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ORIGINAL ARTICLE

Macroethical systems and sustainability science

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Abstract The Industrial Revolution and associated economic, demographic, technological and cultural changes have resulted in what many scientists are beginning to refer to as ''the Anthropocene'' – roughly translated, the Age of Humans. One response to this development is the nascent field of ''sustainability science,'' a multidisciplinary and systemic attempt to perceive and understand this new era. In doing so, however, methodologies and intellectual frameworks must be developed which extend beyond existing, dominantly reductionist, approaches, and are intended to address emergent characteristics of complex systems that integrate cultural and social systems, the engineered and built environment and natural systems. In the area of ethics, this requires developing a capability for ''macroethics,'' or ethical systems and processes capable of addressing issues arising from the emergent behavior of the complicated systems that characterize the Anthropocene.

Keywords Anthropocene · Complex adaptive systems · Earth systems engineering and management · Ethics · Macroethics

Introduction

The need for sustainability science arises from fundamental changes in the state of the world. While it is increasingly apparent that humans have long affected their environments, these impacts were fairly minor (in terms of systemic perturbations) until the last several centuries (McNeill 2000). In particular, it is now apparent that a principal result of the Industrial Revolution and concomitant demographic, economic, technological and social changes is a planet where the dynamics of most major natural systems are increasingly shaped by human activity (Allenby 2005a). Indeed, as *Nature* put it in a 2003 editorial, ''Welcome to the Anthropocene'' – welcome to the Age of Man (Nature editorial 2003).

This world has several important characteristics that differentiate it from past experience. The first, put bluntly, is complexity: a complexity that has expressed itself in many areas of human activity, from business (Senge 1990), to governance structures (Mathews 1997), to built systems at all scales (Hughes 2004; Allenby 2005a), to culture itself (the phenomenon of postmodernism is in part a reflection of, and a reaction to, this cultural complexity) (Harvey 1996; Castells 2000). The second is a far more profound multiculturalism, as a world culture that had temporarily been Eurocentric, and somewhat frozen by the stability induced by the Cold War, fragments into both old and new communities of interest. To make matters more difficult, the accelerating rates of change in economic and technology systems, cultural patterns, institutional structures and power relationships, and stress on local ideological and religious systems result in increased levels of fundamentalism in many societies. The challenge this poses to sustainability science is not just operational, as it is difficult to achieve consensus on difficult questions of implementing treaties and the like amidst, for example, conflicts between major world

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religions. It is, rather, foundational. For example, whose values and definitions will be embedded in the paths that human political dialogs, such as the Kyoto process on global climate change, select for carbon and nitrogen cycles, or for the development of new technologies and resource consumption patterns? What culture and set of values will determine appropriate regulatory structures for such powerful technologies as nanotechnology, biotechnology, information and communication technology (ICT), and applied cognitive science, both individually and as they increasingly coalesce? Who determines the extent to which biological systems will become commoditized as intellectual property, and thus shift from dynamics characteristic of ''natural'' systems to the reflexive and autocatalytic dynamics characteristic of human systems? What economic models, and thus implicit values, will be reflected in global culture, and the continued commoditization of not just biological, but all natural systems?

Indeed, the issue may be more complex than suggested by the term ''multiculturalism''. It is arguably the case that the Anthropocene requires the development of an ability to sympathetically perceive, and integrate, mutually exclusive but at least conditionally valid ontologies (Allenby 2006). This goes beyond multiculturalism, which in many cases is characterized by a tolerance that nonetheless assumes certain basic similarities in worldview. It requires an ability to understand one's own belief structures as contingent and limited, and accept and respect other worldviews that may be not just different, but contrary, to one's own.

