VISUALIZATION AND COGNITION:
THINKING WITH EYES AND HANDS

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I. PUTTING VISUALIZATION AND COGNITION INTO FOCUS

It would be nice to be able to define what is specific to our modern scientific culture. It would be still nicer to find the most economical explanation (which might not be the most economic one) of its origins and special characteristics. To arrive at a parsimonious explanation it is best not to appeal to universal traits of nature. Hypotheses about changes in the mind or human consciousness, in the structure of the brain, in social relations, in "mentalités," or in the economic infrastructure which are posited to explain the emergence of science or its present achievements are simply too grandiose, not to say hagiographic in most cases and plainly racist in more than a few others. Occam's razor should cut these explanations short. No "new man" suddenly emerged sometime in the sixteenth

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century, and there are no mutants with larger brains working inside modern laboratories who can think differently from the rest of us. The idea that a more rational mind or a more constraining scientific method emerged from darkness and chaos is too complicated a hypothesis.

It seems to me that the first step towards a convincing explanation is to adopt this a priori position. It clears the field of study of any single distinction between prescientific and scientific cultures, minds, methods or societies. As Jack Goody points out, the "grand dichotomy" with its self-righteous certainty should be replaced by many *uncertain* and *unexpected* divides (Goody, 1977). This negative first move frees us from positive answers that strain credulity.[1] All such dichotomous distinctions can be convincing only as long as they are enforced by a strong asymmetrical bias that treats the two sides of the divide or border very differently. As soon as this prejudice loses hold, cognitive abilities jump in all directions: sorcerers become Popperian falsificationists; scientists become naive believers; engineers become standard "bricoleurs"; as to the tinkerers, they may seem quite rational (Knorr, 1981; Augé, 1975). These quick reversals prove that the divide between prescientific and scientific culture is merely a border—like that between Tijuana and San Diego. It is enforced arbitrarily by police and bureaucrats, but it does not represent any natural boundary. Useful for teaching, polemics, commencement addresses, these "great divides" do not provide any explanation, but on the contrary are the things to be explained (Latour, 1983).

There are, however, good reasons why these dichotomies, though constantly disproved, are tenaciously maintained, or why the gap between the two terms, instead of narrowing, may even widen. The relativistic position reached by taking the first step I propose, and giving up grand dichotomies, looks ludicrous because of the enormous consequences of science. One cannot equate the "intellectual" described by Goody (1977, chap. 2) and Galileo in his study; the folk knowledge of medicinal herbs and the National Institute of Health; the careful procedure of corpse interrogation in Ivory Coast and the careful planning of DNA probes in a Californian laboratory; the story telling of origin myths somewhere in the South African bush and the Big Bang theory; the hesitant calculations of a four-year-old in Piaget's laboratory and the calculation of a winner of the Field Medal; the abacus and the new super-computer Cray II. The differences in the *effects* of science and technology are so enormous that it seems absurd not to look for enormous causes. Thus, even if scholars are dissatisfied with these extravagant causes, even if they admit they are arbitrarily defined, falsified by daily experience and often contradictory, they prefer to maintain them in order to avoid the absurd consequences of relativism. Particle physics must be radically different in some way from folk botany; we do not know how, but as a stop-gap solution the idea of rationality is better than nothing (Hollis and Lukes, 1982).

We have to steer a course that can lead us out of a simple relativism and, by positing a few, simple, empirically verifiable causes, can account for the enormous differences in effects that everyone knows are real. We need to keep the scale of the effects but seek more mundane explanations than that of a great divide in human consciousness.

But here we run into another preliminary problem. How mundane is mundane? When people back away from mental causes, it usually means they find their delight in material ones. Gigantic changes in the capitalist mode of production, by means of many "reflections," "distortions," and "mediations," influence the ways of proving, arguing and believing. "Materialist" explanations often refer to deeply entrenched phenomena, of which science is a superstructure (Sohn-Rethel, 1978). The net result of this strategy is that nothing is empirically verifiable since there is a yawning gap between general economic trends and the fine details of cognitive innovations. Worst of all, in order to explain science we have to kneel before one specific science, that of economics. So, ironically, many "materialist" accounts of the emergence of science are in no way material since they ignore the precise practice and craftmanship of knowing and hide from scrutiny the omniscient economic historian.

