example, discusses Galileo's presentation of many wonders, including the discovery of four moons of Jupiter, as gifts to patrons. Similarly, R. J. W. Evans, *Rudolf II and His World* (Oxford: Oxford University Press, 1973), is filled with many instances of wonders of the arts, natural philosophy, and magic serving as the currency of patronage, redounding to the power of both the creator and the royal patron.

21. Thomas Coulson, "Otto von Guericke: A Neglected Genius," *Journal of the Franklin Institute* 236 (1943): 241–264, 333–351.



as well how he kept his barometrically achieved mastery of the weather constantly before the citizens of the town through the magical mannikin.

### Cosmic Order, Social Order, and Personal Order

We may speculate an even deeper socio-political role for the demonstration of magus-like mastery, beyond ordinary political charisma. The social, political, and economic deterioration resulting from the Thirty Years' War had created a cultural crisis in Germany. A number of commentators have discussed the role that magic plays in creating a sense of order for a populace during times of religious and political upheaval. As Daniel O'Keefe points out, magic has often served to restore a sense of power to individuals when they have seemed powerless before the forces of politics, institutions, and history.[22] Social despair or disorder in times of rapid change create the need for magical access to animating forces that can reempower the individual. If this psychological need is widespread it can create the social climate for the will to believe, or what Marcel Mauss calls the complicity of the audience with magic—a desire not to inquire too deeply into the reasoning, experience, and efficacy of the magical act, which if held to too-strict standards might call into question the claim to true knowledge of the workings of the universe.[23]

Perhaps historically even more relevant, R. J. W. Evans in his study of the world of Rudolf II finds an extremely important role for magic in the Bohemian court just prior to the Thirty Years' War: magic bridged the gap between an increasingly incomprehensible universe and a faltering medieval theology that no longer seemed to apply. Rudolf II not only brought the most eminent alchemists and natural magicians to his court, but was instrumental in drawing the life and art of his court into a mannerist symbolic expression of the innermost forces of the universe as revealed by these eminent magicians. In this way he tried to draw the political order into the perceived order of the magic universe, thereby creating a hierarchical political order when the medieval political hierarchy could no longer stand on its old presuppositions. Evans notes that although Rudolf II expressed perhaps an extreme version of the importance of magic to create order in a time of confusion, the same

22. Daniel O'Keefe, *Stolen Lightning: The Social Theory of Magic* (New York: Continuum, 1982).

23. Mauss, *General Theory* (above, n. 12), pp. 91–97.

themes are played out more mutely throughout central Europe during this period.[24]

If we then add to the psycho-cultural turmoil in central Europe just prior to the Thirty Years' War the kind of despair and disillusionment that must have followed on that debacle, particularly in that most devastated city of Magdeburg, we can begin to perceive how an apparent control over the natural forces of the universe could have an extremely potent effect in cementing the charismatic political power needed to carry the polity across difficult times. Indeed, in examining German poetry during this post–Thirty Years' War period, we see the most extreme kind of despair, as in the poems and dramas of Andreas Gryphius, and on the other hand the most desperate attempt for some sense of reunification with mystical divine order, as in the poems of Angelus Silesius.[25] Cultural moods played out in art may also be played out in the public theaters of politics and magic.

If we examine von Guericke's own statements of his motivations for entering into his philosophic endeavors, we can find suggestions that he himself was looking to reclaim some sense of universal order within disorder. In book 2 chapter 1 he offers his own account of why he began to investigate the vacuum. After describing the large sizes and distances of astronomical objects and the great number of stars, and thus the immensity of space, he comments:

> Since I had deliberated on these questions for a long time and had likewise been engaged in active study of the structures of the world, not only did the great mass of these world bodies and their enormous distances make me afraid that the human intelligence could not conceive of them, but also—and most particularly of all—the vast intermediate and endless space filled me with curiosity and infused me with a desire to investigate it. (p. 53)

