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Toward a Polanyian Critique of Technology: Attending *From* the Indwelling of Tools *to* the Course of Technological Civilization

James Clement van Pelt[1]

Abstract

As a scientist, Michael Polanyi made significant advances in chemistry and economics. From that deep hands-on experience, he derived a powerful critique of prevailing ideas of knowledge and the proper role of science. He demonstrated that disregarding or eliminating the personal embodiment of knowing in the tacit dimension in pursuit of purely explicit and impersonal knowledge results in knowing that is misleadingly incomplete—"absurd." If technology is the practical application of science, then it should be useful to extend his critique of science to technology. The pursuit of impersonal knowledge parallels the quest for efficiency through the standardizing and programming of technique while devaluing personal knowing in the form of embodied skills, institutional memory, and a "feel" for possibilities that leads to insightful breakthroughs. As technological development continues to accelerate and proliferate unsustainably, the idolizing of efficiency operates to subsume other values that would tend to constrain such development, raising concerns about the future of discovery, of the economic and social order, and of the human soul.

Keywords

indwelling, intuition, personal knowledge, positivism, Polanyi, tacit dimension, tacit knowledge, technology

1. Introduction

Michael Polanyi's intertwined careers as scientist and philosopher of science were remarkably fruitful. As a scientist, he made significant theoretical advances in chemistry. From that deep and practical involvement with science, he derived a powerful philosophical challenge to what he regarded as logical positivism's impoverished view of what constitutes knowledge and the proper role of science. In response to personal encounters with people who held power over science while completely misunderstanding its fundamental character and purpose, Polanyi (1962) demonstrated in *Personal Knowledge*[1] that the personal embodiment of knowing is *sine qua non* to knowledge's veridical representation of reality, and consequently, he described the ideal of purely impersonal knowledge as "absurd"—one might say, a category mistake (pp. 9-12). Toward the end of his life, he elaborated that challenge into a person-centered epistemology that for me and many others has proven revelatory—simple in its fundamentals yet with vast implications and rich extensibility beyond the point to which he was afforded time to develop it.

My experience as a professional technologist has been profoundly informed by Polanyi's ideas, in particular those concerning the experiential aspect of the use of tools—the essence of which he calls *indwelling*. Once synonymous with empathy (as he explains in *The Tacit Dimension*[2]), indwelling in his terminology is the process by which an intentional being capable of using tools transforms an object into a tool by experiencing it as an extension of the user's own body, in the process extending and amplifying inborn capacities beyond their natural bounds. Likewise, if technology can be regarded as a kind of technical complex that encompasses systems of tools assembled, integrated, and operated via technique, then the function of technology can be thought of as an elaboration of the function of tools: to extend and amplify the capacities and powers of individuals and organizations in ways that overcome obstacles to intention—mass, momentum, time, distance, and mental and bodily limitations.

Technology develops according to its own internal logic, which derives from the evolutionarily adaptive idealization

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of efficiency and productivity. Among the obstacles to that development that its logic works to overcome are any competing social values. In deriving sustenance and enrichment from the bounty of the technological complex, everyone who participates in technological civilization interweaves the processes of their daily lives with its operations and implied values. The interwoven result becomes integrated to such an extent that to inhabit technological civilization is to indwell directly or indirectly the entire technological complex and to be reshaped by it.

2. Indwelling: The Extension of Intentional Being

A Polanyian critique of technology and its social ramifications requires at the outset a basic understanding and even a *feeling* of the validity and value of Polanyi's three primary insights into the nature of tools: first, indwelling; second, attending *from* for attending *to;* and third, tacit as opposed to specifiable or articulable technique.

Indwelling for Polanyi is an instinctive experiential phenomenon whose implications are primarily epistemological. The idea of using tools by extending one's being so as to inhabit something nonliving does not imply Cartesian substance dualism, which is an ontological description. Inanimate matter is not literally infused by a substance or personal aspect such as spirit, mind, or life force. Instead, sensory data collected by one's body about the prospective tool is processed mentally to form a conceptual model of the object, which, in turn, is integrated into the mental–sensory model that renders the appearances of reality that become the content of experience. That which is indwelled is not the physical object but rather the mental–emotional representation of the tool-defined object having been incorporated into the indweller's model of reality. As Polanyi (1964) writes,

> [Through perceptual and mental processes] we keep expanding our body into the world, by assimilating to it sets of particulars we integrate into reasonable entities. Thus do we form, intellectually and practically, an interpreted universe populated by entities, the particulars of which we have interiorized for the sake of comprehending their meaning in the shape of coherent entities.[3] (p. 29)

Knowing something explicitly means to have learned those facts about it that can be articulated—spoken, written, illustrated, or otherwise represented in a form that can be entirely instantiated physically. Knowing tacitly means to have experienced what the knowledge is *like—something it is like* to ride a bicycle or play an instrument or design a building that cannot be learned from written or spoken instructions but can only be signified inferentially and instantiated in subtle form. To learn any profession, certain factual knowledge must be acquired; but such knowing is incomplete without some sort of hands-on apprenticeship after the classwork is done, during which the personal example of the mentor and the implicit trust of the apprentice are critical in imparting the tacit knowing that differentiates a professional from a layperson or dilettante.