It seems to me that the only way to escape the simplistic relativist position is to avoid both "materialist" and "mentalist" explanations at all costs and to look instead for more parsimonious accounts, which are empirical through and through, and yet able to explain the vast effects of science and technology.

It seems to me that the most powerful explanations, that is those that generate the most out of the least, are the ones that take writing and imaging craftmanship into account. They are both material and mundane, since they are so practical, so modest, so pervasive, so close to the hands and the eyes that they escape attention. Each of them deflates grandiose schemes and conceptual dichotomies and replaces them by simple modifications in the way in which groups of people argue with one another using paper, signs, prints and diagrams. Despite their different methods, fields and goals, this strategy of deflation links a range of very different studies and endows them with a style which is both ironic and refreshing.[2]

Like these scholars, I was struck, in a study of a biology laboratory, by the way in which many aspects of laboratory practice could be ordered by looking not at the scientists' brains (I was forbidden access!), at the cognitive structures (nothing special), nor at the paradigms (the same for thirty years), but at the transformation of rats and chemicals into paper (Latour and Woolgar, 1979). Focusing on the literature, and the way in which anything and everything was transformed into inscriptions was not my bias, as I first thought, but was for what the laboratory was made. Instruments, for instance, were of various types, ages, and degrees of sophistication. Some were pieces of furniture, others filled large rooms, employed many technicians and took many weeks to run. But their end result, no matter the field, was always a small window through which one could read a very few signs from a rather poor repertoire (diagrams, blots, bands, columns). All these inscriptions, as I called them, were combinable, superimposable and could, with only a minimum of cleaning up, be integrated as figures in the text of the articles people were writing. Many of the intellectual feats I was asked to admire could be rephrased as soon as this activity of paper writing and inscription became the focus for analysis. Instead of jumping to explanations involving high theories or differences in logic, I could cling to the level of simple craftsmanship as firmly as Goody. The domestication or disciplining of the mind was still going on with instruments similar to those to which Goody refers. When these resources were lacking, the selfsame scientists stuttered, hesitated, and talked nonsense, and displayed every kind of political or cultural bias. Although their minds, their scientific methods, their paradigms, their world-views and their cultures were still present, their conversation could not keep them in their proper place. However, inscriptions or the practice of inscribing could.

The Great Divide can be broken down into many small, unexpected and practical sets of skills to produce images, and to read and write about them. But there is a major drawback with this strategy of deflation. Its results seem both obvious—close to being a cliché—and too weak to account for the vast consequences of science and technology that cannot, we agreed above, be denied. Of course, everyone might happily agree that writing, printing and visualizing are important *asides* of the scientific revolution or of the psychogenesis of scientific thought. They might be necessary but they certainly cannot be sufficient causes. Certainly not. The deflating strategy may rid us of one mystical Great Divide, but it will, it seems, lead us into a worse kind of mysticism if the researcher who deals with prints and images has to believe in the power of signs and symbols isolated from anything else.

This is a strong objection. We must admit that when talking of images and print it is easy to shift from the most powerful explanation to one that is trivial and reveals only marginal aspects of the phenomena for which we want to account. Diagrams, lists, formulae, archives, engineering drawings, files, equations, dictionaries, collections and so on, depending on the way they are put into focus, may explain almost everything or almost nothing. It is all too easy to throw a set of clichés together extending Havelock's argument about the Greek alphabet (1980), or Walter Ong's rendering of the Ramist method (1971), all the way to computer culture, passing through the Chinese obsession with ideograms, double-entry book keeping, and without forgetting the Bible. Everyone agrees that print, images, and writing are everywhere present, but how much explanatory burden can they carry? How many cognitive abilities may be, not only facilitated, but thoroughly explained by them? When wading through this literature, I have a sinking feeling that we are alternately on firm new ground and bogged down in an old marsh. I want to find a way to hold the focus firmly so that we know what to expect from our deflating strategy.