But perhaps the essence of the Anthropocene is technology. Unlike science, which purports to study what is, technology represents a creative extension of human will and intentionality, in large part through designed changes in the ambient environment. Further unlike science, which conceptually if not in practice is an observation of external systems, technology like all creative human activities is reflexive, changing not just the environment, but also humans, their economies and their societies in an autocatalyzing process (Grubler 1998; Garreau 2004). Technology is also a more heavily social activity and more highly normative than science; it is creative rather than observational in that it not aimed at understanding the present, but rather in instantiating one of a number of possible futures (Bijker et al. 1997). Moreover, because technology (along with economics, with which it is highly reflexive) is the major mechanism by which human, ''natural'' and built systems become integrated into earth systems, it is necessarily a critical nexus for dialog regarding social and environmental values and choices (Allenby 2005a) – a dialog that these days is primarily identified with the cultural construct known as ''sustainability.''

This then is the background for what can be identified as a major challenge for sustainability science: the development of ethics which are competent to help perceive, understand and design appropriate institutions and engineered constructs in an increasingly anthropogenic, highly multicultural, economically globalizing and highly contingent world. Given that emergent behavior at high levels of integrated human/natural/built systems is a primary vehicle by which the Anthropocene is being instantiated, and given the critical role that technology plays in this development, it is necessary to inquire whether the current explicit ethical structures by which we steer are adequate and, if not, whether it is an important task of sustainability science to contribute to the development of a new and appropriate ethical level, that of macroethics (Allenby 2005b).

Macroethics: lessons from engineering

In beginning this inquiry, one can start with existing ethical systems, which tend to cluster at two levels. The first is the one with which most people are familiar: the individual. It is at this level that professional ethical systems operate, as does the complicated implicit moral structure that all individuals receive as part of their acculturation process. For scientists and engineers, explicit ethical admonitions as well as the implicit ethical systems involved in professional behavior (such as, for example, avoiding plagiarism and reporting data honestly) operate at this level. The second level, that of institutional behavior, is also familiar to many, especially those who have worked in large organizations. Thus, at this somewhat higher level, the idea of ''social ethics'' has been advanced to cover the important intersection between the practice of individual ethics and the institutional context within which those ethics are to be practiced or, in some cases, undermined (Devon 2004). Thus, many ethical dilemmas in the classic professional ethics literature arise from conflicts between institutional demands, especially driven by economic considerations, and professional ethics. A familiar example is the design of the gas tank of the Ford Pinto which was allegedly unsafe because cost considerations driven by management constrained individual engineering choices to lead to what society deemed an unethical cost/risk tradeoff (Fleddermann 1999). Note that it was the institution, not the individual, which created the environment in which the wrong design choice was made.

But the scale of sustainability science is not just that of the individual or of social levels of technology or ethics. Thus, the individual and social levels of ethics are limited, especially in their identification and assignment of ethical responsibility for emergent characteristics of the complex adaptive systems that characterize the Anthropocene. This raises the possibility that a third level of ethics, ''macroethics,'' requires development. This category would include the ethical dilemmas that arise as, for example, technological systems become embedded in, and adapted to, society. It is not necessarily that ethical dialog at this level has not occurred in the past – one might identify the debates over the fundamental ethics of nuclear weapons as a ''legitimate'' technology system as an example. More specific examples might include those arising from the development of genetically modified organisms for agriculture, or the questions regarding the ''digital divide'' and the psychological impacts of the Internet and gaming on adolescents that have been created by the rapid evolution of ICT, or the broad concerns involving nanotechnology as a whole. What is apparent in each of these cases is that ethics at this level – macroethics – raises complex issues that are not as problematic at either the individual/professional or ''social ethics'' level, and thus arguably require different institutional responses if they are to be adequately managed.

Engineering is a useful test area to consider the sufficiency and validity of existing ethical structures for a number of reasons. First, the engineering profession, because its activities so directly and fundamentally affect the public, have long had explicit professional codes of ethics. In general, these have been directed at the behavior of individual engineers (NAE 2004). More broadly, all engineers carry with them an intersection of explicit and implicit ethical networks, which in turn reflect the various communities of which that individual is a part. From a sustainability science perspective, however, it is the rapid evolution of foundational technologies – nanotechnology, biotechnology, ICT and applied cognitive sciences in particular, sometimes collectively referred to as ''NBIC'' – that raise the most obvious, and most complex, challenge to ethical systems (and, it must be noted, to international governance systems and conceptual models of sustainability as a static property, as well). Thus, if our inquiry indicates that existing engineering ethics approaches are incomplete when viewed against the challenges of technological evolution in the Anthropocene, it is a strong indication that they need to be augmented with a macroethical capability.