> Tacit knowledge is not easily shared. [It] involves learning and skill, but not in a way that can be written down [and] consists often of habits and culture that we often do not recognize in ourselves. In the field of knowledge management, [it] refers to knowledge possessed only by an individual and difficult to communicate to others via words and symbols. . . . Tacit knowledge has been described as "know-how"—as opposed to "know-what" (facts), "know-why" (science), or "know-who" (networking). . . . The process of transforming tacit knowledge into explicit or specifiable knowledge is known as codification, articulation, or specification.[4]

One begins to understand and *fully feel* what indwelling connotes—to know its meaning both explicitly and tacitly—by experiencing in a direct, intimately personal way the simple truth that the body serves as an intentional being's primary tool set. Referring to Polanyi's *Scientific Thoughts and Social Realities*, the physicist Yu Zhenhua observes the following:

> Normally, we do not attend to our body as an external object, but we always rely on our body as a means for our intellectual and practical control of the outside world. Polanyi generalizes this point and says, "*We may identify, therefore, our knowing of something by attending to something else with the kind of knowledge we have of our own body by dwelling in it*."[5]

To grasp an object intending to use it as a tool is instinctive precisely because learning to use tools and learning to indwell one's own body are the same process from infancy onward. To illustrate, Polanyi cites "the use of a probe to explore a cavern, or the way a blind man feels his way by tapping with a stick" to maintain and indwell an interior visualization of the unseen cityscape.[6] In both examples, as soon as one begins to poke and probe for something of interest, one no longer feels the stick as something separate from oneself. Until that moment, the stick or cane has been experienced as an object at the focal point of the visual field and as a source of sensations against the nerves in the grasping fingers and palm. Then the focus of attention shifts so that those sensations largely fade into the background, becoming so remote from the focus of attention that it is as if they have disappeared; Polanyi notes that they become *subsidiary* to the sensations of being in touch with whatever the stick makes contact with, just as if the stick or cane were a greatly lengthened finger.

Whether blind or with eyes closed to better perceive the details of the model, one attends *from* the tactile information provided by the stick and thereby attends *to* the features it probes. In distinguishing between primary and subsidiary awareness, Polanyi defines the dynamic of indwelling as attending *to* things of interest by attending *from* the means by which they are attended *to*, and he observes that the awareness of the latter is *subsidiary* in the sense that it is at the very fringe of the attentional field or even outside it.

This attentional shift occurs effortlessly, thoughtlessly, producing the feeling of having extended one's being into and through the stick. In purely physical terms, all that is happening is the transmission of vibrations through the stick to the nerves in the user's hand and thence into the neural system and the mind. But physical reality and experiential reality are two different things; indwelling is as real, both as process and result, as the tool and its user, just as experience and its processes are as real as the experiencing agent and the experienced world. If the indwelling experience were imaginary, rather than sufficiently accurate and natural as to be functionally veridical, tools would be useless, or worse, and the creation and use of tools would not be the decisively powerful evolutionary adaptation it has turned out to be.

3. Toward a Polanyian Critique of Technology

The ideas Polanyi formulated from the 1940s through the 1960s continue to constitute a radical critique of the effects of positivism on what best constitutes science:

> The declared aim of modern science is to establish a strictly detached, objective knowledge. Any falling short of this ideal . . . we must aim at eliminating. The ideal of exact science would turn out to be fundamentally misleading and possibly a source of devastating fallacies. . . . A true knowledge of a theory can be established only after it has been interiorized and extensively used to interpret experience. . . . Thus the ideal of a comprehensive mathematical theory of experience that would eliminate all tacit knowing is proved to be self-contradictory and logically unsound.[7]

If technology can be considered the application of science to practical needs, then a reasonable inference is that a profound critique of science's prevailing ideal could inform a critique of the principles guiding the development of technology—its nature, trajectory, and probable outcome. The merger of person-ness and thingness has become far more complete than we commonly acknowledge, being in the midst of it as fish in water, and day by day all the more so—far more than even Jacques Ellul could anticipate[8] at the stage of development he witnessed along the logarithmic curve predicted by Moore's Law.[9] Given the ever-quickening pace of that vast, towering development engine and the integration of its fruits into every aspect of life and culture, such a critique could be expected to say much about the course of technological civilization. In particular, Polanyi's critique of a science whose ultimate (and, to him, ultimately self-defeating) goal is knowledge purified of any personal component should make us ponder the extent to which technology may be pursuing that same ideal through the conversion of tacit knowing to impersonal programmed operations—and what consequences are now unfurling from that pursuit.

To draw the parallel between Polanyi's critique of science and what might serve as a Polanyian critique of technology, three of his essential ideas seem especially useful. By applying each one to technological development, it may be possible to discern consequences of the contradiction inherent in the ideal of technique purged of its tacit dimension. Polanyi's prophetic warning against "devastating fallacies" in the modern ideal of scientific knowledge (as quoted above) can be applied to a trajectory of technological development whose potential for literal devastation on a massive scale is all too real.

Here is the way I have come to express those three essential Polanyian ideas:

1. All knowledge is personal in some sense and to some degree. Without its personal component, knowledge cannot be comprehensive or complete.
2. The impersonal—explicable, articulable, specifiable—aspect of knowledge is "flat"—constituting only its surface. What gives it depth is its tacit dimension.
3. An integral component to knowledge is the experience of knowing, which has a definite structure. That structure is galvanized and vitalized when a person attends to something by attending from something prior, as one attends to the world from one's own body.

The first statement responds to what Polanyi regarded as the major error of the prevailing ideal of science (in Kuhnian terminology, the regnant scientific paradigm): that the goal of "hard" science (implication: all *real* science) is the eventual distillation of all knowledge into a single expression/algorithm/equation—the theory of everything (TOE) completely abstracted from its empirical moorings and devoid of any personal aspect that would distort its pristine clarity or dilute its integrity—devoid of the very component that would make such a thing interesting, comprehensible, useful, and ultimately veridical; as if a filmmaker were to forget there was any reality greater than the colors and shapes recorded by the camera. At best, it would be TOE3: a theory of everything except experience.

The technology-related parallel of the prevailing idea that science should be the quest for maximally comprehensive, integrated, and abstract knowledge is the prevailing methodology that technology should be the quest to optimize technical systems through the conversion of skillful personal knowing into maximally integrated programmed operations. That parallel is not accidental; it originates in the natural preference for certainty through absolute precision and clarity in both what is known and what is made. Facts about the physical world bolstered by precisely measurable empirical evidence may seem much more real than the sort of knowing derived from less tangible person experiencing, whose evidence is readily dismissed as "anecdotal" and often "anomalous" simply because such experience, by its very nature, does not lend itself to methodologies focused entirely on the physical domain and dependent on the replicable data that characterizes both physical science and technology. The higher ontological priority that, therefore, has come to be assigned to facts that are verifiable or falsifiable or clearly specifiable tends to marginalize and eclipse experience as such, so that it seems neither a fit grounding for "hard-science" nor a reliable component of advanced technical operations. Scientific theory must be both readily replicable and clearly falsifiable just as technique must be standards-based (interchangeable) and patentable (articulable); tacit knowing has none of these traits.