To get this focus, first we must consider in which situations we might expect changes in the writing and imaging procedures to make any difference at all in the way we argue, prove and believe. Without this preliminary step, inscriptions will, depending on the context, be granted either too much or too little weight.

Unlike Leroi-Gourhan (1964) we do not wish to consider all the history on writing and visual aids starting with primitive man and ending up with modern computers. From now on, we will be interested only in a few specific inventions in writing and imaging. To define this specificity we have to look more closely at the construction of harder facts.[3]

Who will win in an agonistic encounter between two authors, and between them and all the others they need to build up a statement S? Answer: the one able to *muster on the spot the largest number of well aligned and faithful allies*. This definition of victory is common to war, politics, law, and, I shall now show, to science and technology. My contention is that writing and imaging cannot by themselves explain the changes in our scientific societies, except insofar as *they help to make this agonistic situation more favorable*. Thus it is not all the anthropology of writing, nor all the history of visualization that interests us in this context. Rather, we should concentrate on those aspects that help in the mustering, the presentation, the increase, the effective alignment or ensuring the fidelity of new allies. We need, in other words, to look at the way in which someone convinces someone else to take up a statement, to pass it along, to make it more of a fact, and to recognize the first author's ownership and originality. This is what I call "holding the focus steady" on visualization and cognition. If we remain at the level of the visual aspects only, we fall back into a series of weak clichés or are led into all sorts of fascinating problems of scholarship far away from our problem; but, on the other hand, if we concentrate on the agonistic situation alone, the principle of any victory, any solidity in science and technology escapes us forever. We have to hold the two eyepieces together so that we turn it into a real *bi*nocular; it takes time to focus, but the spectacle, I hope, is worth the waiting.

One example will illustrate what I mean. La Pérouse travels through the Pacific for Louis XVI with the explicit mission of bringing *back* a better map. One day, landing on what he calls Sakhalin he meets with Chinese and tries to learn from them whether Sakhalin is an island or a peninsula. To his great surprise the Chinese understand geography quite well. An older man stands up and draws a map of his island on the sand with the scale and the details needed by La Pérouse. Another, who is younger, sees that the rising tide will soon erase the map and picks up one of La Pérouse's notebooks to draw the map again with a pencil . . .

What are the differences between the savage geography and the civilized one? There is no need to bring a prescientific mind into the picture, nor any distinction between the close and open predicaments (Horton, 1977), nor primary and secondary theories (Horton, 1982), nor divisions between implicit and explicit, or concrete and abstract geography. The Chinese are quite able to think in terms of a map but also to talk about navigation on an equal footing with La Pérouse. Strictly speaking, the ability to draw and to visualize does not really make a difference either, since they all draw maps more or less based on the same principle of projection, first on sand, then on paper. So perhaps there is no difference after all and, geographies being equal, relativism is right? This, however, cannot be, because La Pérouse does something that is going to create an enormous difference between the Chinese and the European. What is, for the former, a drawing of no importance that the tide may erase, is for the latter the *single object* of his mission. What should be brought into the picture is how the picture is brought back. The Chinese does not have to keep track, since he can generate many maps at will, being born on this island and fated to die on it. La Pérouse is not going to stay for more than a night; he is not born here and will die far away. What is he doing, then? He is passing through all these places, in order to take something *back* to Versailles where many people expect his map to determine who was right and wrong about whether Sakhalin was an island, who will own this and that part of the world, and along which routes the next ships should sail. Without this peculiar trajectory, La Pérouse's exclusive interest in traces and inscriptions will be impossible to understand—this is the first aspect; but without dozens of innovations in inscription, in projection, in writing, archiving and computing, his displacement through the Pacific would be totally wasted—and this is the second aspect, as crucial as the first. We have to hold the two together. Commercial interests, capitalist spirit, imperialism, thirst for knowledge, are empty terms as long as one does not take into account Mercator's projection, marine clocks and their markers, copper engraving of maps, rutters, the keeping of "log books," and the many printed editions of Cook's voyages that La Pérouse carries with him. This is where the deflating strategy I outlined above is so powerful. But, on the other hand, no innovation in the way longitude and latitudes are calculated, clocks are built, log books are compiled, copper plates are printed, would make any difference whatsoever if they did not help to muster, align, and win over new and unexpected allies, far away, in Versailles. The practices I am interested in would be pointless if they did not bear on certain controversies and force dissenters into believing new facts and behaving in new ways. This is where an exclusive interest in visualization and writing falls short, and can even be counterproductive. To maintain only the second line of argument would offer a mystical view of the powers provided by semiotic material—as did Derrida (1967); to maintain only the first would be to offer an idealist explanation (even if clad in materialist clothes).

