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AFRICA BUREAU
EVALUATION REVIEW PROJECT

Volume II

International Statistical Programs Center

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BUREAU OF THE CENSUS

Africa Bureau Evaluation Review Project

Volume II

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Dr. DeGregori's report contains information generated specifically for this subcontract as well as excerpts from his previous works which he selected for their appropriateness to this subcontract. Some selections were taken from books or other publications and no attempt was made to edit or retype these. It is afterall the ideas and information contained in these selections that are important and not the format or editorial aspects. With this in mind we hope the reader will enjoy this part of the report for its information content and applicability to evaluating development projects.

May 27, 1983

Africa

Project Evaluation Review:

Integrating Technology Transfer into the Evaluation Guidelines

Final Report under Purchase
Order Number BC83YAA20811

by: Thomas R. DeGregori

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1.0 INTRODUCTION

This report summarizes the work done under Purchase Order BC83YAA20811 for the Bureau of the Census (BuCen) as a part of their work for the Agency for International Development (AID). The Bureau's agreement with AID called for reviewing development project evaluation reports prepared prior to the issuance of the new evaluation guidelines, analyzing the contents of these reports using criteria based on the information requirements implied by the guidelines and expanded in the subquestions developed under this project, and proposing cost effective alternatives for collecting and processing the guidelines.

The purpose of this purchase order was to sumarize my experience in technology transfer and African economic development and apply it to the work being carried out by BuCen and the Africa Bureau at AID. In addition, my work included participation in workshops during March 1983 and leading a seminar on technology transfer and participating in a series of seminars from May 10-12, 1983, as principle speaker on technology transfer and the relationship of the guidelines to technology transfer.

This report discusses the basic characteristics of technology transfer in section 2.0 and incorporating technology transfer into the guidelines in section 3.0. Section 4.0 summarizes my seminar presentation. Section 5.0 discusses appropriate technology. The principles of technology are contained in section 6.0. The appendices listed in the table of contents detail my previous work on technology transfer that has been applied to this project.

To properly understand the nature of our research it is necessary to understand the characteristics of technology transfer. My input to this work

included a brief statement of this which is repeated here as background information for this report.

The central unifying characteristic of technology is that it is a problem solving process. Technology involves tools, skills necessary to create and use these tools, and, most important, the ideas in the tool-maker's and tool-user's head that determine the motor functions to carry out the tool-creating and using activity. Because tools involve skills and skills are a form of behavior, then one aspect of tool-using is always its societal or cultural context. Human tool-using is a process, and because it is a process, it is differentiated from tool-using by other animals. The human tool-using process is dynamic, combinational, and accelerates through time.

Given this broader definition of technology, for the purpose of A.I.D. it can be argued that technology transfer in its initial phases occurs when new improved ways of doing a task desired by the recipient are adopted and integrated into the ongoing economic and societal system. (1) These new ways could conceivably (but probably not often) use all the existing technologies already in place and therefore be in essence the movement of an idea from one place to another; (2) It could be a training program which would then be the diffusion of an organized set of ideas called knowledge; or (3) It could be these two in combination with actual physical products of modern science and technology, such as tools, machines, seeds, or another human artifact. For number 3 to take place, elements of 1 and 2 are a necessary concomitant.

Transferring an improved problem solving technique is only the initial characteristic of technology transfer. If this is the extent of the effort, it is, then, technique or tool transfer, and not technology transfer. Technology transfer only occurs when the new technique is integrated into the recipient culture and is simultaneously linked to the dynamics of the

international technological system that brought it into being. For it is only with this linkage with other technologies that cross-fertilization and interaction can give rise to future dynamic accelerating development, which is an essential characteristic of technology and especially of successful technology transfer. The basic characteristics of technology are discussed in greater detail in section 2.0.

2.0 TECHNOLOGY: SOME BASIC CHARACTERISTICS

All human societies are founded on tool using. In fact, some anthropologists have defined man (in the generic sense) as homo faber, man the tool maker. Furthermore, tool using precedes man in the evolutionary processes. One of the dominant theories in physical anthropology is that proto-humans began to use very simple tools, fist or hand axes, as they are called. Having a stone tool gave some higher primates a competitive advantage for survival over other higher primates. Within this group of tool-using higher primates, those with a greater capacity to make and use tools would have a still greater possibility for survival. In this instance, the capacity for tool-using would not only include developments in the structure of the hand but also in the size of the area of the brain governing the use of the hand.