Thus, the technological corollary of the quest for the TOE is the continual process to consolidate, integrate, miniaturize, proliferate, and ephemeralize[10] physical instrumentality into a single integrated complex of systems in which all techniques are standardized and programmed, seamlessly interfaced to its users' intentions. In the development of technology, the ruling principle is *efficiency*; Buckminster Fuller, perhaps technology's greatest booster ever, aptly defined efficiency as "doing more and more with less and less."[11] Technical efficiency is both adaptive in practice (in the evolutionary sense) and compelling in principle, determining technology's *telos*, meaning the outcome entailed by the logic of the situation that pulls the course of development toward itself. That *telos* is a perfected and completely integrated military–industrial–commercial–political–intellectual complex, "its hour come round at last"[12]—proceeding according to its own agency beyond effective human control, and whose artificial intelligence is the programmed substitute for human skill and judgment—a full convergence of systems entirely for the maximization of efficiency.

As progress toward that outcome accelerates, the complexity and comprehensiveness of the increasingly integrated technological complex surpasses the capacity of persons to employ it in the way a tool is employed to extend one's reach and amplify one's powers. Instead its operations instrumentalize—*incorporate*—persons individually and collectively, employing them as tools to extend its capabilities toward the fulfillment of its telic course. At the terminus of this process, all tacit knowledge possessed by humans would be converted entirely into explicit technique—programs—to automate and optimize overall functionality. Think of the skilled factory worker whose actions are recorded and abstracted into numerical control programs guiding the manufacturing operations of robots that take over her job on the assembly line; the worker's tacit knowing—with all its possibilities for originality, adaptability, innovation, and insight—is thereby made as extraneous as John Henry and his great hammer at the advent of the steam drill.[13]

4. Technique and Specifiable Versus Tacit Knowledge

The second essential Polanyian idea extends from and validates the first (quoted from above and expanded):

> The impersonal—explicable, articulable, specifiable—aspect of knowledge is "flat"—constituting only its surface. What gives it depth is its tacit dimension—the part that exists as ineffable personal experience of what is known and to be known—the "soul" of what we know but cannot express except by empowering others to model it and thereby to discover and replicate that experience for themselves.

In his 1964 Terry Lectures at Yale and in the resulting book, *The Tacit Dimension*[2], Polanyi convincingly demonstrates that personal knowing—the embodied experiencing of knowledge—is essential to even the most abstract scientific expressions. Even a formula as abstract as Einstein's world-changing equation accounting for energy in terms of matter's relation to space–time began as an experience: Polanyi recalls that Einstein said he had intuitively felt out the truth expressed in the equation as a boy of 16, well before he was versed in advanced mathematics, which he worked out 10 years later guided by his sure sense of having already traveled the route that the mathematics would map in its pure abstraction. To those who have not similarly retraced that heuristic journey, $E = mc^2$ is little more than a set of symbols whose full meaning remains accessible only to those who can "feel it out" by inhabiting mentally its ineffable form in the tacit dimension.[14]

Anyone who has struggled to learn how to meet the challenge of furniture "with some assembly required," or has learned to cook despite recipe instructions such as "add a dash" and "season to taste" is familiar with the tacit dimension of knowledge—the space in which one "feels" how to do something. The division between specifiable and tacit knowledge is well marked at the point in the learning of a language when the student discovers heuristically that all the specifications of grammar, syntax, and vocabulary provided in books and drills have been internalized, so that that explicit structure is suddenly subsidiary and the student realizes that she is for the first time thinking in the new language; it is that moment that defines when a language is actually learned.

Those of us who have worked in a technological field for a reasonable time know that the experience thus gained enables one to intuit the operation of new systems often an order of magnitude faster than others can do, partly because the experienced tech can anticipate how the system's anonymous designer's thought processes unfolded. A person who grows up amid advanced technology and internalizes it as she does language and other skills relevant to her civilization has been called a "digital native," as opposed to someone who must learn it from "the outside in"—a "digital immigrant."

This introduces a new sequential element to the use of technology. Where previously a person mastering a skill would cross from specifiable to tacit knowing, with the articulable specifics becoming subsidiary to the tacit (inarticulable, ineffable) doing of the skill, the advance of technology has accelerated to the point that the crossing over happens by generation and even by cohort. New devices and techniques are introduced and popularized more rapidly, their underlying metaphors altered more persistently than the vast majority of their intended consumer-users can internalize their specifics to become subsidiary to an intuitive "feel" for how to make them part of one's new, improved lifestyle. It is as if new and improved versions of the English language—thorough revisions—were being introduced so rapidly that only those whose early childhood overlapped with the newest one could really learn it, while everyone older struggled constantly to make the transitions, clumsily falling farther and farther behind with every new version. The "digital divide," a term that once connoted the division between those who have the means to master computer skills and those who do not, now refers to this sequential gap between the tech-savvy youth and their parents, teachers, and other elders who depend on them for classroom tech support. Then those children grow up and some become teachers, who then find technology has advanced to the point that it is they who are the "digital immigrants" tech-dependent on the next generation of "digital natives."

The "digital divide" is magnified by the two parts of improved efficiency: greater integration and greater elegance—"easy power"—that which makes an Apple iWhatever *cool*. As mentioned above, as more and more functions are integrated into a single device (be it a sleek cellphone–typewriter–camera–datebook–alarm–jukebox–TV–GPS–computer in one's pocket, a vehicle–guidance system–entertainment center–office in the garage, or a copier–printer–scanner–fax–coffeemaker at the office), control systems and the user interface become primary factors determining the "usability" and therefore the success of a product. To avoid having such MFDs (multifunction devices) obscured by zillions of buttons and knobs, the control systems must be continually consolidated into control sets that appear simple only because each control does many things in combination with the others.