Puzzling over the magnitude of the universe is not an unusual mental activity for humans, and certainly children are famous for confronting these issues directly. Yet to have fear about the human inability to encompass that magnitude certainly expresses some anxiety about whether there is a comprehensible order to the universe accessible to humankind, and a failure of faith in traditional accounts of the human's place in the vastness of the creation. Interestingly, von Guericke does not despair of the task, but rather sets to it. Through long pondering and the mechanical ingenuity of an engineer he comes up with the answers of this book. That is, he has entered into the Faustian quest and has found answers that satisfy at least himself, and he presents himself now publicly as master of the knowledge gained through private ruminations (and engineering skill). He has exhibited a belief that the human intelligence is capable of comprehending the mysteries of the vast and complicated universe. This belief in the human intelligence to master the forces of the universe is thematic to Renaissance magic, as Webster points out; in fact, it indicates the centrality of human intelligence to the great scheme of things, for it is human intelligence that makes order out of the apparently chaotic.[26]

In this context we can perhaps even see some significance in an odd detail in the account of the sulfur globe. In giving instructions on casting the sulfur globe, von Guericke specifies that the glass sphere should be "about the size of a child's head" (p. 147). This passing comparison seems a powerful icon of human intelligence in the path to enlightenment, especially when poured full with the divine life/fire/animation of sulfur. Such imagery is certainly consistent with the hermetic expression of the times.[27]

## Natural Philosophy outside the Enclosures of the New Institutions of Scientific Community

I am not here suggesting that von Guericke's thoughts and experiments are simply a fantasy projection of his psychological need for power and order—nor am I suggesting any sort of cynical manipulation of political charisma, in the way some modern analysts

24. Evans, *Rudolf II* (above, n. 20), chaps. 6 and 7. Simon Schaffer in private communication has also suggested that this willingness to believe among continental Protestants may be particularly due to von Guericke's attempt to create a new cosmology based on phenomenal appearances and incorporating the wonders of engineering's material manipulation. Unlike the Catholics, for whom the age of miracles had not yet passed, and who could accept wonders as simply miraculous occurrences which did not threaten the fundamental divine cosmology, von Guericke and his fellow continental Protestants needed to re-create a coherent cosmology that took account of all material wonders without explaining them away as miracles. Thus, whereas Schott presents von Guericke's air pump just as a separate wonder, von Guericke himself must make it part of an explanation of the entire universe.

This cosmology of phenomenal appearance also contrasts with the intellectual world of British natural philosophy, which in the name of social harmony had largely given up public discourse on cosmological matters and sought a meliorist intellectual world of investigation of material phenomena without dwelling on their larger meanings (Jacob, *Newtonians and the English Revolution*; Shapin and Schaffer, *Leviathan and the Air-Pump* [both in n. 2, above]).

25. Angelus Silesius, *Saemtliche poetische Werke*, ed. Hans Ludwig Held (Munich: Carl Hanser Verlag, 1952).



26. Webster, *From Paracelsus to Newton* (above, n. 8), chap. 3.

27. See, for example, Shumaker, *Occult Sciences* (above, n. 12), p. 123.

have discussed the magical charismatic politics of such countries as Indonesia. I am not even suggesting that von Guericke deliberately presented himself as a magician, nor that he ever showed that he could harness the natural forces for immediate advantage. Certainly not. All his self-reflection and overt methodological statements, as in the preface to his book, point toward ambitions to a new empirical philosophy. He was not, however, averse to making public displays of his understanding of the natural forces, often in highly political and public forums. The point is that his impulse for natural knowledge realized itself within a particular cultural atmosphere with its attendant discourse impulses, a cultural atmosphere where the boundaries between natural philosophy, politics, and theology had not been strongly drawn the way they were starting to be in Restoration England.

Von Guericke seemed comfortable in making much broader claims for his systematic knowledge of the workings of the universe than we might think his experiments would allow, and at least parts of his audience seemed comfortable in taking at face value his sweeping claims to knowledge. Only within the specialized community developing around the Royal Society and other centers of scientific communication could there be a reinterpretation and critique of his claims on much narrower terms, more in line with what might be considered empirically and rationally warrantable.