Ethics and macroethics: the internet case study

In considering this possibility, it is useful to analyze some prototypical case studies. We can begin with the Internet, a complex and autocatalyzing system which is clearly entirely human in origin; every piece of it – from routers, to transmission infrastructure, to personal computers and cell phones used to access it – is of human design and manufacture. This is also true of the content, which is human in origin either directly or, if modified or generated by software systems, indirectly. But taken as a system, the Internet has not been designed by any single individual or institution; indeed, there are not even any good maps of the Internet, for it continually redesigns itself. It is a self-organizing system (Barabasi 2002), responding unpredictably to changes in internal and external state (such as, for example, economic opportunities and constraints). Moreover, the implications of the Internet, from its acceleration of cultural change to its integration into, and extension of, individual human cognitive systems, are neither planned nor, in many cases, even perceived. Against this background, consider the role of the engineer and the ethical considerations that guide him or her.

Assume that the task for a particular engineer as part of a design team is to create a new router for the Internet. If that router routinely catches fire as a result of negligent design, most would hold the design engineers ethically responsible – indeed, it is quite likely that at the social level, which is that of the manufacturing firm, legal liability would attach as a similar judgment regarding ethical culpability (Fleddermann 1999). Thus, we may conclude that, at least in this example, the individual/professional and the social ethical structures are both competent and operative. Whether they are ''adequate'' involves a value judgment about the ethical systems, but that they exist is incontestable.

To continue the analysis, suppose the router functions as designed, and in doing so contributes to the continued growth of the Internet. The full environmental and social implications of this growth are currently unknowable, but they are liable to be quite fundamental, including developments such as possible changes in cognitive networks and function among the youth that use the Internet, or the increasing substitution of virtual for real realities over time, and a consequent reduction in interest in environmental issues as we now conceptualize them. To take another example, the dramatic increase in economic complexity and activity enabled by the dematerialization of money and its reification as information structures and flows, platformed on the information capability of the Internet, has huge implications for the structure and behavior of global systems, and is properly an object of interest for sustainability science (Castells 2000) – albeit very poorly understood at this point. More fundamentally, one might see significant shifts in economic productivity and cultural authority as those societies whose elites structure their cognitive networks to include functionality enabled by the Internet draw ever more ahead of those that do not, thus enhancing both local and global inequality in violation of the traditional egalitarian formulation of sustainable development (WECD 1987). In short, it is clear that the emergent behavior of the Internet, and more broadly ICT, raise significant ethical issues and do so at a scale of interest to sustainability science.

Most people, however, would regard an effort to charge the design team with ethical responsibility for these effects to be inappropriate on several grounds. First, for many people, designing a small component of a large system does not imply a corresponding responsibility for the larger system: the mining firm that produces ore that ends up in artillery shells is generally not held responsible for war as a result. More importantly, perhaps, individuals are not generally held responsible for systems' ramifications that are far beyond the capability of any engineer or design team to predict or foresee. There are simply too many unpredictable intervening decisions and stochastic events, reflecting the fact that the Internet is a complex adaptive system, and that its impacts across society, especially given the strong reflexivity between technology and subsequent economic, cultural and social evolution, are most likely fundamentally unpredictable. This does not mean that society cannot, and should not, respond ethically to the challenges raised by this system; only that ethical systems based on personal and institutional interest are unlikely to comprehend, much less guide, such responses. It is clearly apparent that for the most part the implications of large technology systems such as the Internet are neither perceived nor understood very well by society as a whole at this point (Allenby 2005a). Consequently, there is a gap between the ability of society to respond to the ethical considerations raised by the high-level emergent characteristics of this technology system and the increasingly obvious need to do so. Addressing this gap is the realm of macroethics.