Tools and human evolution became intricately interrelated. There was a selective adaptability to the capacity for tool using. Any accidental variation or mutation that enhanced any of these traits would tend to remain and diffuse throughout the group in succeeding generations. The interbreeding of the survivors with these traits would tend to intensify them. Thus we have a process that has direction, i.e., the ever greater capacity to use tools, but it is not teleological in that it is not moving toward some foreordained end. There is also a positive feedback mechanism in operation. The greater capacity for making and using tools establishes the conditions for further evolutionary development in tool using capacity.

Technology is developmental. A stick for an East African primate has an end-in-view, and its usefulness essentially terminates there. Tools as used by humans were combined with other tools to create new ones. The bow

and arrow, one of man's first compound tools, can be used to obtain food or as a weapon of war. From the bow and arrow, early humans created the bow drill, descendents of which can still be seen in operation throughout the less developed world. Adding strings to the bow created a lyre or any of dozens of string instruments still in use around the world. Putting a resonating box behind the strings created other musical instruments, as did enclosing the strings and equipping the instrument with devices to pluck or pound them. And so it goes. The small details of the evolution of these musical instruments equally illustrate the dynamic combinational character of technological change. One can draw virtually from the entire history of technology to illustrate this thesis. The airplane initially was a combination of an internal combustion engine and a glider. One author has shown that the modern diesel engine is a direct lineal descendent of a Malayan blow gun.

Technological development, then, is combinational and cumulative in a dynamic evolutionary process. Though it may seem strange to trace a diesel engine to the blow gun, in a larger sense all modern technology comes from primitive technology. Without simple fist axes, complex tools do not emerge. Without more developed singular tools, compound tools do not emerge.

Tools in and of themselves are static. Tools used by man generate dynamic processes known as technology. With technology we get another uniquely human dynamic cumulative and closely related (and interactive) process: science. Unless some humans somewhere had created simple tools, then more complex and compound stone tools, then metal ones, and so on, we would not have satellites circling the globe nor atomic energy, nor laser beams. That does not mean, of course, that all men must pass through each and every stage of the process. Mankind in general has continually created expanded means for further creation of technology and the development of knowledge.

Technology is also a resource creating process. The unqualified assertion that technology destroys resources reflects a lack of understanding of both technology and resources. For technology creates resources, as has been shown by many writers (including this author). Resources do not exist apart from technology. The raw materials of the universe become useful to men when the technical means of using them for human purposes is devised. New and improved technical means convert raw materials into resources. Lack of technological progress is more likely to destroy resources than is technological change. For example, in Nepal, the population pressures are leading to a cutting down of the forests on the mountain slopes for fuel and building materials and to create land for cultivation. At best, two or three crops are planted and harvested before the land is eroded away. It is in fact true that a technology operating with non-renewable resources will, given enough time, use all of that available resource. In that sense, technology uses (i.e., destroys) resources, but since all men are tool users or part of tool-using cultures, there seems to be little choice but to create and consume resources. Whether we can continue to do so depends upon our conception of technology and the policies following from it. If we view resources as being fixed, then any technology will eventually exhaust them, no matter how frugal we are in our use. Few would argue that we can base modern civilization on "renewable" resources alone. If we view technology as a dynamic, resource-creating and resource-conserving process, then we can form policies that seek to promote scientific and technological progress and then we can lay the basis for continuous development. As in the case of Nepal, the one sure way to destroy resources is to use yesterday's technology to solve the problems of today's and tomorrow's population. Yet the sum and substance of many critics of technology is to return to earlier technologies. What the Nepals of the world need is new forms of energy (in some instances renewable energy, e.g. solar),

improved ways of agriculture, and more effective means of population control. In a word, what is needed is more technology, not less.

