PHILOSOPHICAL METHODOLOGY, TECHNOLOGIES, AND THE TRANSFORMATION OF KNOWLEDGE

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There are many methodological approaches employed by scholars working within the general area of the philosophy of technology. This methodological richness is rightly the cause of a certain degree of pride felt by many members of this society. For we clearly work hard at encouraging and maintaining a form of methodological pluralism that has evaded at least the mainstream American philosophical community. Philosophical provincialism also seems to threaten productive interchange between divergent points of view on the Continent as well, witness the almost total breakdown of communication between the so-called postmodernists and analytical philosophers. Nevertheless, despite our sense of having preserved diversity of viewpoint within the Society for Philosophy and Technology, there is a different perception of our work held by the larger philosophical community. To put it bluntly, work in the philosophy of technology is deemed largely marginal.

And yet, it is equally clear, given the pervasive character of technology in modern life and with the apparently increasing rate of technological innovation and dispersion, its effect on our ways of living and our values, that technology is a central, if not the central, feature of the human world. As such, it demands philosophical examination in all its various aspects and manifestations. So if technology is so central, then why is the philosophy of technology so marginal?

Of the many possible reasons for this state of affairs, I want to concentrate on the one I believe to be at the heart of the problem. After examining the cause of our problem, I will suggest an alternative approach to exploring questions in the philosophy of technology, which approach ought to make our work not only more appealing to the larger philosophical community, but make it of greater value to all of us by facilitating greater understanding of our different points of view.

I am convinced that the work of the members of this society should and could be of immense value to our philosophical colleagues and to society at large. What I am about to put before you is framed by the fear that because we have taken the tack we have up to this point, that we will continue to be ignored and to experience further disintegration as an organization. I also want to emphasize the need to find a way to maintain and encourage the diversity of viewpoints that makes this organization so exciting. So, another precautionary note—I am not trying to impose a single point of view on us. Rather, I am trying to find a way to accommodate and nourish our diversity while at the same time providing us with an entry into the larger philosophical dialogue. So, to work.

The problem, as I see it, is that most of the work in the philosophy of technology is perceived, rightly or wrongly, mostly wrongly, as being expressed within one highly charged ideological framework or another. Furthermore, that framework is perceived to be highly antagonistic to technology. It is not just that many of us are critics of specific features of various technological intrusions in our lives. This by itself would not be enough to cast suspicion on our work. Not all social critics are viewed as working at the margins of the philosophical world; consider much of the work currently appearing under the heading of social and political philosophy. Social criticism *per se* is not the problem. It is rather the context within which the criticism occurs that is the villain.

Earlier I labeled this context "ideological." By that I mean two things: (1) what sets the context is a discreet kind of conceptual scheme; (2) to call it a conceptual scheme is to identify it as a structure for thinking. As such it can be misused by individuals who, for whatever reason or cause, assume the guiding principles of that scheme are inviolate. In short, an ideology is a pathological conceptual scheme. By that I do not mean that the scheme is pathological, but rather, that the people who employ it do so in a manner which can be interpreted as such. It is, of course, people who are pathological, not conceptual schemes. What does this mean for us? It means that one of the reasons some work in the philosophy of technology is ignored or marginalized is because those outside the circle view that work as being conducted within an isolated and insulated context, a context whose users refuse to admit any challenge to its assumptions. And *that* means that it is not seen as being includable within the wider philosophical discussion.

Now, this diagnosis of what I have called "our problem" assumes a certain view of philosophy. I would like to lay out that view, my view, and discuss its implications for our work. My view of philosophy derives in large part from a rather remarkable characterization of philosophy by the 20th century American pragmatist, Wilfrid Sellars. According to Sellars,

> The aim of philosophy is to understand how things in the broadest sense of the term hang together in the broadest sense of the term. Under 'things in the broadest possible sense', I include such radically different items as not only 'cabbages and kings', but numbers and duties, possibilities and finger snaps, aesthetic experience and death. To achieve success in philosophy would be, to use a contemporary turn of phrase, to 'know ones's way around' with respect to all these things, not in that unreflective way in which the centipede of the story knew its way around before it faced the question, 'how do I walk?' but in that reflective way which means that no intellectual holds are barred. [1]

In short, the aim of philosophy is to make it all fit together and to know how it fits together. It is to know what all the pieces are and to know how to move them and how they are connected. That much is Sellars. From now on it is me and my interpolation of that view. This conception of philosophy *assumes no privileged point of departure*. It does not assume, for example, that all discussions must be carried out in terms of the ethical, moral, or value implications of the topic under discussion. It does not assume that philosophical issues are questions of power seeking. It does not read every question of technology as one of political correctness. It does not assume that in the process of finding out how it all hangs together there is already one set and agreed upon value system that determines the relevance and importance of all other considerations. It means, likewise, that not all philosophical issues are to be approached as matters of language. Further, it means that there must be some demonstrable relevance of philosophical ruminating to living, which is, minimally, the "finding one's way around" part.