At the same time, however, as we recognize the context of von Guericke's demonstrations and utterances within cultural arrangements that predate modern science, we should also recognize that as a figure in transition, he also had some limited contact with the newly emerging system of scientific communication. This communication is most evident in the matter of the air pump, whose fame following the demonstration at Regensburg grew rapidly, particularly aided by Gaspar Schott. Schott's texts reached Britain and gave Robert Boyle the idea for his own apparatus and demonstrations, which became both widely known and controversial. Interest in the air pump led to correspondence between von Guericke and natural philosophers both on the continent and in Britain. Some of the earlier discussion on the air pump and the vacuum found its way into von Guericke's book (which was completed in 1665, although not published until 1672), where he takes issue with some interpretations. Other correspondence enters into the volume, particularly an extended correspondence with the Polish knight Stanislaus Lubienietzki, which began concerning some questions about comets, but extended throughout issues of the nature of the universe and vacuum, eventually focusing on the weight of the air.



It is out of such correspondence that the *Philosophical Transactions of the Royal Society* developed in 1665.

In addition to responding to the criticisms and questions of his contemporaries, von Guericke also showed awareness of the developments and findings produced by others, which he cited appropriately—as in the first book's long discussion of the development and elaboration of the Copernican view of the universe. Book 4 on the terrestrial virtues, however, remains at a greater distance from explicit involvement with the developing communication in science. There is some specific mention of Kircher and Schott (and once of Niccolo Cabeo), and occasional mention of and response to the claims of other scholars (often phrased in precisely that anonymous way—e.g., "an observation made by various scholars" [p. 102]); nonetheless, the bulk of the book is presented as an original and undisputed claim directly from the wisdom of the author. (The only major exception is the last chapter, discounting astrological influences, which cites a number of continental authorities who line up against astrology.) The chapter on the sulfur globe experiments has no cited sources except for the appearance in the last paragraph of a very general quotation by Kircher about the wondrous miracles of nature, and a mention of the traveler Monconys's published account of his witness to the sulfur globe experiments.

We have already discussed why von Guericke may have wished to obscure the magnetico-electrical sources.[28] He may also have wished to obscure the hermetical and natural magical sources that underlay his general orientation to occult forces, to distance himself from the suspect magical tradition. In any event, these sources would have been only at a distance, antiquated and outside his network of personal acquaintance. His actual circle of corresponding peers seems to have been rather small, based within a group of continental Jesuits.[29] Despite being on the Protestant side in the Thirty Years' War, and remaining part of the Protestant Brandenburg Electorate, his strongest ties seem to have been with Jesuitical philosophers, who often had a magical cast to their work—primarily with Schott (initiated at the Regensburg demonstration) and his teacher Kircher, but also with other Jesuits such as Niccolo Cabeo and Giovanni Battista Riccioli. As a Protestant, he gives a different cast to this tradition, moving away from the explicitly magical and miraculous and toward creating a cosmology that accounts for wondrous

28. Von Guericke does mention Gilbert, but only in a narrowly magnetical context in *Experimenta Nova*, book 4, chap. 7; book 5, chap. 15; and book 7, chap. 4.

29. Heilbron, *Electricity* (above, n. 3), chap. 4.

material phenomena as part of the daily, but divine, order. Yet the drive toward cosmology and his overt communication with the Jesuit natural philosophers once again suggest that the communication of natural philosophy, before the emergence of modern scientific communication systems, was deeply implicated with other networks of communication with their own complex goals and arrangements.

Thus, while the main stream of scientific communication was forming in London around the Royal Society and in Paris around the Royal Academy, von Guericke's work was on a side branch, not as intently organized around what we would now consider scientific investigation: empirical proof, organized criticism, agonistic competition, and public validation. And yet, as with the vacuum pump, although to a lesser degree, there was some communication of von Guericke's sulfur globe demonstration to the Royal Society, when Monconys wrote Robert Moray of the experiment in 1664. Later, in 1671, Gottfried Wilhelm Leibniz also wrote to Henry Oldenburg on the subject. After von Guericke's book was published in 1672, a notice of the book appearing in the *Philosophical Transactions* made mention of sulfur globe experiment; some attempts at replicating the experiment by John Locke and Boyle followed, but both experimenters and the society soon lost interest.[30]