How does one learn to use such control sets with facility, without explicit thought, with *flow*? Experience with current trends in technology indicates a growing prevalence of tacit over specifiable knowledge in the fact that comprehensive instruction manuals are rarely provided with consumer electronics and software, other than two items: a sheet of legally required safety warnings and a single sheet showing a series of simple images to guide setup. Furthermore, the controls for ever-more-complex devices get increasingly minimalist in number and design to attain the high praise of "cool"—less and less explicit, more and more allegedly "intuitive," that is, reliant on tacit knowing. The typical user "plays around," asks around, observes others, directly or via YouTube videos, and gradually "gets it"—"groks it," in the 1960s phrase.[15] Designing such "intuitive" GUIs (graphical user interface control systems) in the first place obviously requires the very innovation, creativity, and imagination that is characteristic of tacit knowing, to be able to match the control system to what the user's experience with the device is likely to be and how she is likely to respond to it. "Usability testing" reveals how the design can be modified to better reflect the user's tacit experience with the product or system.

An extreme example of this sort of elegance is the control system of a stealth aircraft, whose demands now outstrip the physical limits of even the most adept young pilots. The neural processing from perceiving to deciding to activating controls with hands and feet can be fatally slow at supersonic speeds, especially given gravity effects that starve the brain to the edge of unconsciousness. The response is heads-up displays and virtual controls: the control panel is projected onto the underside of the windshield, merging with the outside view, and the pilot merely looks at points on the display to guide and shoot, steering merely by moving the body this way and that as in luge sledding. The next generation will directly interface the pilot's brain to the aircraft's control systems, using technology that already exists for the direct control of prosthetic limbs. Thus, the far-leading edge of technological development requires maximum use of the tacit dimension. If a stealth jet and its pilot do *not* merge into a single entity, neither will survive a challenging situation.

In pursuit of efficiency and the competitive edge, wherever possible the skills and organizational memory of workers, craftspersons, and artists are being supplanted by automated simulations of those assets. Yamaha's computerized piano (really a computer with a piano peripheral) converts code recorded on a CD-ROM into what we experience as music, precisely recreating not only the notes played by a specific concert pianist but also the timing and degree of pressure on keys and pedals. From that code, the piano's computer invokes a kind of doppelganger of the pianist's tacit knowing, which was digitized into numerical control sequences that activate the piano's robotic components; the forms represented by those numbers are actually the surface of the forms experienced by the human being whose skills are automated. Lacking the depths below that surface, fine music can be replicated at the highest skill level, but only as the precise duplicate of a particular recorded experience; no creativity or innovation or response to changing contexts is possible, except possibly by the kinds of brute force methods used to by a supercomputer programmed to take on a human chess master. The difference between living intelligence with access to the tacit dimension versus "zombie" artificial intelligence lacking such experiential access has been aptly summarized: "The lights are on, but nobody's home." The implication is that a person is "home" only when experiencing tacitly.

5. Codified Programming Versus Tacit Knowing for Control

In pursuit of providing an accessible user interface for controlling ever-more-complex multifunction devices for the average consumer, ever-more-intuitive control systems must be provided that are increasingly reliant on the user's tacit knowing. Thus, the tendency toward systems based on codified and programmed operations competes with the need for tacit knowing to control and use technical products. The contention between integration and elegance sets up a bizarre bifurcation: tacit knowing is required to make good use of technology at the same time it is being structured out of technology's production and distribution processes. That contention actually has a deleterious effect on tacit knowing. Multifunction devices have often dazzling and diverse capabilities, but those capabilities are nonetheless limited by standardization and programming. Consequently, what can be known tacitly is circumscribed in its possibilities; the open horizons of the tacit dimension are closed off, though users are unaware that their opportunities for discovery have been thus constricted.

In this way, the association of efficiency and consistency with impersonal preprogrammed substitutes for skillful and heuristic personal knowing logically tends to lead to a loss of flexibility and adaptability. In a world organized on such principles, the user becomes a cog in the production–consumption cycle—replaceable in more and more instances. The very human and very spiritual experience of unbounded discovery and transcendent creativity becomes available to fewer and fewer denizens of Tech World, with an attendant collective loss of adaptability in response to surprising situations—a gravely dangerous state of affairs should such situations present themselves as unprecedented crises. Speaking in a collective sense, as the present civilization is revealed to be more and more unsustainable, systemic breakdowns can be expected to provide the catalyst for cascading failure of the complex integrated systems on which technological civilization. The disruption of supply lines reaching across the ~~globe, caused~~ by the recent earthquake~~-tsunami in Japan, is~~ an apt harbinger.

6. Technology as the Complex of Systems of Tools

Of the three essential Polanyian ideas I enumerated previously, the one with the most profound implications when applied to technology is certainly the third:

> An integral component to knowledge is the experience of knowing, which has a definite structure. That structure is galvanized and vitalized when a person attends to something by attending from something prior, as one attends to the world from one's own body. It is the process of embodiment that extends one's self into the structure of knowing.

Being part of a civilization whose use of tools has become almost indescribably complex, we encounter tools most commonly in a sequence of levels interacting in a from–to dynamic. We attend from the one closest at hand to the next, in a succession of attentional shifts from tools to objects of interest, such that the object becomes the indwelled tool from which the next object in the sequence is attended to. With each such shift, the focus of attention shifts from subsidiary awareness of the tool to primary awareness of the object in a kind of attentional cascade.

Indwelling a sequence of tools by extending one's awareness and control from the subjective center "outward" means attending from POV_0 (the original point of view) to $Object_1$, such that one indwells $Object_1$ and repurposes it as a tool, relocating one's POV into it experientially so it becomes POV_1; the next shift in the sequence is from POV_1 in $Object_1$ (now $Tool_1$) to $Object_2$, shifting attentional focus to POV_2, and so on. As the POV extends from point to point in the sequence, the primary awareness of that level becomes subsidiary—participating in the tacit dimension. In that process, especially in the case of massive electronic systems, the usual sensation that one's personal center is located behind the eyes and between the ears can become completely displaced by a sense of being, say, in cyberspace with a loved one across the continent, sometimes even resulting in temporary disorientation when the sequence/connection is disrupted.