The aim of this paper is to pursue the two lines of argument at once. To say it in yet other words, we do not find all explanations in terms of inscription equally convincing, but only those that help us to understand how the mobilization and mustering of new resources is achieved. We do not find all explanations in terms of social groups, interests or economic trends, equally convincing but only those that offer a specific mechanism to sum up "groups," "interests," "money" and "trends": mechanisms which, we believe, depend upon the manipulation of paper, print, images and so on. La Pérouse shows us the way since without new types of inscriptions nothing usable would have come back to Versailles from his long, costly and fateful voyage; but without this strange mission that required him to go away and to come back so that others in France might be convinced, no modification in inscription would have made a bit of difference.

The essential characteristics of inscriptions cannot be defined in terms of visualization, print, and writing. In other words, it is not *perception* which is at stake in this problem of visualization and cognition. New inscriptions, and new ways of perceiving them, are the results of something deeper. If you wish to go out of *your* way and come back heavily equipped so as to force others to go out of *their* ways, the main problem to solve is that of *mobilization*. You have to go and to come back *with* the "things" if your moves are not to be wasted. But the "things" have to be able to withstand the return trip without withering away. Further requirements: the "things" you gathered and displaced have to be presentable all at once to those you want to convince and who did not go there. In sum, you have to invent objects which have the properties of being *mobile* but also *immutable, presentable, readable* and *combinable* with one another.

II. ON IMMUTABLE MOBILES

It seems to me that most scholars who have worked on the relations between inscription procedures and cognition, have, in fact, in their various ways, been writing about the history of these immutable mobiles.

A. Optical Consistency

The first example I will review is one of the most striking since Ivins wrote about it years ago and saw it all in a few seminal pages. The rationalization that took place during the so-called "scientific revolution" is not of the mind, of the eye, of philosophy, but of the *sight*. Why is perspective such an important invention? "Because of its logical recognition of internal invariances through all the transformations produced by changes in spatial location" (Ivins, 1973:9). In a linear perspective, no matter from what distance and angle an object is seen, it is always possible to transfer it—to translate it—and to obtain the same object at a different size as seen from another position. In the course of this translation, its internal properties have not been modified. This immutability of the displaced figure allows Ivins to make a second crucial point: since the picture moves without distortion it is possible to establish, in the linear perspective framework, what he calls a "two way" relationship between object and figure. Ivins shows us how perspective allows movement through space with, so to speak, a return ticket. You can see a church in Rome, and carry it with you in London in such a way as to reconstruct it in London, or you can go back to Rome and amend the picture. With perspective exactly as with La Pérouse's map—and for the same reasons—a new set of movements are made possible: you can go out of your way and come back with all the places you passed; these are all written in the same homogeneous language (longitude and latitude, geometry) that allows you to change scale, to make them presentable and to combine them at will.[4]

Perspective, for Ivins, is an essential determinant of science and technology because it creates ''optical consistency,'' or, in simpler terms, a regular avenue through space. Without it ''either the exterior relations of objects such as their forms for visual awareness, change with their shifts in locations, or else their interior relations do'' (1973:9). The shift from the other senses to vision is a consequence of the agonistic situation. You present absent things. No one can smell or hear or touch Sakhalin island, but you can look at the map and determine at which bearing you will see the land when you send the next fleet. The speakers are talking to one another, feeling, hearing and touching each other, *but* they are now talking *with* many absent things presented all at once. This presence/absence is possible through the two-way connection established by these many contrivances—perspective, projection, map, log book, etc.—that allow translation without corruption.