Within the continental scientific community, von Guericke corresponded with both Leibniz and Christiaan Huygens concerning the sulfur globe experiment; nonetheless, his findings were largely ignored and lost track of until Dufay in 1733 reported an unsuccessful attempt at replication.[31] Not until 1767 was he given credit for the discovery of repulsion by Priestley, who retroactively recast the work in purely electrical terms foreign to the spirit of von Guericke's presentation.[32] After Priestley established von Guericke's claim to repulsion, all following citations abandoned the spirit of

30. *Philosophical Transactions of the Royal Society* 7 (November 18, 1672), pp. 5103–05. See Thomas Birch, *The History of the Royal Society*, vol. 3 (London, 1746), pp. 59, 61, 63. Oldenburg wrote of the sulfur globe to R. F. Sluse on December 29, 1673 (Henry Oldenburg, *Correspondence*, vol. 10 [Chicago: Mansell, 1975], p. 417, item 2412). See also Fritz Krafft, *Otto von Guericke* (Darmstadt: Wissenschaftliche Buchgesellschaft, 1978), p. 36, concerning an apparently unsent letter from von Guericke to Oldenburg.

31. Krafft, *Otto von Guericke*, pp. 34–35; the correspondence with Leibniz is reprinted in the addenda to Schimank's German translation, von Guericke, *Neue Magdeburger Versuche* (above, n. 10).

32. Joseph Priestley, *The History and Present State of Electricity* (London, 1767), pp. 9–13.



his work, taking the demonstration as a discrete empirical experience, to be explored for its relations with other discrete empirical findings. It was no longer viewed as a token of a larger system. That system (already old-fashioned in von Guericke's day) was abandoned as no longer of interest.

## Final Comments: Continuities and Discontinuities

Von Guericke writes within older social arrangements and discourse patterns, yet adjusting to newer notions of knowledge production. He peripherally recognizes changing patterns of communication that would draw scientific formulation into an esoteric, institutionally regularized forum. His transitional status can shed light both on what came before and on what came after. The rhetorical attributes of magical communication that we found in his text can deepen our analysis of earlier transitional figures like Francis Bacon and Gilbert who, it is now recognized, had strong roots in magical philosophy. But also we can find in Gilbert and Bacon clear attempts to differentiate themselves from the discourse that they were enmeshed in, attempts that set scientific discourse on a new trajectory. That new trajectory transformed and relocated the social relations and activities that dominated von Guericke's discourse, rather than destroying them outright.

We can see, for example, the remnants of wondrous magical productions within science as both a recruitment device and an amusement. Priestley in part 7 of *The History and Present State of Electricity* describes a number of amusing experiments for neophytes in order to attract them into electrical experimentation. Similarly, Benjamin Franklin used a public performer, Ebenezer Kinnersley, to stir up interest in natural philosophic investigation into electricity in the prerevolutionary American colonies.[33] Franklin also used magical display as a kind of jeu d'esprit, to celebrate the powers he and his fellows had mastered—for example, a picnic was planned on the banks of the Schuylkill to open with an electrical display, and then to consist of a turkey electrocuted and electrically roasted, to be followed by electrically charged glasses of spirits.[34] Indeed, throughout the latter half of the eighteenth century, after the invention of the Leyden jar, electricity provided many amusing parlor tricks.

33. Joseph Lemay, *Ebenezer Kinnersley: Franklin's Friend* (Philadelphia: American Philosophical Society, 1964); idem, "Franklin and Kinnersley," *Isis* 52 (1961): 575–581.