This cascading effect, and the dramatic phase change occurring at each major transition point, can be observed in the way a student driver relates to a newly assigned car. At first the student self-consciously and mechanically applies the specifiable knowledge acquired in driver training class ("book learning"): turning the steering wheel makes the car's front wheels turn, pressing on the accelerator pedal increases the amount of gasoline going to the engine, and so forth. Sitting on the car seat while focused on performing the required actions, the student translates explicit knowledge into individualized actions with no sense of the integrated embodied performance Mihalyi Csikszentmihalyi calls *flow*.[16] The focus is on the steering wheel, the pedals, the dashboard symbols, and so on, almost as if they had nothing to do with the changing scenery as the car moves and turns. The focus of attention then shifts naturally to the workings of the car: the "feel" of the tires against the road, the engine responding to the accelerator, the chassis rocking this way and that. The focus shifts again, with the former focus becoming subsidiary, as the driver attends now to the feeling of the car moving down the road, the experience of being in traffic (inside the car only subsidiarily)—contending *as the car* with road conditions, routes to be followed, and so forth. The driving instructor knows what the student is experiencing, not because the student can articulate it—the knowing is tacit—but because the instructor has experienced it himself and now experiences it vicariously through her; he attends *from* his past experience and the tacit knowing it involves *to* her own tacit experience as his primary attentional focus, enabling him to empathize with her and thus offer appropriate assistance. Rather than providing instructions about the manipulation of the car's controls, he speaks to her as if she were the car's guiding intelligence—"okay, now lean into the turn . . .

ease up . . . just glide along"—as if she were as "at one" with the car while she is driving it as she is at one with her own body. She indwells the car, moving with it naturally as it turns, with only subsidiary awareness of using the steering wheel or pressing the pedals, no longer driver in car or driver of car, but driver-and-car, beyond user-indwelling-tool to a full human–machine merger. The extreme case of this is the well-documented phenomenon of the driver who arrives at the intended destination with essentially no recollection of what happened during the journey; the entire travel experience has become subsidiary to the driver's preoccupations.

Using technology involves this same sort of sequence, from control systems through the levels of functionality to the final result. Usually a number of stages are encrypted, meaning that the instrumentality is inaccessible to the user; the device is a "black box" whose operations are unknown—it "just works." The driver of a car does not experience the inner workings of the transmission, much less of the car radio, any more than the user of the stick experiences how its cellulose is constructed in a way to make it suitable as a probe.

Extending Polanyi's indwelling dynamic to apply to a sequence of attendings along a continuum of utility, as exemplified above, provides important clues about what it is for a person to adapt to this technology-saturated world in which tools are integrated into systems of tools, systems of tools into complexes of systems, and so forth until the result is technological civilization as we know it. Although humans have depended on tools and technique for tens of thousands of years, the humans of this century indwell a culture more completely integrated and defined by and dependent on technology than any known before—with the workings of its systems and devices and "apps"[17] having advanced beyond the ken of all but a dwindling percentage of the population. If Arthur C. Clarke was correct that any sufficiently advanced technology is indistinguishable from magic, then truly those born into this century—named the "millennials" as if a new breed—take magic entirely for granted.[18]

A compelling image of the continuum between the tool and the technological complex, with the level after level of encrypted tools and systems in between, can be viewed in Stanley Kubrick's visionary 1968 cinematic interpretation of Clarke's novel, *2001: A Space Odyssey*.[19] As the film opens, a tribe of prehumans is threatened with extinction, at the mercy of enemies and natural forces—until one of them is inspired mysteriously to pick up a long thigh bone. For the first time an object is re-envisioned as a tool—this one for breaking and crushing and striking out—tool and weapon. A short time later, after the tribe deploys its new advantage to conquer its enemies, they leap about in exultation, and the discoverer hurls the long white bone high into the sky. In an instant the image is replaced by a military satellite of the same shape and color orbiting above the Earth. The bone, the satellite: as extensions of human indwelling they are one and the same, tool and weapon, at opposite ends of the continuum of technique between which is an eons-long sequence of successive indwelling from one tool level to the next.[20]

7. The Supremacy of Efficiency: Using Tools and Becoming Borg

From the moment a proto-human ancestor picked up a stick or a bone to indwell as a tool, a powerful organizing principle began to guide the further development of intelligent life and thence civilization: the principle of intended efficiency, which is adaptive in its tendency to maximize effectiveness and minimize costs.

Through the dynamic of indwelling, a tool is absorbed into the user's being, but as tools become systems of tools, and those systems aggregate and integrate into technologies in quest of ever greater efficiency, the sense of aggrandizement the user derives from the amplification of personal power by using tools becomes a kind of thrill from merging into something greater than oneself. The user's priorities and interests become identified with those of the system, in effect making the user a component of the system sharing in its overall efficiency and collective power, rewarded by the system's effectiveness and a sense of one's small contribution as a cog in the great machine. At the same time, the system's ever-increasing efficiency benefits those who control it to advance their own interests. The logic of efficiency is to overcome anything that might impede its progress, be it physical limits or social constraints; efficiency becomes an organizing principle that competes with and challenges value systems based on other principles such as concern for human welfare or environmental well-being. Over time, that contention tends to favor efficiency because of the material benefits it can produce, so that the constraining value systems are gradually neutralized, marginalized, and subverted.

As technological development overcomes constraints and takes on its own momentum, the long-standing tendency for humans to objectify and instrumentalize one another interacts with the dynamics of indwelling to absorb humanity collectively into an increasingly integrated technological matrix. Those individuals and cultures offering resistance are marginalized or overcome by those who have already been absorbed into the advancing collective. What begins as the indwelling of living being into nonliving object-tools becomes human components drawn into and drawing personal satisfaction from the organization's efficiency-centered operations.