There is another advantage of linear perspective to which he and Edgerton attract our attention (1976). This unexpected advantage is revealed as soon as religious or mythological themes and utopias are drawn with the same perspective as that which is used for rendering nature (Edgerton, 1980:189).

> In the West, even if the subject of the printed text were unscientific, the printed picture always presented a rational image based on the universal laws of geometry. In this sense the Scientific Revolution probably owes more to Albrecht Dürer than to Leonardo da Vinci. (p. 190)

Fiction—even the wildest or the most sacred—and things of nature—even the lowliest—have a meeting ground, *a common place,* because they all benefit from the same ''optical consistency.''[5] Not only can you displace cities, landscapes, or natives and go back and forth to and from them along avenues through space, but you can also reach saints, gods, heavens, palaces, or dreams with the same two-way avenues and look at them through the same ''windowpane'' on the same two-dimensional surface. The two ways become a four-lane freeway! Impossible palaces can be drawn realistically, but it is also possible to draw possible objects as if they were utopian ones. For instance, as Edgerton shows, when he comments on Agricola's prints, real objects can be drawn in separated pieces, or in exploded views, or added to the same sheet of paper at different scales, angles and perspectives. It does not matter since the ''optical consistency'' allows all the pieces to mix with one another. As Ferguson says, the ''mind'' has at last ''an eye'':

> Oddly enough, linear perspective and chiaroscuro, which supply geometric stability to pictures, also allow the viewer a momentary suspension of his dependence on the law of gravity.

> With a little practice, the viewer can imagine solid volumes floating freely in space as detached components of a device. (Edgerton, 1980:193)

At this stage, on paper, hybrids can be created that mix drawings from many sources. Perspective is not interesting because it provides realistic pictures; on the other hand, it is interesting because it creates complete hybrids: nature seen as fiction, and fiction seen as nature, with all the elements made so homogeneous in space that it is now possible to reshuffle them like a pack of cards. Commenting on the painting "St. Jérome in his study," Edgerton says:

> Antonello's St. Jérome is the perfect paradigm of a new consciousness of the physical world attained by Western European intellectuals by the late fifteenth century. This consciousness was showed especially by artists such as Leonardo da Vinci, Francesco di Giorgio Martini, Albrecht Dürer, Hans Holbein and more, all of whom . . . had even developed a sophisticated grammar and syntax for quantifying natural phenomena in pictures. In their hands, picture making was becoming a pictorial language that, with practice, could communicate more information, more quickly and by (sic) a potentially wider audience than any verbal language in human history. (1980:189)

Perspective illustrates the double line of argument I presented in the previous section. Innovations in graphism are crucial but only insofar as they allow new two-way relations to be established with objects (from nature or from fiction) and only insofar as they allow inscriptions either to become more mobile or to stay immutable through all their displacements.

B. Visual Culture

Still more striking than the Italian perspective described by Ivins and Edgerton, is the Dutch "distance point" method for drawing pictures, as it has been beautifully explained by Svetlana Alpers (1983). The Dutch, she tells us, do not paint grandiose historical scenes as observed by someone through a carefully framed windowpane. They use the very surface of their paintings (taken as the equivalent of a retina) to let the world be painted straight on it. When images are captured in this way there is no privileged site for the onlooker any more. The tricks of the "camera obscura" transform large-scale three-dimensional objects into a small two-dimensional surface around which the onlooker may turn at will.[6]

The main interest of Alpers' book for our purpose is the way she shows a "visual culture" changing over time. She does not focus on the inscriptions or the pictures but on the simultaneous transformation of science, art, theory of vision, organization of crafts and economic powers. People often talk of "world views" but this powerful expression is taken metaphorically. Alpers provides this old expression with its material meaning: how a culture *sees* the *world*, and makes it visible. A new visual culture redefines both what it is to see, and what there is to see. A citation of Comenius aptly summarizes a new obsession for making new objects visible anew:

> We will now speak of the mode in which objects must be presented to the senses, if the impression is to be distinct. This can be readily understood if we consider the process of actual vision. If the object is to be clearly seen it is necessary: (1) that it be placed before the eyes; (2) not far off, but at a reasonable distance; (3) not on one side, but straight before the eyes; and (4) so that the front of the objects be not turned away from, but directed towards, the observer; (5) that the eyes first take in the object as a whole; (6) and then proceed to distinguish the parts; (7) inspecting these in order from the beginning to the end; (8) that attention be paid to each and every part; (9) until they are all grasped by means of their essential attributes. If these requisites be properly observed, vision takes place successfully; but if one be neglected its success is only partial. (cited in Alpers, 1983:95)

This new obsession for defining the act of seeing is to be found both in the science of the period and in modern laboratories. Comenius' advice is similar to both that of Boyle when he disciplined the witnesses of his air-pump experiment (Shapin, 1984) and that of the neurologists studied by Lynch when they "disciplined" their brain cells (Lynch, 1985). People before science and outside laboratories certainly use their eyes, but not in this way. They look at the spectacle of the world, but not at this new type of image designed to transport the objects of the world, to accumulate them in Holland, to label them with captions and legends, to combine them at will. Alpers makes understandable what Foucault (1966) only suggested: how the same eyes suddenly began to look at "representations." The "panopticon" she describes is a "fait social total" that redefines all aspects of the culture. More importantly, Alpers does not explain a new vision by bringing in "social interests" or the "economic infrastructure." The new precise scenography that results in a world view defines at once what is science, what is art and what it is to have a world economy. To use my terms, a little lowland country becomes powerful by making a few crucial inventions which allow people to accelerate the mobility and to enhance the immutability of inscriptions: the world is thus gathered up in this tiny country.

Alpers' description of Dutch visual culture reaches the same result as Edgerton's study of technical drawings: a new meeting place is designed for fact and fiction, words and images. The map itself is such a result, but the more so when it is used to inscribe ethnographic inventories (end of her chapter IV) or captions (chapter V), skylines of cities and so on. The main quality of the new space is not to be "objective" as a naïve definition of realism often claims, but rather to have optical consistency. This consistency entails the "*art of describing*" everything and the possibility of going from one type of visual trace to another. Thus, we are not surprised that letters, mirrors, lenses, painted words, perspectives, inventories, illustrated child books, microscope and telescope come together in this visual culture. All innovations are selected "to secretly see and without suspicion what is done far off in other places" (cited in Alpers, 1983:201).

C. A New Way of Accumulating Time and Space

Another example will demonstrate that inscriptions are not interesting per se but only because they increase either the mobility or the immutability of traces. The invention of print and its effects on science and technology is a cliché of historians. But no one has renewed this Renaissance argument as completely as Elizabeth Eisenstein (1979). Why? Because she considers the printing press to be a mobilization device, or, more exactly, a device that makes both mobilization and immutability possible at the same time. Eisenstein does not look for one cause of the scientific revolution, but for a secondary cause that would put all the efficient causes in relation with one another. The printing press is obviously a powerful cause of that sort. Immutability is ensured by the process of printing many identical copies; mobility by the number of copies, the paper and the movable type. The links between different places in time and space are completely modified by this fantastic acceleration of immutable mobiles which circulate everywhere and in all directions in Europe. As Ivins has shown, perspective plus the printing press plus aqua forte is the really important combination since books can now carry with them the realistic images of what they talk about. For the first time, a location can accumulate other places far away in space and time, and present them synoptically to the eye; better still, this synoptic presentation, once reworked, amended or disrupted, can be spread with no modification to other places and made available at other times.