34. Benjamin Franklin, *Experiments and Observations on Electricity* (London, 1754), p. 200.

However, in all these eighteenth-century displays, unlike von Guericke's presentation a century before, there was a much stronger division between the behind-the-scenes scientific explanation and the hoop-la of the special effect. The particular features of the demonstration wherein lay the amusement often had very little to do with the underlying scientific explanation, as when kisses or attempts to remove a crown from the king's portrait were met with shocks. Even when these demonstrations carried deeper beliefs, they were not beliefs in cosmological order so much as beliefs in vitalism, with electricity as the fire of the life force.[35]

In contrast to von Guericke's seriousness about the meaning of appearances, the whole modern notion of magic as performance is based on a complicitous understanding between the audience and the performer that there is some alternate explanation for the illusion, which the performer intentionally keeps hidden. Modern magicians often tease audiences about their attempts to guess the truth behind the illusion; nonetheless, these same magicians often retain the grand schematic account of the occult forces of the universe as material for patter between the tricks, and as inspiration for costumes and stage decoration. Similarly, modern performers retain the trappings of the magus, as the knower of mysteries who can speak with authority to the ignorant layperson and can manipulate natural phenomena in astounding ways. Even the Faustian adventure into forbidden knowledge remains part of the magician's stage persona. But of course, all these occult trappings are just show business to the professional magicians, who advise each other and rising magicians on how to create the patter and persona appropriate to the act. Indeed professional magicians often show outrage at magicians who violate the proper limits of showmanship and try, like Uri Geller, to claim truth to the appearances.

While the occult authority of the magician is now just show business, we do now also have public authorities who can expound on the order and mysteries of the universe. Scientists such as Stephen Jay Gould, Carl Sagan, and Jacob Bronowski have authority warranted by their place within the esoteric scientific community. Yet this authority respects the difference between the communal production of knowledge within the esoteric community, and the individual's public exposition on television and in popular magazines.

Sometimes within the broader cultural, public realm we even

35. See Simon Schaffer, "Natural Philosophy and Public Spectacle in the Eighteenth Century," *History of Science* 21 (1983): 1–43.



canonize icons of scientific wisdom, maguses of the modern age, who come to stand for the depth of wisdom not attainable by the rest of us mere mortals: Einstein, Pasteur, Madame Curie, and James Watson. Yet here too, the public person is separated from the production of knowledge and is a distinct social phenomenon, the result of either larger social forces[36] or the self-conscious political planning of a shrewd tactician trying to gain public support and cooperation for great research and technological endeavors.[37]

In the twentieth century science has come to rely on public support and the political economies of modern states have come to rely on science, but this mutual reliance is carried out in well-defined channels and through elaborate institutions that keep science and politics at some distance as distinct systems of discourse that must meet over specific policy and funding issues. Thus while science maintains a public political face, it does not carry out its work within a highly politicized forum. Science and government do support each other in both concrete and charismatic ways, but usually only in the interaction between the two systems, as when the strength of a nation is demonstrated by its ability to support technological communities that put people in space or develop new electronic marvels. Authority in science does not usually translate directly into political authority, nor does political authority translate directly into scientific.[38]

Many other interactions may be noted between the enclosed discourse system of the sciences and other discourse systems that comprise the modern world. Yet in each case, we may note how science has attempted to withdraw its primary discourse from those other spheres, and thereby to develop its own special characteristics. This does not mean that there are impermeable boundaries be-

36. As in the case of Einstein: see Marshall Missner, "Why Einstein Became Famous in America," *Social Studies of Science* 15:2 (1985): 267–292; and Alan J. Friedman and Carol Donley, *Einstein as Myth and Muse* (Cambridge: Cambridge University Press, 1985).

37. As in the case of Pasteur: see Bruno Latour, "Give Me a Laboratory and I Will Raise the World," in *Science Observed*, ed. K. Knorr and M. Mulkay (Beverly Hills: Sage, 1983), pp. 141–174; and Bruno Latour, *The Pasteurization of France*, trans. Alan Sheridan and John Law (Cambridge, Mass: Harvard University Press, 1988).