Ethics at the level of the individual as a member of a particular culture or profession are not free of disagreement and complexity. They are, however, codified, accessible and surrounded by a fairly large body of explanatory literature. Macroethics, however, is not simply existing personal or social ethical systems raised to a higher level. To take a simple example, most professional ethics, although they may be phrased in terms of duty owed to the public, tend toward some sort of (usually indirect) utilitarian calculus. (A utilitarian calculus favors actions that create ‘‘the greatest good for the greatest number''.) We tend to evaluate the ethics of a professional decision by intent or by actual consequences, or some combination of the two. However, this approach assumes that enough can be known at the time a decision is taken to be able to determine such factors. If, instead, we are dealing with complex adaptive systems, such as modern technological systems, that are inherently unknowable, then we can neither form any realistic intention as to what we hope to achieve, nor be judged by the consequences of the act. In the former case, the complexity of the system response means intent is essentially irrelevant, since whatever the individual wants is unlikely to occur; in the latter case, the consequences are unknowable a priori and unfold only in real time and over significant timeframes. We are thus precluded from familiar simple and understandable ethical approaches.

Moreover, while individual ethics can be phrased in terms of a unitary underlying worldview, this is increasingly difficult with large technology systems that are global and thus necessarily profoundly multicultural (Allenby 2006). In the debate over GMOs, for example, European environmentalists were strongly, indeed theologically, opposed to the technology. For large agricultural producers such as the USA, Canada and Brazil, however, these perceived ethical constraints were far less important. Conversely, in the case of stem cell research, significant minorities in the USA viewed the science and technology as unethical, a concern that did not substantially bother other countries. Indeed, the USA went to the extent of trying to force the United Nations to adopt its particular ethical stance regarding this technology, but failed precisely because in a multicultural world with different cultures and worldviews, there was no consensus on the appropriate ethical stance to take globally.

Developing a macroethical competence

Accordingly, as the examples above suggest, macroethics must be thought of in terms of the challenge of enabling ethical design and management of the large and tightly coupled economic, social, environmental and technological systems that characterize the Anthropocene. To return to the Internet example, this requires developing macroethics in the context of an accelerating technological evolution, especially as regards information systems of all kinds, and the electronic systems that support such evolution. This is particularly complicated because ICT is not developing in a technological vacuum, but is increasingly integrated with other rapidly evolving technological systems, especially nanotechnology, biotechnology and cognitive sciences, each of which also raises difficult and complex macroethical issues as well. Moreover, these ethical issues are generally not inherent in the physical technology, but in the integration of technology, culture and economics and the reflexive interactions among these components of earth systems. It is the technocultural system, not just individual artifacts, which increasingly raises concerns that must be recognized and responsibly addressed. Doing so may not satisfy all activist stakeholders, but it can substantially reduce the possibility that the public will support their disruptive behaviors.

This observation, based on the characteristics of complex adaptive systems, has a number of operational implications. For one, it means that ethical implications adhere less to specific choices regarding actions, as in traditional ethics, and more to an on-going choice of process by which individuals and the institutions of which they are a part choose to interact with the relevant system. Macroethics thus differs from existing ethical approaches in requiring a far greater concern with processes, as opposed to single actions. The choice of the process by which the individual becomes engaged in a dialog with the system, rather than each individual choice, is what becomes ethically critical. Conversely, the choice not to adopt a process that fits the system becomes unethical, for to so chose is to deliberately undermine the ability to exercise informed choice in the context of the complex adaptive system.