After discussing historians who propose many contradictory influences to explain the take-off of astronomy, Eisenstein writes:

> Whether the sixteenth century astronomer confronted materials derived from the fourth century B.C. or freshly composed in the fourteenth century A.D., or whether he was more receptive to scholastic or humanist currents of thoughts, seems of less significance in this particular connection than the fact that all manners of diverse materials were being seen in the course of one life time by one pair of eyes. For Copernicus as for Tycho, the result was heightened awareness and dissatisfaction with discrepancies in the inherent data. (1979:602)

Constantly, the author shifts attention with devastating irony from the mind to the surface of the mobilized resources:

> 'To discover the truth of a proposition in Euclid,' wrote John Locke 'there is little need or use of revelation, God having furnished us with a natural and surer means to arrive at knowledge of them.' In the eleventh century, however, God had not furnished Western scholars with a natural and sure means of grasping a Euclidean theorem. Instead the most learned men in Christendom engaged in a fruitless search to discover what Euclid meant when referring to interior angles. (1979:649)

For Eisenstein, every grand question about the Reformation, the Scientific Revolution, and the new Capitalist economy can be recast by looking at what the publisher and the printing press make possible. The reason why this old explanation takes on new life in her treatment is that Eisenstein not only focuses on graphism, but also on changes in the graphism that are linked to the mobilization process. For instance, she explains (p.508 and seq. following Ivins, 1953) the puzzling phenomenon of a lag time between the introduction of the printing press and the beginning of exact realistic pictures. At first, the press is used simply to reproduce herbaries, anatomical plates, maps, cosmologies which are centuries old and which will be deemed inaccurate much later. If we were looking only at the semiotic level this phenomenon would seem puzzling, but once we consider the deeper structure this is easily explained. The displacement of many immutable mobiles comes first; the old texts are spread everywhere and can be gathered more cheaply in one place. But then the contradiction between them at last becomes *visible* in the most literal sense. The many places where these texts are synoptically assembled offer many counterexamples (different flowers, different organs with different names, different shapes for the coastline, the various rates of different currencies, different laws). These counterexamples can be added to the old texts and, in turn, are spread without modification to all the other settings where this process of comparison may be resumed. In other words, errors are accurately reproduced and spread with no changes. But corrections are also reproduced fast, cheaply and with no further changes. So, at the end, the accuracy *shifts from the medium to the message,* from the printed book to the context with which it establishes a two-way connection. A new interest in "Truth" does not come from a new vision, but from the same old vision applying itself to new visible objects that mobilize space and time differently.[7]

The effect of Eisenstein's argument is to transform mentalist explanations into the history of immutable mobiles. Again and again she shows that before the advent of print every possible intellectual feat had been achieved—organized scepticism, scientific method, refutation, data collection, theory making—everything had been tried, and in all disciplines: geography, cosmology, medicine, dynamics, politics, economics and so on. But each achievement stayed local and temporary just because there was no way to move their results elsewhere and to bring in those of others without new corruptions or errors being introduced. For instance, each carefully amended version of an old author was, after a few copies, again adulterated. No irreversible gains could be made, and so no large-scale long-term capitalization was possible. The printing press does not add anything to the mind, to the scientific method, to the brain. It simply conserves and spreads everything no matter how wrong, strange or wild. It makes everything mobile but this mobility is not offset by adulteration. The new scientists, the new clerics, the new merchants and the new princes, described by Eisenstein, are no different from the old ones, but they now look at new material that keeps track of numerous places and times. No matter how inaccurate these traces might be at first, they will all become accurate just *as a consequence* of more mobilization and more immutability. A mechanism is invented to irreversibly capture accuracy. Print plays the same role as Maxwell's demon. No new theory, world view, or spirit is necessary to explain capitalism, the reformation and science: they are the result of a new step in the long history of immutable mobiles.