The philosopher then must be constantly reevaluating what she knows as she finds new things and new problems to consider. Under this conception of philosophy a philosopher cannot come to a problem with a predetermined solution or approach unless he or she is willing to allow that those assumptions are only starting points and can, nay, *must* be examined for their appropriateness as part of the process of inquiry and synthesis. This view of philosophy also means that the philosophical process of trying to make it all hang together in the broadest possible sense of "hang together" is not and cannot be complete. For as we discover new things about us and about the world in which we live, we must be constantly reassessing and reformulating our account of how it all fits together. If such constant reformulation and reevaluation is the steady state, then any assumption of privilege must be mistaken. And just to make the point as clean, or as obnoxious, as it can be, the opposite view, i.e., the assumption of an *a priori* privileged perspective in the doing of philosophy, I will call *fascist philosophy*. It applies to all schools of philosophy from analytic to existentialist, from empiricist and rationalist to politically correct. You simply can not do philosophy with the Sellarsian aim in mind if you use the crutch of a school or a single method.

And now, I suppose I would do well if I were a bit reflexive. Is the claim of no privilege itself not a privileged claim? I think not. For it does not assert in a non-refutable way that there can never be a privileged perspective. Rather it says that there is no *a priori* privileged point of view that one can justifiably bring to any and every philosophical problem that is immune from challenge. One must start somewhere and somehow. What I am saying is that both starting point and methodology are constantly up for grabs, depending on how we are doing. I am also suggesting that I do not think that it will ever be possible to establish once and for all time a privileged point of view because we are constantly in a state of coming to know new things. That is an empirical claim which may be false; however, I am willing to live in that state of indeterminacy for the moment. But note that if we *do* think that we have achieved that exalted state of privileged point of view, then we will also have come to the end of human creativity, for only when there is nothing new under the sun, to quote the preacher, can such a stance make sense.

Let us now enumerate some of the parts to be related in this constant effort to figure out how it all hangs together. In the context of discussing that technological marvel, the space program, and taking our cue from Sellars, we are looking to see how such disparate things as scientific instruments, scientists, space shuttles, laboratory experiments, our concepts of knowledge, science, and standard experimental conditions, hang together and cohere not only with themselves but with challenges to the value of the space program, cries for feeding the needy and housing the homeless, and various assertions about the way in which large scale technological projects such as the space program politically disenfranchise us. It is in this context that I wish to examine the topic of changing knowledge.

Knowledge changes. Furthermore, it changes in two ways. First, in terms of its content, i.e., in terms of the specific things we know. Second, in terms of what we mean by the very notion of "knowledge." Not only do we know more than our forebears, but we can and do expect our children to experience even greater wonders than we have. The fact that what we know changes is not in dispute. However, it remains a question, if not something of a mystery, as to how the content of our knowledge changes, and what affects such changes in the content of our knowledge have on our *concept* of knowledge.

According to the popular current story, science is portrayed as a major player in the process by which knowledge changes. Beginning at least with the Copernican Revolution, science, it is alleged, has explored the world around us, revealing nature's secrets in increasing detail and at an accelerating pace. I think this picture is wrong.

Science is *not* what forces us to change and correct what we know. Science is not responsible for our new vision of an expanding universe. Science cannot be credited with revealing, in ever increasing detail, the structure of, for example, the human genome. At least, science cannot do all these things by itself. Rather than credit science with increasing our knowledge, I want to argue that it is the technological infrastructure of science, rather than science itself, which is responsible for these monumental changes. In other words, the popular and well entrenched view that science is responsible for how knowledge changes is a myth, a popular, well-entrenched myth, but a myth nonetheless.

Technological innovation and its incorporation into an increasingly sophisticated technological infrastructure is what makes it possible for us to cast off false views and replace them with what we hope is a continuously improving understanding of our world. The picture of science as the major mover responsible for the transformation of knowledge is inaccurate because it leaves out the role of technology, both in the generation of knowledge and in the development of science. In the popular story, when and if technology is begrudgingly included in the story of human progress, it is always as an afterthought, as, at best, a nice benefit of scientific research. That is not only false, it is historically myopic and potentially dangerous. One last point here. When I refer to "the technological infrastructure of science," I am not just indicating scientific instruments used in experiments. No, I mean such complicated social structures as the control room at Houston complete with enormous television screens, computers, various computer programs and telephone hookups, the building itself, the communications network, the space shuttle, etc. I *mean* the *infrastructure* which makes the doing of science in space possible.