3.0 INCORPORATING TECHNOLOGY TRANSFER INTO THE AFRICA BUREAU EVALUATION GUIDELINES

The evaluation guidelines were created in response to stated needs by AID Africa Bureau officers in Washington to obtain more effective information with which to evaluate development projects. There was a frequently articulated frustration that information coming in from the field in typical project evaluation reports was not adequate to accomplish the task of either selecting appropriate projects for specific settings or evaluating their compliance with overall agency goals. Hank Miles interviewed various Africa Bureau and Agency staff members as to the specific types of information they wanted and what types of procedures or questions would best achieve these results. The evaluation guidelines are a compilation, integration, and organization of these results. More detailed sub-questions were added to assist those in the field to respond more effectively to the 11 major guideline questions and to make the evaluations comprehensive. The evaluation was also structured to draw out a set of responses that made the project implementors more aware of the issues involved in technological transfer and change.

In addition to responding to stated needs of the Africa Bureau, the guidelines will hopefully facilitate the achievement of broader agency goals. The four pillars of AID development programs are: technology transfer, private enterprise, policy changes, and institution building.

By specifying the issues of technology transfer, the guidelines focus on the centrality of technology in the process of development. More important, the conceptual framework used as a basis for these questions provides the organizing principles for embodying these goals into particular development projects. The twenty-five principles of technology listed in the previous section recognize that technology is much more than mere hardware. Technology transfer means

technology in use. Using technology involves both policy and institutional factors. Bad political and economic policies can not only limit the potential benefits of new technologies but also are probably already limiting the utilization of existing technologies. Good policies can allow people to use existing technologies to their fullest capability and can facilitate the introduction of new technologies. Since technology-in-use requires knowledge, skills, habits of mind, and organization structures, then what is called institution building becomes a necessary component of technology transfer. Finally and more importnat, technology is dynamic. Successful technology transfer is much more than the diffusion of some techniques and hardware. Technology transfer is a process. If successful, it transfers the dynamics of technology such that the recipients are able to continue to borrow and adapt on their own. Institution building is one means of sustaining technological transfer and development. The private enterprise system, if aided and not restricted, can become the main vehicle for the ongoing, dynamic diffusion of ideas, techniques, and all other aspects of technology.

3.1 Constraints: Technology and Policy Changes to Alter Them

Questions I and II concern the identification of constraints. Frequently, the most significant contraints are government policies, particularly pricing policies. If policy constraints are restricting the use of existing technologies, then there is a strong probability that new technologies will not be used effectively. The evaluation guideline seeks to obtain information not only on the constraints to be removed but also on other constraints that would affect the project but had not previously been specified. Realistically, constraints that involve policy decisions may not be changeable by AID donor. However, having identified these policy constraints, the donor has the options of: 1) seeking to modify the constraint by using the project as leverage;

2) designing the project to work around the policy constraint as well as the technological constraints; and 3) not funding the project at all if (1) and (2) are not feasible.

By requiring the identification of all constraints in the evaluation, it is expected that this identification process will eventually be included in the preliminary stages of the project, allowing the options noted above.

Many constraints are not policy-related. Given the broad concept of technology being used, issues of institutional adjustments, lack of skills and knowledge, as well as environmental limitations to the use of technology become potential constraints to technology transfer. Providing the framework, the sub-questions seek to identify these constraints and the way in which the project will overcome them. Essentially, these questions are seeking a statement concerning the larger technology, policy, and environmental system in which the technology transfer program will operate.

3.2 Institution Building and Responsive Indigenous Institutions

Question IX on the delivery systems and Question IV and V on the intended beneficiaries relate to the goal of institution building. A delivery system can become part of the recipient country's institutional structure for the continued borrowing of technology. Building other institutions, such as research laboratories or training schools, provide ~~in later phases~~ delivery systems for technologies and for sustained technology transfer. If it is unlikely that A.I.D. will be funding research institutes in less developed countries to explore the basic structure of the cosmos (however important that inquiry may be), then it is likely that a successful research institution will turn out results supportive of the operating technologies of the country. Because technology transfer is seen as a process and not a one-time event, then the delivery system must in fact become part of the structure

of sustained technology transfer. Throughout, the questions in the evaluation guidelines seek out evidence of the sustainability of the technology transfer.