Taking up Ivins' argument, both Mukerji (1983) and Eisenstein focus again on the *illustrated* book. For these authors, MacLuhan's revolution had already happened as soon as images were printed. Engineering, botany, architecture, mathematics, none of these sciences can describe what they talk about with texts alone; they need to show the things. But this showing, so essential to convince, was utterly impossible before the invention of "graven images." A text could be copied with only some adulteration, but not so a diagram, an anatomical plate, or a map. The effect on the construction of facts is sizeable if a writer is able to provide a reader with a text which presents a large number of the things it is talking about in one place. If you suppose that all the readers, and all the writers are doing the same, a new world will emerge from the old one without any additional cause. Why? Simply because the dissenter will have to do the same thing as his opponent. In order to "doubt back," so to speak, he will have to write another book, have it printed, and mobilize with copper plates the counterexamples he wants to oppose. The cost of disagreeing will increase.[8]

Positive feedback will get under way as soon as one is able to muster a large number of mobile, readable, visible resources at one spot to support a point. After Tycho Brahe's achievement (Eisenstein, 1979) the dissenter either has to quit and accept what cosmologists say as a hard fact, or to produce counterproofs by persuading his prince to invest a comparable amount of money in observatories. In this, the "proof race" is similar to the arms race because the feedback mechanism is the same. Once one competitor starts building up harder facts, the others have to do the same or else submit.

This slight recasting of Eisenstein's argument in terms of immutable mobiles may allow us to overcome a difficulty in her argument. Although she stresses the importance of publishers' strategies, she does not account for the technical innovations themselves. The printing press barges into her account like the exogeneous factors of many historians when they talk about technical innovations. She puts the semiotic aspect of print and the mobilization it allows into excellent focus, but the technical necessities for inventing the press are far from obvious. If we consider the agonistic situation I use as reference point, the pressure that favors something like the printing press is clearer. *Anything* that will accelerate the mobility of the traces that a location may obtain about another place, or *anything* that will allow these traces to move without transformation from one place to another, will be favored: geometry, projection, perspective, bookkeeping, paper making, aqua forte, coinage, new ships (Law, 1984). The privilege of the printing press comes from its ability to help many innovations to act at once, but it is only one innovation among the many that help to answer this simplest of all questions: how to dominate on a large scale? This recasting is useful since it helps us to see that the same mechanism, the effects of which are described by Eisenstein, *is still at work* today, on an ever increasing scale at the frontiers of science and technology. A few days in a laboratory reveal that the same trends that made the printing press so necessary, still act to produce new data bases, new space telescopes, new chromatographies, new equations, new scanners, new questionnaires, etc. The mind is still being domesticated.

III. ON INSCRIPTIONS

What is so important in the images and in the inscriptions scientists and engineers are busy obtaining, drawing, inspecting, calculating and discussing? It is, first of all, the unique advantage they give in the rhetorical or polemical situation. "You doubt of what I say? I'll show you." And, without moving more than a few inches, I unfold in front of your eyes figures, diagrams, plates, texts, silhouettes, and then and there present things that are far away and with which some sort of two-way connection has now been established. I do not think the importance of this simple mechanism can be overestimated. Eisenstein has shown it for the past of science, but ethnography of present laboratories shows the same mechanism (Lynch, 1985a, 1985b; Star, 1983; Law, 1985). We are so used to this world of print and images, that we can hardly think of what it is to know something without indexes, bibliographies, dictionaries, papers with references, tables, columns, photographs, peaks, spots, bands.[9]

One simple way to make the importance of inscriptions clearer is to consider how little we are able to convince when deprived of these graphisms through which mobility and immutability are increased. As Dagognet has shown in two excellent books, no scientific discipline exists without first inventing a visual and written language which allows it to break with its confusing past (1969,1973). The manipulation of substances in gallipots and alambics becomes chemistry only when all the substances can be written in a homogeneous language where everything is simultaneously presented to the eye. The writing of words inside a classification are not enough. Chemistry becomes powerful only when a visual vocabulary is invented that replaces the manipulations by calculation of formulas. Chemical structure can be drawn, composed, broken apart on paper, like music or arithmetic, all the way to Mendeleiev's table: "for those who know to observe and read the final periodic table, the properties of the element and that of their various combinations unfold completely and directly from their positions in the table" (1969:p.213). After having carefully analyzed the many innovations in chemical writing and drawings, he adds this little sentence so close to Goody's outlook:

> It might seem that we consider trivial details—a slight modification in the plane used to write a chlorine—but, paradoxically, these little details trigger the forces of the modern world. (1969:p.199)