What I intend to do now is look first at the major change in our conception of scientific knowledge which Galileo helped establish. I will then look at how, once technologies were accepted as part of the knowledge generating process, they have become increasingly crucial to it—so crucial that they have in fact transformed our conception of knowledge anew, under our very noses, without our being aware of it.

One way to see how knowledge changes is to consider changes in the criteria by which something is said to qualify as knowledge. When the criteria change, the things for which it is the criteria can be said to change. In previous work I have sometimes called these criteria "values." I am changing terminology here to avoid unnecessary confusions. But for those who know my previous work, I am not changing much by way of the general position. The criteria associated with knowledge I will call epistemic criteria. What I have in mind here are such notions as truth, conceptual economy, usefulness, justification, and simplicity, among others. These are the notions according to which we determine if some claim or other is going to count as knowledge. Thus, while the statement, "There are 231 mountains on the moon," may or may not be true, in order for someone to say that they *know* and not merely *believe* that there are 231 mountains on the moon, that statement *must* be true. Truth can function in two different ways: first as a property of a statement, i.e., this statement is true; and second, as a criterion by which we determine if a statement qualifies as knowledge and if its user can be said to know something. Because we are using the notion of truth to determine the acceptability of the claim being made, truth functions here in its second sense, as a criterion; and that is what I wish to look at in greater detail. Since epistemic criteria are the key to what we mean by knowledge, if the criteria change, then what counts as knowledge changes. That means that what we thought we knew two hundred years ago, today we may decide no longer counts as knowledge. Furthermore, this need not be due to the discovery of new facts which cast the old knowledge into doubt. It can be a simple case of our changing our mind as to what counts as knowledge.

To understand what this means and what it implies for our conception of knowledge, let us take a look at an historical example of change in epistemic criteria. The example concerns Galileo's efforts to incorporate mathematics and observation within what were then the standard criteria for scientific knowledge.

After looking at Galileo's arguments, I will turn briefly to our contemporary situation. If, as Galileo's case shows us, the development of new instruments opens up scientific research to the development of a technological infrastructure, then we need to ask what happens to our understanding of what counts as knowledge when, as is now the case, the conditions for observations change again, such as in the new environments of space. Most importantly, we need to consider the effect on our conception of knowledge made by the entire technological infrastructure which allows us access to space and how that infrastructure, employing as it does new techniques and machines and data processing devices, impinges on our understanding of the components of knowledge. In short, in what sense is data gathered in space—digitalized and transmitted by radio to a receptor on earth, retransformed into codes, and finally, through further computer programs reconstituted into an image—count as an observation? But first, Galileo.

Galileo did two things which had a major impact on the conception of knowledge. He insisted on the role of mathematics in scientific knowledge and he changed our understanding of observation through the use of his telescope. Let us look at these in order, first the role of mathematics. Shortly after he perfected the telescope in 1609, Galileo secured a job with the Duke of Tuscany as his chief mathematician and philosopher. Galileo's title at Florence is important because it tells us something about the organization of science in the 17th century and that has important ramifications for the understanding of what constituted knowledge at that time.

In the 16th and 17th centuries Italian universities were dominated by the Catholic Church and the conceptual framework of Aristotle which had been acquired primarily through the writings of Thomas Aquinas. The predominant way of thinking about the world, that is, the Aristotelian/Thomist framework, also included a taxonomy or structural organization of the sciences in terms of what was supposed to be each science's proper domain of inquiry. There were many deep and maybe even perverse reasons for this structure, but we cannot risk going into them or we will find ourselves in the middle of an Umberto Eco novel. For our purposes today, it is enough to remember that the sciences were divided into major sciences and subfields, not unlike today. [2]

Furthermore, also like today, their precise order cannot be said to be set at any time during this period. There were many variations, depending on a variety of factors. But Galileo had intimate knowledge of and seemed to be concerned with the doctrine most favored at the Collegio Romano, the home institute of the Jesuits, located in Rome. On this account there are five total sciences, understanding by the notion of a science a source of knowledge. These five were a science of God, a science of intelligences, a science of being in common, a science of natural bodies, and a science quantity, i.e., mathematics. It is most interesting for our purposes that mathematics was not to be applied to corporeal substance, that is, matter. The subject matter of mathematics was "nude quantity," i.e., matter considered only in terms of necessary connections and not through relations of cause and effect. That means that the proper subject matter of mathematics was abstract relations among quantities. Mathematics could not be applied to physical matter. In other words, physics as we know it today, i.e., mathematical physics, was not possible.