Moreover, the ICT example is useful because it is not just the technology systems that are changing, but, partially as a result of the technological changes, the structure of the mental models that underlie particular ethical stances is also changing. This in itself is not shocking, for cultural constructs are historically contingent and continually evolve. Thus, environmentalism, like any discourse, has language that embeds contingent perspectives in powerful cultural constructs. So, for example, the older image of a patch of permanently wet land as a pestilent ''swamp'' has been replaced by the construct of a productive, green and highly valued ''wetland,'' and the dangerous and alien ''jungle'' of the past has become instead the Edenic ''rain forest'' of today. Two hundred years ago when Europeans reached the New World they saw a Satanic and fallen ''wilderness'' in front of them, and their mission from God was to tame it. Now, of course, ''wilderness'' is not only a good thing, but for many it is Sacred, the last residence of the Holy (Cronon 1995). And, of course, ''wilderness'' and ''nature,'' and what is to be preserved, differ by culture: Europeans are very attached to a particular landscape characterized by small farms and ''folk'' agriculture; Americans to a ''wilderness'' that reifies their exceptionalism and individualism; Japanese to gardens that represent highly designed forms of ''nature'' with substantial cultural meaning. These cultural constructs provide a basis for many people to develop and project the ethics that they wish to embed in a ''sustainable world,'' but each of these mental models is a product of a particular time and place and culture. At heart, each represents a different worldview as well as different ethical formulations that express themselves through the construction of particular models of ''nature.''

At the very least it is a defensible hypothesis that these pivotal cultural constructs are evolving more rapidly than they used to, in alignment with the rapidly accelerating pace of technological, economic and social change. And it is also true that, as before, we must rely on our cultural constructs. This raises a significant challenge to those that must design and manage earth systems, or, indeed, try to understand and implement sustainability science because a shorter cycle time means that the changes in cultural constructs now overlap with the extension of environmental and sustainability policy initiatives, such as those responding to global climate change and biodiversity issues. However, while short-term policy initiatives can assume that for practical purposes cultural constructs are fixed in meaning, longer term initiatives cannot: values and underlying cultural constructs are increasingly contingent, not fixed, over the relevant time periods. This means that managing interactions with such integrated human/natural earth systems responsibly requires not just dialoging with the systems but also with the foundational values that one is using to guide the relationship with the system, for both are in fundamental flux. In short, in the Anthropocene we are in a situation where both the systems affected by our actions and the values which we bring to those actions – and by which we judge potential paths for the systems – are shifting in real time. Although this is somewhat equivalent to rebuilding a sailboat from the keep up while in full sail in the middle of the ocean, it is not an impossible situation to manage. Unarguably, however, it certainly creates an ethical complexity at the level of macroethics which to date we have not had to contend with.

Implementing macroethics

In moving towards a macroethical capability, we can begin by rejecting two common approaches. The first, which various governments have already tried, is to simply ban particular fundamental technologies. Unfortunately, this approach is arguably both ethically questionable and historically useless. It is ethically questionable because activist groups demanding such bans seldom reflect the interests of the broader society. For example, the environmentalist organizations that demanded that genetically modified agricultural organisms (“GMOs”) be banned notably included none of the farmers who benefitted from being able to use less herbicide or pesticide. Also, the fundamentalist Christians that demanded a U.S. ban on stem cell research notably included none of the patient groups that would conceivably benefit from the resulting therapies. Bans of powerful technologies thus tend to represent capture of administrative and legal processes, rather than broad democratic dialog. Additionally, bans tend to reflect particular ethical stances, and, consequently, from a pragmatic perspective they fail in a highly multicultural world, for they simply shift the development of those technologies to other cultures. Thus, the European environmentalist movement to ban GMOs did not halt deployment of that technology, but only shifted the use of it to large producers such as the USA, Canada and Australia and, increasingly, to developing countries such as China, India and Brazil. The U.S. effort to “regulate,” or effectively ban, stem cell research had the effect of shifting research activity, and a number of world class researchers, to other centers of technology development such as Singapore. The effectiveness of bans as expressions of specific ethical stances is especially questionable where, as here, the technologies are likely to lead to a powerful economic advantage over time (e.g., more efficient agriculture and use of land, or new therapies and drugs).