In the television series *Star Trek: The Next Generation* the outcome of this logic is symbolized by a race of humanoid beings so deeply integrated into their technological matrix that their individuality is completely absorbed.[21] They are the Borg, short for cyborgs, short for cybernetic organisms, equal parts organic and mechanical—tinmen too far gone ever to seek after hearts. They advance from planet to planet absorbing any civilization whose technology is inferior; their calling card and their promise is "Resistance Is Futile." Their relentless advance parallels technological civilization as it has obliterated traditional cultures refined and sustained over millennia, reducing their traditional ways of life to quaint costumes and folk rituals to be reenacted for the amusement of tourists. As technology-driven cultural absorption continues apace, and as our bodies and lifestyles continue to be technologized, the Borg may be how we would appear to our ancestors, and how our descendants may appear to us.

8. Impersonal Knowledge and Workerless Production

In socioeconomic terms, the technological equivalent of impersonal knowledge is workerless production. A primary driver of technological development is enhanced efficiency as measured by productivity improvement, which is calculated by dividing the value of what is produced by the cost of producing it. Quarter by quarter, economic well-being is evaluated in terms of gross national product[22] and productivity per worker. That sets up an irresistible tendency to increase efficiency and thus profit by developing technology that can produce more with the same number of workers, or the same as before with fewer workers. The trend goes unnoticed as long as the goods and services produced are fully consumed. When an economic squeeze occurs and demand falls, production is curtailed proportionally and some workers are "surplused" and jettisoned via layoffs. But when demand recovers, it becomes clear that their jobs have been obviated by automated systems so that rehiring them would be unproductive and inefficient.

Currently millions of manufacturing, distribution, clerical, sales, reception, and even middle-management positions are being absorbed through the conversion of tacit knowledge to programmed procedures, in a process that increasingly "purifies" the system by replacing human components with technological alternatives that from the viewpoint of surface knowledge are more consistent, reliable, and cost-effective. Consider just the number of workers replaced over the past decade by telephone information systems using voice recognition linked to computer databases, or by Internet e-commerce systems customers anywhere in the world use without human intervention, or by the just-in-time inventory technology that helps Wal-Mart eclipse the small businesses of the communities it colonizes. In the first half of the past century, live music on radio was replaced by recordings, throwing musicians out of work; then the automation of radio programming displaced thousands of disk jockeys; now downloadable mp3 music files are constricting both the recording and radio industries. For decades, IBM's slogan was "Machines Should Work; People Should Think." The reality is that fewer and fewer thinkers are required to make machines that do more and more of the work.

The hallmark of modern technological development is its geometric pace of advancement. The prediction of Moore's Law[9] has held for nearly four decades: that microprocessors could be expected to double in power every 18 to 24 months. Because microprocessors are the critical component of all control systems, the geometric growth predicted by Moore's Law has been generalized to all technology, with corollaries that prices would plummet and accessibility would soar at the same rate.

Unquestionably technological development creates new employment. New materials, devices, and systems are designed, produced, marketed, sold, maintained, and discarded, and workers can be retrained for those new jobs. Furthermore, the willingness of immigrants and people in developing countries to work for lower wages extends the viability of employing people rather than automating their work.

But if productivity is to improve over time, either demand must continually increase in step with productivity, or fewer workers must be retained to meet level or declining demand. Unlike technology, demand in the aggregate usually does not grow geometrically, especially when political policies and cultural expectations cause median incomes to remain steady or even decline. Combine geometric growth in productivity per worker with relatively constant or declining demand for that which is produced, and the result can be expected to be a relatively steady reduction in the need for (human) workers.

Such a dynamic can lead to several outcomes. One is the direct conversion of surplus derived from soaring productivity into equitably distributed benefits such as shorter workweeks under better conditions at level or increasing compensation, resulting in a boom in leisure-related pursuits and an increase in personal service jobs in which tacit knowledge cannot be replaced by programming. Futurist and economist Robert Theobald, one of the past century's leading experts in the economics of abundance, outlined that option in great detail as early as 1964 in books[23] explaining what a future might be like should technology advance to the point that machines do the work and employment is regarded as a kind of recreation.

The latter option—currently the operational one, in which work for most is a compulsory, anxiety-ridden exchange of lifetime for sustenance—concentrates the surplus at the very pinnacle of the economic pyramid to benefit the majority owners of the technological complex, leading to chronic structural unemployment and an ever-growing legion of the "long-term unemployed" who have given up the seemingly futile search for jobs.

In and of itself, the logic of technology includes no provisions for equity and is subject to no social constraints other than that the generally ethical operation of industry, government, and markets enhances overall efficiency. That logic seeks to overcome all constraints, social or otherwise, and is blind to the conditions it creates for steadily increasing structural unemployment, because technological advancement continues to accelerate regardless of that outcome. The inexorable quality of this logic recalls the old metaphor of the frog gradually adjusting to the temperature of water being heated in a pot until his fate is sealed.

As productivity per worker increases, the surplus value that results is concentrated at the top, while private employers avoid taking on workers they no longer need, causing median incomes to decline. Demand under such conditions can keep pace with productivity only through the "invention" of money through borrowing against assets whose value is thereby eaten away, creating what in hindsight turns out to be a "bubble" that contributes mightily to the instability of the overall economic system. At some point, inevitably, demand must fall, even crash, and a permanent version of the situation currently besetting much of the global economy must become locked into place: "jobless recovery" providing fewer and fewer jobs along with ever-increasing production capacity together with ever-declining purchasing power to consume what is produced and an ever-harsher competitive environment for all but those at the very top of the economic pyramid.