One way to view Galileo's methodological research program is to see him, and a few select others like Kepler and Calvius, as engaged in the preliminary conceptual battles that made it possible to make sense of and to accept the views of the new mathematical physicists like Descartes and Newton. One of Galileo's primary considerations was to incorporate mathematics into our very conception of how to describe and reason about the world. [3] He makes this case in a number of places, but most notably in his famous *Dialogue on the Two Chief World Systems*. There Galileo urges us to use mathematics wherever we can, especially in talking about the physical world. His criticism of Aristotle is not that his arguments are bad ones, but that they could be so much better if framed mathematically. Consider what he has to say at the very beginning of The *Dialogue*. It is the first argument discussed, namely the argument of the followers of Aristotle, called Peripatetics, that the earth cannot be a planet and move as do the other planets. The first step in the Peripatetic argument is to show that the earth is complete and perfect. (We will not consider the rest of the argument; my objective here is merely to demonstrate Galileo's point about the use of mathematics.) First they present Aristotle's argument:

> [The earth] is not a mere line, nor a bare surface, but a body having length, breadth, and depth. Since there are only these three dimensions, the world, having these, has them all, and having the Whole, is perfect (p. 7).

Galileo's response is not to attack the proof and show it is wrong, but rather to help it along. To this end he notes,

> To be sure, I much wish that Aristotle had proved to me by rigorous deductions that simple length constitutes the dimension which we call a line, which by the addition of breadth becomes a surface; that by further adding altitude to this there results a body, and that after these three dimensions there is no passing further—so that by these three alone, completeness, or so to speak, wholeness is concluded (p. 8).

He then goes on to draw a little diagram using the basics of geometry to prove the very point.

Galileo's strategy throughout the *Dialogue* is to argue for replacing and/or augmenting the convoluted semantic arguments of Aristotle's followers with mathematical proofs. Each time an Aristotelian proof is offered, he counters with a mathematical one making the same point, only in more intuitive and obvious fashion. His apparent objective is not to disprove Aristotle, but where possible to show how his ideas can be improved by employing mathematics, and, where not possible, to argue for the correctness of the mathematics. He concludes,

> It is best to have recourse to a philosophical distinction and to say that the human understanding can be taken in two modes, the *intensive* or the *extensive*. Extensively, that is, with regard to the multitude of intelligibles, which are infinite, the human understanding is as nothing even if it understands a thousand propositions; for a thousand in relation to infinity is zero. But taking man's understanding *intensively*, in so far as this term denotes understanding some proposition perfectly, I say that the human intellect does not understand some of them perfectly, and thus in these it has as much absolute certainty as Nature itself has. Of such are the mathematical sciences alone; that is, geometry and arithmetic, in which the Divine intellect indeed knows infinitely more propositions, since it knows all. But with regard to those few which the human intellect does understand, I believe that its knowledge equals the Divine in objective certainty (p. 103).

Since Galileo is here talking about mathematics, it might be thought that he is concerned only to claim that we can know some of the truths of mathematics as well as God can. And if one were to concentrate on this short paragraph alone that would be so. But if we look further we will see that more is going on. First, let me emphasize one thing from what I just quoted. Galileo says that it is the mathematical sciences *alone* that provide certainty in knowledge. This means that none of the other sciences do. So, to the extent that you can have knowledge at all, it must use mathematics. Second, in the rest of Day 1, he always follows his mathematical proofs with an empirical example. In many ways this resembles the old logical positivist's idea of interpreting a formal abstract language using only the observation terms of normal language to give you the language of science. Galileo does not say this, but the regular way in which he follows every proof by an empirical example, suggests that he is urging his reader to draw the parallel between the points of the proof and the physical situation in the example. That is what gives you knowledge of the world.

The point of examining this dimension of Galileo's work is to provide an example of how, by emphasizing a new or different kind of epistemic condition, you can change the very conception of knowledge. Galileo urges us to consider an alternative epistemic criterion, alternative to the Aristotelian. For the Peripatetics, knowledge is based on the writings of Aristotle. If you are an Aristotelian, to show that a particular claim is a knowledge claim requires fitting it into the categorical scheme of the great philosopher which precluded mathematics from providing knowledge of the world. On the other hand, in his new account of knowledge, Galileo insists on the value of providing mathematical proofs and empirical counterparts to those proofs. It is not enough, he is saying, to merely cite the words of some approved authority. This marks a major turning point in Western science and in our conception of knowledge. For, until the language of mathematics is acknowledged as a legitimate means of expressing knowledge, mathematical physics cannot develop into the powerful tool it has become today.