The second approach that can be rejected is that which simply attempts to impose macroethical responsibility on the individual. This is just another effort to extend individual ethical structures to comprehend complex systems effects, and it fails for the reasons discussed above: it is simply impossible for an individual to understand, predict or have enough knowledge in many cases to even perceive such effects. In practice, then, this strategy is actually just a variant of the first approach in that such efforts frequently appear to be little more than an attempt to freeze scientific and technological evolution.

It is at the institutional level that mechanisms can be established by which scientific and technical communities, and society at large, can dialog with complex adaptive systems such as the Internet or the intersections between ICT and social equity. Not only will such on-going dialogs with the technological system on the one hand and the ethical and cultural constructs on the other be extremely difficult, but they will obviously also be highly multidisciplinary, multicultural and multiontological. This reinforces the conclusion that it is inappropriate to attempt to require individuals to bear the responsibility for such a dialog, for no single individual has the requisite knowledge, and very few have the ability to suspend their own ontologies, as required by such a dialog. The institutional host of macroethical dialogs should combine technical knowledge with a broad, transparent and open process, and be sensitive to its own agendas and ontologies so that they are not unconsciously imposed on the dialog. It is also important that such dialogs be protected from capture by a particular religious or political agenda; this is an ongoing problem and, as an example, one that some have noted with regard to stem cell research in the USA.

If done well, such dialogs become not just necessary from an ethical perspective, but they also become mechanisms by which sustainability science research in complex systems can be advanced as well as learning processes for those who will participate in the on-going process of design, operation and management of earth systems. Indeed, because macroethical dialogs will occur not just as part of an earth system design and management process, but as part of the social response to the Anthropocene, they will be highly reflexive. Because of this, they will represent important vehicles of learning at many levels, an aspect of macroethics that must be explicitly embraced. For some people, the fact that macroethics is thus informed as part of its own process, rather than being entirely rule-based ab initio, may be uncomfortable, but complexity – scientific, ethical and ontological – is an unavoidable dimension of the Anthropocene (Johnson 1997). Denial of this reality, with the effect of reducing society’s ability to rationally and ethically function in the anthropogenic world, is itself a highly questionable ethical stance. Being ignorant because of circumstances beyond one’s control is one thing, and perhaps ethically neutral; choosing to remain ignorant in the face of the challenges of sustainability science is not.

It is here that we can also identify an important role for the practitioner of sustainability science, including in that term social scientists, humanists, natural scientists and engineers. While the dialog itself may require an institutional setting, it will require individual initiative to encourage appropriate institutions to assume such a responsibility, to obtain the necessary funding and resources and to build an on-going capability. Thus, in line with the process ethics discussion above, it seems quite reasonable to charge the individual scientist or engineer with a fundamental responsibility to ensure that appropriate institutional macroethical capabilities, reflecting his or her profession and activities, are developed. In the case of ICT, for example, while one might not hold the individual engineer responsible for the Internet, the "digital divide" or foundational technologies such as nanotechnology, one could charge them with the ethical responsibility to push their professional organizations, such as the IEEE, to create an institutional framework for macroethics. Institutions – including academic institutions and their collaborations – that address issues of the anthropogenic world and sustainability science should consider seriously whether developing macroethical capabilities is not a core part of their function.

Conclusion

Existing ethical structures tend to address issues that arise at the individual and institutional levels. They are, however, inadequate when applied to the emergent behaviors and inherent unpredictability of the integrated natural/human/built complex adaptive systems of the Anthropocene. Accordingly, there is a need to develop a macroethical competence to fill this gap. Creating such a capability will not be trivial and indeed may well require significant institutional experimentation. Moreover, the effort is one that many scientists and engineers are not experienced in and, in addition, it will certainly include others, perhaps from very different cultures and disciplines. In so doing, however, we begin to move towards a framework that remains based on individual ethical responsibility but that reflects the increasing complexity of the problems, options and constraints that characterize the anthropogenic earth. Equally important, we move towards establishing sustainability science on an appropriate ethical basis.

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