Recent films such as the *Terminator*[24] series have proven to be prophetic about the consequences of applying this same logic to military technology. The rise of unmanned reconnaissance and attack drones controlled by soldiers safely ensconced thousands of miles away and used for "surgical strikes" on enemy command-and-control facilities and personnel betokens an evolution toward war minus soldiers to minimize the political resistance to war-making that arises from a constant flow of human casualties. As more and more capabilities are programmed into such weapons systems, shifting their operations from the tacit to the explicit domain, what is required from their controllers diminishes, and the day approaches when making war becomes completely automated, with monstrous ethical implications.

9. The Lure of Limitlessness and the Monster of the Id

Because it increasingly drives and is driven by snowballing technological development, the techno-economic complex increasingly comes to serve not the well-being of its producers and consumers but only the forces of the market—the name for the collective human desires and fears in response to which products are designed, manufactured, and used. Wall Street's testosterone-soaked metaphor for the market at its most successful—a great bull charging through the china shop of civilization—recalls the metaphor cited by Jacques Ellul in his final jeremiad to technological civilization: The unconstrained subhuman will of the Beast ruling over the doomed world pictured in the Book of Revelation.[25]

In the 1954 film *Forbidden Planet*,[26] ~~human space explorers~~ discover the world of a long-extinct race who had developed technology so advanced and powerful that they could effect any intention merely by envisioning it, without the need for physical instrumentality—to *will* the objects of their hearts' desires directly into being. They could not foresee that during the very first night on which that capability became available, their sleeping superegos would release their collective libido to take control of that technological edifice and give form and substance to their darkest desires, from which emerged their own Beast—the "Monster of the Id." Produced at the same time when Ellul was writing his magnum opus, *The Technological Society*, and as Polanyi was hitting his stride in ~~the~~ crusade against personless science, the film seemed to warn that the closer technologies come to giving us godlike powers, the closer we would come to releasing the forces of our own destruction.

Godlike powers? The ~~*Book of Genesis*~~[27] portrays the emergence of humanity to have occurred at the primeval point when a line is crossed that sets our species apart from all others: on gaining the realization of the implications of mortality, and almost simultaneously, the understanding that mortality implies at least the possibility of its opposite: to be unbounded by physicality—the conception of limitlessness. But knowledge of what it is to be limitless cannot be indwelled by beings who by their essential nature must indwell the matrix of mortality, any more than the sky can be encompassed in a photograph. The desire to be as gods, when experienced from within the inherent constraints of mortality, translates into the desire to transcend, in turn, each new limit to what can be known—what can be done—what can unbind the condition of being mortal from the necessity of death.

> Advertising signs they con
> you into thinking you're the one
> that can do what's never been done
> that can win what's never been won
> meantime life outside goes on
> all around you.[28]

In ~~*Genesis*,~~ humans forego the chance to indwell the community of living beings intelligence divinely charged with caring for a vibrantly, poignantly mortal paradise, choosing instead, to seek to transcend mortality through the acquisition of the knowledge definitive of divinity. In doing so, they come to know what it is to be exiled in the parched chasm between what they have become and what they limitlessly aspire to have and to be. According to ~~*Genesis*~~ and other creation myths as well, technology, a divine gift granted to humanity for the purpose of achieving sufficiency, is immediately set to the task of traversing the distance between mortality and divinity, as symbolized in the story of the Tower of Babel—whose purpose is to bridge the gap between the mud ~~into~~ which we are born and the heavenly abode of the immortals.[29]

As the present civilization converges on its crucible, its technologies enable us to indwell those long-sought godlike powers. To fly in the manner of Apollo across oceans and continents outpacing the advancing dawn; to link instantly with other minds regardless of their physical location; to carve out mountains and level hills and valleys; to banish darkness at the flick of a finger; to draw out the riches of a hundred million years and consume them in pursuit of lives of luxury and ease that would beggar the emperors of old; to know the secrets of the cosmic evolution; to have the answer to a question as quickly as it can be asked; to deconstruct and defeat the agents of disease, rebuild broken bodies, and restore damaged senses; to master the alchemy of transmuting milk and oil into almost any imaginable form or substance; to explore other planets, touch down on comets, and make man-made moons signal us how to get where we want to go; to grow crops whose bounty surpasses all past harvests; to share the fruits of arts and science and yet apply them to maim and kill ever more artfully; to redesign the structures of life so that plants and animals become our living machines . . . could such a list not go on for thousands of pages? Would the authors of Genesis not survey such wonders and judge us near to achieving the ancient aspiration to be as gods—having consumed the fruit of the Tree of Knowledge and come close to possessing the fruit of the Tree of Life? Or would they instead prophesy our fate to be the one implied by those words found graven in stone amidst the sands of some trackless desert: "My name is Ozymandias, king of kings: Look on my works, ye Mighty, and despair!"[30]

The lure of the limitless is integral to the dynamic that drives the exponentially accelerating pace of technological development now determining our fate. Whenever one indwells a tool or system of tools, one feels the thrill of being extended and expanded, aggrandized, momentarily "buzzed" by the power to transcend one's natural faculties—the limits of mortality. But quickly those feelings recede and become subsidiary to the further desire to surpass limits, constantly edging its way into primary awareness, driving us toward whatever "upgrade" promises to assuage that desire. As Augustine confessed, in the midst of another empire won through technological superiority yet already in decline, *Nos fecisti ad te et inquietum est cor nostrum donec requiescat in te*—"We are made for You, and restless is our heart until it rests in You."

To revise that ancient prayer for this fast-changing age: "We indwell our tools to gain godlike powers in pursuit of the promise of plenitude; but in so doing we make ourselves the tools of a thing vast and impersonal driving us toward we know not what, feeding on our restlessness, heedless of our need to rest in You."