Let us now turn to the impact of Galileo's telescopic observations on knowledge. Using his telescope to make careful observations of the heavens, Galileo saw things no one had seen before such as the phases of Venus and the moons of Jupiter. These observations had a devastating effect on the Aristotelian conception of the structure of the solar system. Let us call this the Aristotelian theory. This theory was complicated and yet very elegant. Beginning with the claim that there are only four elements, air, earth, fire, and water, and the principle that each element has its appropriate place, earth being the heaviest, its natural place was at the center. The universe had no top or bottom; therefore if all the earth matter in the universe seeks its natural place down, it will come to the center of the void. So we get the final theory with the earth motionless at the center of the universe and the heavens in rotation around it. If you jazz this up with metaphysical assumptions such as the only motion appropriate to the heavens is perfect circular motion, and some later theology which argues that the earth being at the center is as it should be according to the Bible, there can be no other centers of action in the universe. Imagine their surprise when Galileo reports his observations of the moons of Jupiter, showing that there is yet another planet with moons rotating around it, i.e., another center.

There are other observations we could discuss and other effects, but the point here does not require that we do a detailed analysis. Basically, what we have is the impact on the Aristotelian theory of observations made possible by technological innovation. The impact is significant enough to force reconsideration of the theory, and ultimately it is responsible for its downfall. Galileo forced us to reconsider the adequacy of a theory which was used to explain why the universe is the way it is through non-empirical abstract metaphysical reasoning. In addition, by pushing for the superiority of framing knowledge claims in the language of mathematics and having them backed up with empirical observations, he makes it possible for Newton to turn to the work of Kepler for a set of purely mathematical relationships in order to put together a new theory to replace Aristotle's. We need only mention in passing the fact that in creating that new theory, Newton also had to invent a new form of mathematics, the calculus, to see how far we have come in a short one hundred years in our understanding of the criteria for knowledge.

Let us jump now to the present and the impact of space-based experiments on our conception of knowledge and changes in the criteria associated with our contemporary account of knowledge. The March-April 1990 issue of *American Scientist* contained a piece entitled, "Effects of the Space Environment on Space Science," by Joselyn and Whipple. In that article Joselyn and Whipple carefully review the variety of factors which affect space-based experiments, causing instruments to produce what they call "ephemeral data." As they relate, the environment of space affects our experiments in ways hard to correct for. The solar wind, solar flares, electromagnetic radiation, all produce particles and forces we have to be aware of and account for. Likewise, the very materials we use to construct both our spacecraft and the instruments they carry actually interfere in the information to be generated. Some of these factors can be anticipated, others cannot.

What does this mean for our concept of knowledge? To begin with, one basic point seems settled. Given the random influence of the multitude of factors which interfere with our understanding of the significance of the data from space provided by our instruments, any conception of knowledge embodying any sense of certainty must be abandoned. Second, the very fact of space-based experiments forces us to confront in unmistakable terms the technological infrastructure of science, and the extent to which we depend on that technological infrastructure. We often speak in casual fashion of the link between science and technology. In so doing we generally take an ideological stance with regard to assessing their relative significance. Science, it is argued, is an example of pure intellect and *ipso facto* must be superior to any form of technology. But when the very possibility of the science is shown to rest on a massive technological investment such as the space program, the question of superiority should be, at best, blurred.

However, I want to argue, we should not rest content with just blurring our understanding of the relation between science and technology. We are in a position to dissolve old distinctions and reconfigure the entire relation. The fact of the matter is that space-based experiments would not be possible without the technology behind the space program. Thus, the fact of doing science in space forces us to face the fact that this science *requires* this technological infrastructure. The example of experiments in space may seem to force the issue in an artificial way. But, on reflection, it is easy to see that any mature science absolutely demands an extensive technological infrastructure. Where would microbiology be without the ultracentrifuge and a host of sophisticated machines and counters? Is it possible to do astronomy today without computers and computer programs, cameras, and mountain top observatories with a variety of telescopes, mounts, buildings, and supplies? Particle physics is almost too easy a target. But when all is said and done, the fact remains that contemporary mature science requires much more than a theory about a domain. Focusing on space-based experiments brings that sharply into view.

The relationship between science and its technological infrastructure which we come to see when we concentrate on these experiments also allows us to see the problems that emerge when the technological infrastructure mediates the science. The claims of scientific theories are seen now through the machines and devices of the infrastructure. This raises the question of the extent to which the technology transforms and influences the formulations of the theory. More importantly, and we are finally at the point where we can concentrate on the truly important issue, when we consider the significance of the technological infrastructure for space-based science, we can isolate some of the presuppositions we have not recently paid attention to regarding experimental practice.

If, as Joselyn and Whipple suggest, not only do the materials involved in the space stations and orbiters affect the experiments, but the environment of space itself also makes a difference, then we need to examine the kind of difference. With respect to the materials used to build the space stations, etc., that perhaps may be merely a matter of fine-tuning. The real problem comes from the randomness of the influences of the environment of space. If we cannot anticipate with any degree of regularity the environmental influences, then what happens to the bed-rock concepts behind the reliability of experimentation? One such notion leaps out: *standard conditions*. If the environmental influences of space are sufficiently random that we not only cannot build in safeguards against them, but also cannot calibrate our instruments to account for them, then what do our space-based experiments tell us? Another way to ask this question is: to what extent does an empiricist theory of knowledge presuppose standard conditions? The answer must be totally. "Standard conditions" is a fundamental epistemic criterion. If we reject or even reformulate the concept, then we have changed the meaning of knowledge. Furthermore, by emphasizing the degree to which what we know is dependent on our technology, I suggest we are left in the following paradoxical situation. The better we get at devising and constructing the means for learning new things about our world and universe, the *less* we know. Let us look briefly at these two points in some detail.