The intended beneficiaries are basic to what AID is presumably about, trying to help poorer people of a country help themselves. The evaluation guidelines go into great detail in attempting to have project designers specify both the target group and of the mechanism for achieving the stated results. Thus, not only do the recipients benefit, but this process requires their participation. An attempt is made in the guidelines to get at all of the issues of behavioral and cultural changes necessary to carry out the project and the types of resistances that might undermine it. These questions not only get to the ideational and behavioral aspects of technology but also more fundamentally get to the roots of the potential for technological change. Widely distributing the benefits of technological change gives more people a stake in its continuation. Wide distribution of benefits can be a basis for developing the kind of free institutions that we argue in principle so greatly facilitate the evolution of technology.

3.3 The Private Sector

In virtually every question category there are clarifying sub-questions that raise the issue of private sector involvement. The questions on constraints wish to know both why the private sector is currently unable to remove them and in what way it can be used in the project to overcome them. Of the many ways in which these questions seek to get at private sector involvement, one is possibly unique to the evaluation guidelines. Given the dynamic concept of technology, these questions are trying to focus on the creation of indigenous free market structures that will sustain the dynamism and serve as a vehicle for continued technology transfer. Technology transfer as a process involves the sustaining mechanism of the market.

3.4 Technology Transfer

These questions attempt to treat all development projects as attempts at technology transfer (in the broadest sense of that term). Though all of the questions should be applicable to most projects, it is possible that occasionally a question or two will not be relevant to a particular project. The point is not whether all questions are applicable to the projects but whether for all projects these evaluation guidelines form ask the critical questions.

Question III, in looking at the environmental context of technology, essentially stresses technology as problem solving and the necessity to adapt a technology to fit the nature of a problem. Question IV and V are concerned in part with the technology transfer from the perspective of the recipient. Perception of risk and benefit will influence adoption rates. If the skills or action involved in the use of a technology involve behavioral change, then again these are the choices of the recipient.

Questions VII and VIII are at the heart of the technology transfer issue, for they deal with the dynamics of technology transfer. Question VIII focuses on the private sector's role in sustaining continued technology transfer. Question VII seeks the totality of forces set in motion to create sustained technology transfer. Simply stated, too many projects purporting to be technology transfer are really technique transfer. These two questions, in differentiating between technique and technology, are defining the difference between helping people to achieve economic stagnation at a higher level or helping people help themselves in a sustained long-term development process.

4.0 Summary of Seminar Presentation by Thomas R. DeGregori

The following discussion is a summary of the seminar presentation as given by me at six seminars for the Africa Bureau of A.I.D. and other participants from A.I.D. and from the Bureau of Census. The ideas and illustrations used came from a longtime study of the history of technology and technological diffusion. The ideas were also refined and enhanced by a study of the evaluation questions and the thirty-five structured responses to them. The principles of technology (a separate document) were originally only fifteen after completion of a study of the history of technology. Work on this project led to their expansion to twenty-five and now to twenty-eight and possibly thirty. The principles were structured and oriented to meet the needs of the project and the seminar material was organized to present the material to facilitate the understanding of technology transfer and the carrying out of project evaluation.

Given the time limitations of the seminar, only four basic principles or characteristics of technological development and transfer were outlined. They are: 1) The cumulative and accelerating characteristic of technology; 2) the ideational character of technology and technology transfer; 3) the feedback or complementary character of technological change and technology as a problem solving process and the way it has influenced the nature of technology transfer. For each of these principles, episodes in the history of technology were chosen to illustrate them.

The cumulative/accelerating nature of technology was simple to illustrate since the principle is so obvious. First, we took 1 million years as the time

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in which protohumans crossed the threshold into being humans. This was a conservative figure, since estimates generally range well above this number. Of this million years, 98% of the time humans were living in the Paleolith or Old Stone Age, characterized by "simple stone or other tools." Ninety-nine percent of this time (or until about 10,000 years ago), all humans were pre-agriculture or hunters and gatherers. The Mesolithic or Middle Stone Age 20,000 years ago was noted for its compound tools (bows and arrow, for example). With an increasing assemblage of tools, there was a multiplying array of possibilities for combination and the creation of new technologies. Agriculture leads to more stable and denser settlement patterns, further accelerating the process of cumulation and combination. Needless to say, we are still accelerating, as we have gone from the Stone Age to the Space Age in less than 10,000 years!