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Notes

1. See Polanyi (1962, pp. 9-12).
2. Polanyi (1964, pp. 17-18).
3. I find it helpful to bear in mind that descriptors such as "interiorize," "inward," and "outward" are strictly metaphorical, since one's being is not actually bottled up inside something (e.g., the skull), nor is it locked away from the content of experience located outside.
4. See Collins (2001) and Wikipedia article "Tacit Knowledge," en.wikipedia.org/wiki/Tacit_knowledge.
5. See Zhenhua (2002).
6. Polanyi (1964, p. 12).
7. Polanyi (1964, pp. 20-21).
8. All contemporary philosophy of technology is informed by Ellul's classic, *The Technological Society* (1954/1964).
9. Moore's Law was conceived ca. 1965 by Gordon Moore, the founding chairman of the Intel Corporation. Projecting the trajectory of microprocessor development, he stated that it was reasonable to expect the computing power of microprocessors (measured by the number of circuit elements in a logic circuit, or the number of transistors on the chip) to double about every 18 months. He could have added two essential corollaries: that the cost would be halved, and that general access to advancing technology would proliferate at the same logarithmic pace. Four years later, Intel's very first integrated circuit product, the Intel 4004, measured an 8th of an inch by a 16th of an inch and "had about the same amount of computing power as the original ENIAC which weighed 30 tons, occupied 3,000 cubic feet of space and used 18,000 vacuum tubes" [ideafinder.com/history/inventions/microprocessor.htm]. Because microprocessors are the foundation of all contemporary electronic devices and systems, and also because of the overall techno-zeitgeist, that "law" has been generalized to apply to the pace of development of all technology, stretching the interval to be between 18 and 36 months depending on the technological segment to which it is applied. Moore's Law has held true since 1965, but because of fundamental physical limits and the variability of quantum phenomena at extremely small scales, there is a near-term endpoint at which the validity of the "law" must run out. However, no one knows how long that terminus can be extended by basic research and technical refinements at the quantum level of reality.
10. *Ephemeralization* is the term used by Buckminster Fuller to represent the process whereby technology is made more efficient by minimizing the inertia of its physical instrumentality. An example is communications, which began with marks on clay tablets and animal skins carried by messenger from place to place; then progressed to papyrus and then paper sent by post; then code signals transmitted through wires; then voice and images over wires and via wireless broadcasting; and currently a blend of wired, wireless, and digital display systems making paper and postal delivery more and more obsolete. The transition from looking up something in one of the *Encyclopedia Britannica*'s 36 volumes to locate a few paragraphs on paper pages, to searching for it via iPhone and Google and getting 10,000 "hits" that disappear with the brush of a touch screen is a very recent example of ephemeralization. Anyone who has boxes of past written work on paper but suffers the loss of hundreds of pages of current work stored on a feckless hard drive appreciates the downside of ephemeralization.
11. "Doing more and more with less and less" was actually Fuller's definition of ephemeralization, which to him was synonymous with the quest for ever greater efficiency.
12. See Yeats (1920).
13. "Some labor advocates interpret the legend as illustrating that even the most skilled workers of time-honored practices are marginalized when companies are more interested in efficiency and production than in their employees' health and well-being."—From the Wikipedia entry "John Henry (folklore)."

14. See Polanyi (1962, pp. 9-12).
15. The term *grok* comes from Robert A. Heinlein's *Stranger in a Strange Land*, a best-selling Hugo Award-winning science fiction novel first published in 1961. During the 1960s and early 1970s grok became established as the slang equivalent of tacit knowing, ~~though of~~ those who spoke about grokking this or that were aware of Polanyi's contemporaneous work. There is no evidence that Polanyi ever heard Heinlein's term, or that Heinlein ever heard of Polanyi's, despite the obvious memetic coevolution.
16. See Csikszentmihalyi (1990).
17. "App" is slang for "application software program" (as opposed to operating system software) coined by users of Apple's iPod devices and canonized by Apple to describe the hundreds of thousands of free or inexpensive single-purpose programs that have become available for its iPod, iPhone, and iPad, and the similar devices offered by other manufacturers.
18. See Clarke (2000).
19. ~~2001: A Space Odyssey~~ is the Paramount Pictures film portraying Clarke's simultaneously published novel of the same name (New York: Roc/Signet [now imprint of Penguin Group], 1968), which in turn was a novelization of his 1948 short story "The Sentinel" first published in the magazine *10 Story Fantasy* in 1951, under the title "Sentinel of Eternity."
20. One who participates in the society that produced the orbiting satellite, ~~and , who~~ has some idea of how and why it comes to be in space, maintains a tacit connection to it via every intervening system, however encrypted—an ineffable, felt connection that locates the satellite as a part of one's model of reality in just the same way the bone–tool–weapon was presumably located in the reality models that kept our distant ancestors alive.
21. *Star Trek: The Next Generation*, © Paramount Pictures, "Q-Who?" Episode 142, directed by Rob Bowman, written by Maurice Hurley, originally broadcast May 8, 1989.
22. The calculation of gross national product is in itself a contentious issue. In reference to the topic at hand, the issue is that the current calculation method measures only activity that shows up at the surface of the economic system; consequently it omits a huge amount of activity involving tacit knowing, such as the care of children at home, which does not show up on that surface.
23. Robert Theobald, *Free Men and Free Markets* (1963), *The Triple Revolution* (with others; 1964), *The Guaranteed Income* (edited; 1966), *An Alternative Future for America* (1968), and others.
24. *The Terminator* (1984), *Terminator II: Judgment Day* (1991), *Terminator III: Rise of the Machines* (2003), and *Terminator Salvation* (2009). James Cameron directed the first two and was the lead writer of all but the fourth.
25. See Ellul (1990). Ellul's 1977 book, *Apocalypse*, was nominally a theological interpretation of the Book of Revelation.
26. *Forbidden Planet*, film directed by Fred M. Wilcox, screenplay Cyril Hume, story by Irving Block (Metro-Goldwyn-Mayer, March 15, 1956).
27. The Hebrew Bible, Genesis, chapter 3.
28. Bob Dylan, "It's Alright, Ma (I'm Only Bleeding)" from LP recording *Highway 61 Revisited*, Copyright © 1965 by Warner Bros. Inc.; renewed 1993 by Special Rider Music.
29. The myth of Prometheus contains parallel themes, as does the story of Sisyphus in Hades.
30. Shelley, Percy Bysse (1817), "Ozymandias".

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