Despite his attack on Aristotle's conceptual framework, Galileo still agreed with Aristotle's definition of knowledge as certainty. If we know something, we are certain about it, not merely psychologically, but logically certain. That is what Galileo was talking about when he said that intensive knowledge gives us an understanding of necessity. This view lasted until David Hume destroyed it in his *Treatise of Human Nature* published in 1739. Since Hume's devastating attack, philosophers having been trying to come up with an account of knowledge which acknowledged that whatever we say we know must be bracketed by a certain probability. How to do that and still give us an account of knowledge which is intuitively plausible is *the big epistemological problem*. The reason for the problem is the unabashed attachment we have to the idea that knowledge must be related to truth. However, if, as Kant did, we can recognize the fact that we cannot ever get to the truth about the world, as our data about the effect of the space environment shows us, then we may be able to make some headway on knowledge.

Kant showed that we could not ever know the way the world really is because our way of thinking about the world can never be tested against the world in a naked, unbiased way. We always interpret what we see and experience; it has to be that way. Our knowledge is, therefore, necessarily contaminated, just as our data from space are. The interesting feature of the Joselyn/Whipple article is their observation that, on the other hand, if we guard too heavily against the features which contaminate the data, we will not get anything worth using and, on the one hand, if we do not guard against these interferences, we can not use the data anyway. It would seem, therefore, that data do not contribute to knowledge. This is *the dilemma of knowing*. We must trust our data, knowing that they are not trustworthy. Furthermore, we do not know how far to go in not trusting the data, since we cannot compare them against the world to know if we have made the right adjustments. Our continued use of instruments to provide the data from space does not make this a new problem; it merely reveals the depth of the problem.

Perhaps one more look will help us make the case more convincing. Optical astronomy has come a long way since Galileo's little eight power hand-held telescope. We do not need to turn to the Hubble to see that. Not only have telescopes grown in size, but the necessary support systems have become more complicated. The truly large telescopes require massive housings, highly sophisticated background technologies to produce the machines and lenses, electricity to run the equipment and, once cameras are introduced, all the apparatus needed for quality night time photography and the optical theories to support interpretations of the products, computers to calculate position, manage the photography and coordinate the systems. But there is more yet; consider the contrast between Galileo's original hand-held telescope which we can take into the countryside, and a typical mountain top astronomical installation, with roads, electrical generators, sewage systems, housing, buildings to house the various types of telescopes and the computers and the other equipment. But even then there is more, for we need to consider the auxiliary support systems which the main *system* needs to carry out whatever theoretical investigations are in order. There is, for example, the entire support system which developed and produced the computers and the cameras and the programs and the space technology to launch telescopes, satellites, interstellar probes, etc. There is the optics of the camera, the new types of film . . . shall we stop here?

Astronomy is the science of the heavens. Its function is to describe the constitution of the universe in terms of the relative positions of its parts. To accomplish this goal astronomers need to be able to see the heavens. And so we have the elaborate technological infrastructure of the optical telescope. But to assume that the components of the universe are limited to those which can be seen by the human eye is absurdly homocentric. So if you add to the optical infrastructure the radio telescopes and theories upon which they are based, the spectral telescopes, the use of high speed computers to not only control the telescopes, but to generate and interpret to at least the first and second order the information they generate, the computers and the computer programs necessary for all that, the launching of space-based telescopes and the technological systems behind that, the infrastructure behind the computers, etc., the list goes on. If you add all that in, the technological infrastructure of astronomy appears to swamp the goal of the science. But there is more, for at each stage, the development of the instruments is constrained by the fit with other instruments and the theories with which they interact and sets of instruments and their backup systems. The result of employing these systems forces restructuring of theories all the way down the line. Just reflect on the disaster with the Hubble and you will see the extent to which the systems of the technological infrastructure interact and affect one another. It is not just that new observations force revisions in the description of the heavens. The questions include how do you integrate spectral telescopy with optical? Do the theories behind the instruments cohere? One of the hot issues in cosmology today is the problem posed by the fact that the visual picture of the universe provided by astronomy does not cohere with the predicted mass of the universe. So now everyone is looking for dark matter. How do anomalous results from one instrument, e.g., excessive red shift, affect the other theories?