38. Thus, while teachers of scientific writing frequently profess the importance of speaking to the general audience, teachers and writers ought to be aware of the manifold needs the writer must then address and the complex authoritative relations the writer must rise to. Nor must teachers of scientific writing ignore the remaining need to address specialist communities, which approach texts as part of a shared endeavor among peers, even though great programmatic divisions may exist within the specialized communities.

tween the internal system of science and its external connections: recent social studies of science have convincingly demonstrated the interpenetration of the internal and the external; but to notice interpenetration does not deny an overall tendency toward separation and internal enclosure. Before the social enclosure of modern science began, activities that retrospectively are labeled early or protoscience were played out in other realms of discourse, so that the social ensemble of language activity embedded in the statements made (and later translated into modern scientific terms) was part of very different language games.

Particularly striking in von Guericke's case, and of general contrastive signficance for modern science, are (1) the ethos and social relationships of the author, and (2) the role of demonstrations and empirical experience in relation to the larger goals of the discourse and the intertextual web it is part of. Concerning the role of the speaker, there are many guises from which one can profess knowledge. Within modern science, the individual within the community subordinates the self to the ongoing conversation—asking validation for one's own claim, but always in a context of competition and evaluation by peers, and in relation to long-standing knowledge established by predecessors. Thus agonistic individuality is framed within complexes of relations with the individual's agonists and evaluators. When facing outward to nonscientific communities, it is the general authority of science that stands at the scientist's back. A scientist's individual fame or eminence, even of an Einstein, is just a local manifestation of that general authority.

Without that communications enclosure to speak into, and to use as backdrop, when knowledge is professed directly to the general public, one takes on a semidivine role—an individual who has access to mysteries not available to others. One's voice, one's credibility, and one's statement are bound together in an utterance that either is charismatically powerful or is nothing. This is especially so where the knowledge one pretends to must fill diverse and powerful social-psychological-political needs of the complex audiences one is speaking to—audiences not selected out and filtered through the normative goals, attitudes, and practices of specialized knowledge communities.

Concerning the role of empirical experiences within the discourse, we must be aware that there are many kinds of claims and many uses of experience within them. Ludwik Fleck noted in his characteristic terminology that what distinguishes modern science among thought communities is the active pursuit of passive constraints.[39] That is, modern science tries at every possible turn to force its actively pursued symbolic social constructions of knowledge into constraints imposed passively by things beyond human control, as perceived through the human experience of them. Or even more simply, science tries hard to bump up against reality, as it perceives reality to be and in the terms in which it considers reality. This active pursuit of passive constraints is part of both claim making and claim reception—writing and reading. If Fleck was right about modern science, then von Guericke was not engaged in modern science. He does use empirical demonstrations, but not to constrain or even prove his claims, just to demonstrate their power. That is, the sulfur ball demonstration was not in any way designed as a test for the claim. Rather, because it works out in a manner that can be represented and perceived as consistent with the general claims made, it demonstrates the general power of the claim and, by implication, the mastery of the claim maker. This is why the trappings of the claim (the sulfur, the child's head, the global shape) are an important concern in von Guericke's discourse universe—more important than similarities to other experiments, labeled electrical, carried out in other frameworks by others. The phenomena bear no interest or importance in themselves—he is not announcing an empirical finding out of which, in conjunction with other such findings, an empirical order of the universe may be constructed. Rather, he has a vision of the order of the universe, and he casts about for suitable displays. His primary accountability is not to the extension of empirical experience, but to the establishing of a sense of universal order, and indirectly thereby he may be driven by the need to establish social/psychological order more than to develop a reliable account of the experienced universe.

Although von Guericke is a figure in transition, with many impulses that can be seen to be consistent with modern science, yet we must leave with the final impression that the experiences of life can mean many things, and that the discourse in which experiences are embedded helps us know what we are to do with them. The empiricist project of modern science has invented new things to do with our experiences; moreover, it has changed our relationship to those who claim to know about the universe we live in.

The empiricist project carries out these novel activities and relationships, however, only within the novel enclosed social space it has created for the presentation and validation of phenomena and

39. Fleck, *Genesis* (above, n. 1), p. 95.

theoretical claims. As the social arrangements of science change, so also changes what it means to do science. Knowledge is in the symbols used to formulate it and in the activities used to realize it; the symbols and activities gain their human meaning within the social space where they are enacted. Other social forums produce other forms of knowledge.