We look with awe at the picture which the new space probe, appropriately called Galileo, sent back to the Earth on its way to Jupiter. If we think about the technological infrastructure behind the pictures, we get some sense of what is involved. The pictures are not simply sent from the space vehicle, traveling at high speeds in its own trajectory, to earth, also traveling at high speed and on *its* own trajectory, the "pictures" are transmitted as electronic code. That means they have to be disassembled, sent, reassembled, etc. The machinery, the programming and the capacity for mistakes is enormous. If you add the testing of scientific theories to the problem, and the interaction between the theories and the technological infrastructure, as well as among themselves, there can never again be a simple history of the ideas of science, nor should there be.

If the science is astronomy, or even cosmology, once we understand what it takes to do cosmology today, we must turn to the technological infrastructure to understand its results. It is no longer possible to say, "Science tells us . . .," and it is certainly misleading to say, "Science and technology tell us . . .," for no one has taken the time to spell out what that means. When we do spell it out we will find what we really wanted to say was, "The technological infrastructure within which scientific theories are being developed and transformed makes it possible for us to describe and explain the universe in the following way." This contextualization of our science is extremely important. The kinds of things we come to know about the universe, or to put it more dramatically, the universe modern science reveals to us, is a function of this complex interaction between theory and technological infrastructure.

The second point I noted above was that the better we get at building instruments and devising ways to use them, the less we know. We know less because we do not know how to filter the data. This too is not new. We never knew, *a priori*, how to interpret whatever data we got. In sum, we really do not know what we know. And we do not know what we know because the more data we get, the less we know what to do with it. Finally, thanks to the technological success which makes space science possible, things are going to get worse, not better. Technology not only drives science, its continued development forces us to radically reconsider our conception of knowledge. For knowledge cannot be data nor can it simply rely on data. Technology may drive science, but it also may not contribute to knowledge. This leaves us with the following final problem. Since the word "science" comes from the Latin "scientia," meaning knowledge, and if space science puts us in the position of knowing less and less, in what sense is it science? In short, we may be confused about the meaning of knowledge because we have identified it too closely with science.

The source of the problem here is the extent to which the efforts to make space science and its fancy new experiments yield new knowledge reveals the inadequacies of one of the major criteria constitutive of our current concept of knowledge. That criterion is *standard conditions*. The problem of ephemeral data is due to our inability to know which variables to account for, i.e., what are the standard conditions for space-based experiments? The problem is fundamental because those conditions will change depending on the experiment, since the knowledge the experiment is supposed to yield relates to earthly phenomena to be found in earth's environment, not to celestial phenomena in a celestial environment.

The very criteria for knowledge are under attack here. Our current sense of knowledge rests heavily on the notion of experience. We must be able to back up our claims by appeal to empirical data which count as evidence. These conditions for evidence are otherwise known as *standard conditions*. If they can not be specified, then our evidence is in doubt and our knowledge shaky. This then is how current space science is transforming knowledge. It is forcing us to reconsider the notion of standard conditions as an epistemic criterion.

Finally, in closing, we are led to question the very value of such a large scale venture as the space program, especially if it leaves us with a totally bankrupt conception of knowledge. And while we are at it, we might as well note that the expense of the enterprise is itself suspect given large scale social needs we have at home. On the surface, three things seem obvious: (1) If the space program can not generate knowledge, then has it not lost its primary justification? (2) If we have been captured by our initial investments in it, which capital outlay now forces us to continue investing in a fiercely financially debilitating program which we can not give up because of the adverse economic effects it would have, then is not someone like Langdon Winner right about the autonomy of technology? [4] (3) Should we not give up the space program and spend all our money on the poor and the homeless? Well, and I am sure this will come as no surprise, my answers are no, no, and no. Here is why.

First, the fact that our current criteria for knowledge are inadequate does not mean that the space program has no justification. The fact that we are having a difficult time figuring out what we have actually come to know from these new ventures does not mean the ventures are flawed; it means our account of knowledge is. But this is no big deal. Our account of knowledge is constantly being revised, as I have tried to show, in the light of new conceptual developments and factual information. The fact that on the Aristotelian scheme mathematics could not yield knowledge did not mean that knowledge could *never* be had. We had to change our criteria and our conception of knowledge. The fact that on the

Aristotelian/Ptolemaic account of the universe there could be no other place than earth where objects revolved around a planet did not mean that the moons of Jupiter did not exist. By way of analogy, the discovery that they did meant that we needed a new way to explain and accommodate that set of phenomena.

As I have suggested, given the epistemological problems presented by the space program, we need to give up simple-minded empiricism as a foundational criterion of knowledge and reevaluate. It looks like the criteria for knowledge are going to have to be extended to include social structures and institutional criteria as well as some commitment to large scale coherentism. The fact that the universe has forced us to acknowledge that we do not have the intellectual equipment to understand it yet does not mean we should tuck our satellites and space stations and interplanetary probes between our legs, so to speak, and run for home. Our hubris has once again been exposed; so much the worse for hubris. There is clearly philosophical work to be done, i.e., epistemological conceptual work.

Now let us turn to the second point above. Given the scale of the investment, it is clear that we can not abandon the space program. Two reasons for this: (a) we have already invested so much, and (b) it would be too disruptive to the economy. Therefore, Winner is right, we are slaves of a run-away technological project which has stripped us of our political will and disenfranchised us. Well, I am afraid not. We can stop the program or features of it at any time. The current design of the American space station is being challenged and downscaled. Just as with other large scale technological ventures such as the super collider, the fact that we have invested so much already is no longer an acceptable justification for continuing to invest in that project. This is only rational. If we fail to learn from our mistakes we are irrational. This is Pitt's Commonsense Principle of Rationality, CPR. If we lacked both the will and the power to learn from our mistakes then perhaps Winner would be right. But we do learn and we do act. Winner's claims have been outstripped by real world events. The space program has not become autonomous, because we can interrupt it and transform it no matter what the consequences are as long as we have the will. Thank you Bill Clinton for proving a philosophical point.

Finally, given the problems back here on earth, *should* we not give it up and spend the money on more important problems? Again, I am forced to disagree. Let me use yet another analogy to underline my reasoning. The late middle ages saw the construction of the great cathedrals of Europe. The building of these magnificent edifices employed hundreds of workers, forced architectural designs and building skills to unimagined heights (bad pun), and brought our level of artistic and physical accomplishment to unprecedented levels. At the same time, this was a period in which human knowledge was having to be reconstructed, the cost of these buildings impoverished societies just crawling out of a period of excessive poverty, banditry, and disease. This was the period of the black plague, of petty fiefdoms waging petty wars with devastating results on the innocent. And yet, to what I assume was supposed to be the greater glory of god, these magnificent buildings were raised amid poverty and disease and rampant human bickering. The cynic could say that this is yet one more example of the corruption of organized religion. It certainly seems so. But to limit the issue there would be to shortchange ourselves. For there is more to the tale.

The ability of the human spirit to rise above its miserable, debilitating, squalid environment, inspired by the search for something transcendent, however misguided, is noble and fundamentally humanizing and enabling. Even if the motivation of those who initiated these projects and those who followed by envy was less than admirable, what they produced was admirable. And so, I would argue, likewise for the space program. This is not to deny that there is misery at home. This is not to deny that more needs to be done to alleviate that misery. But do not deny as well the need to search for more than we can see and deal with here. The space program represents the modern version of the building of the great cathedrals. It is a venture full of all that marks it as a great human undertaking. It has its dark side, its darkly human side full of politics and greed and avarice and the follies of power. But it also gives us what cannot be produced without this kind of mobilization of human resources. It challenges our abilities to accomplish feats of incredible physical achievement like walking on the moon and establishing a permanent human home in space. It does more, however. For in showing us how inadequate our concept of knowledge and value are in the face of change, it forces us to rethink who we are and what we are and where we are and who, what, and where we will be. To meet that challenge we need to be intellectually flexible and ready and capable of being challenged. This requires that we acknowledge that what we now use as criteria for knowing may not be adequate in the face of new data. It means that what we now value may not be valuable in the face of new discoveries. It requires a philosophical approach that gives each its due, but none undue privilege.

So, my final question. How do we know if we are in fact employing such a philosophical methodology or if we have fallen back into corrupt ways and have become again pathological? I think I have an answer to that. Is your characterization of a given situation able to handle a variety of different types of philosophical questions asked of it? If you have a problem, is the source of the problem also open to being queried for different kinds of problems? I tried to show how this was to done by showing how the space program presents a challenge to our conception of knowledge and *also* allows for us to ask questions about its moral standing and its political character. In short, have you characterized a situation in a way such as to close it off from the interests and concerns of other philosophers? If you have, then they have a right to accuse you of being insular and isolated. But if you can present your problem in such a way as to allow other problems to be raised without changing the problem topic, then you have succeeded in doing philosophy of technology in a way which Sellars, and I, would approve of.

NOTES

1. See W. Sellars, "Philosophy and the Scientific Image of Man," chapter 1 in his *Science, Perception and Reality* (Routledge and Kegan Paul, 1968), p.1.
2. See W. Wallace, *Galileo and His Sources* (Princeton, 1984).
3. See J. Pitt, *Galileo, Human Knowledge, and the Book of Nature* (Kluwer, 1992).
4. See, for example, L. Winner, *The Whale and the Reactor* (Chicago, 1986) p. 175.