The second principle we illustrated was that of the essentially ideational character of technology and technology transfer. For illustrative purposes, we used the diffusion of the arts of printing to Europe. Printing was one of the four inventions noted by Sir Francis Bacon as being responsible for Europe's ascendency. All came to Europe from Asia and the Middle East. To have printing or printing by moveable type requires skills and capabilities such as metalsmithing, an alphabet, an ink that will adhere to a typeface and dry on paper or some other material, the paper, a press, etc. We looked at the evolution of each of these components. Paper is the clearest illustration of the movement of ideas. Paper is not derivative from papyrus as is commonly believed. Paper making is a felting process; papyrus is a product of a weaving-type technique. The idea of felting came to China from Central Asia, where it was used with hairs to make materials for tents. In China the idea was applied

to rice fibers to make paper. We can trace many of the episodes of the diffusion of paper making to Europe, including the capture of two Chinese paper makers by the Persians. There is no evidence of the movement of paper as a physical artifact from Asia to Europe. And if there were, in this instance it would be irrelevant. There was a movement of ideas that required skills to be carried out. For, with the idea and the skills, replication is possible to a magnitude far greater than the number of artifacts that could diffuse. Further, with the ideas and skills there is the ongoing possibility of further improvement and combination with other capabilities. We stressed in the lecture on development that just because technology transfer is ideational, it does not follow that it is not measurable. If you bring tools or machines to a people but not the underlying idea structure, the tools may rust and the machinery break down. If ideas are diffused, then they should manifest themselves in measurable physical transformations.

We went through the same analysis for other components of the technology: the alphabet from the Middle East, centuries earlier, the press from the olive and grape presses around the Mediterranean, the basic arts of printing from Korea and China by way of Central Asia. There was also the indigenous growth of metal smithing and the linseed oil-based inks derived from the same source that painters derived the oil base for their paints. All these were in place by the 1440s, but it was not until about twenty years later than Gutenberg made his contribution, the cheap sandcasting of type. The latter was the last but essential piece which gave printing by movable type enormous economic advantage over all other means of mass reproduction of language.

Printing as it emerged in Western Europe was a combination of items that had diffused to Europe at different times and indigenous capabilities that were

synthesized to fit local circumstances and solve local problems. As with the individual items (paper, as described above), there is no evidence of any physical movement of printing presses. And even if there were, it would be largely irrelevant. Granted, the physical embodiment of an idea can be a useful part of the diffusion of the idea itself; nevertheless, it is the diffusion of the idea that is the essential characteristic of technology transfer.

The third episode was the description of the development of steam power as an illustration of the principles of feedback and complement. Of course, if the principles of technology expounded in the accompanying report are correct, then any technology should embody most if not all of them. However, some more easily lend themselves to the illustration of particular principles. Such is the case with steam power. Steam power can be found in use as early as ancient Egypt, where it was used to open and shut temple doors, and in Greece and Rome, in a toy called the heliophile. Some have argued that the ancients had steam power but never developed steam engines because with a large supply of slave labor they did not need a labor-saving device. This is incorrect on at least two counts. First, as we shall see below, a new technology such as steam power can not only substitute for existing factors of production such as labor, but it can also do new things that previous technologies could not do. Secondly, to have a functioning high pressure steam engine requires a metal jacket for the boiler that is strong enough to withstand the pressure. For early steam pumps (the forefunner of the steam engine), copper jackets could be used, but for a steam engine, steel was necessary. Thus, for an idea (e.g. a steam engine) to become a reality, complementary developments are required in other areas. In this instance, it was in steel making. Steam power was to feed back into steel making, providing the power to send the heat through blast furnaces.

The final principle discussed was that of technology as problem solving, exemplified in a series of episodes involving the diffusion of agricultural technology. The agricultural writers of the Roman Empire looked at agriculture north of the Alps as a lost cause. The climate and the soils were inferior and destined to remain so. Rome had taken to Gaul, Mediterranean agricultural technology and practices, complete with the Latifundia. In other words, agricultural technology had a capital A and a capital T. When the people of Northern Europe took command of their destiney, they did not throw out all Mediterranean agricultural technology as being inappropriate. Rather, theirs was a synthesis of local technologies and imported technologies, either adapted or used as received. In a word, a complex of technologies is appropriate to the particular problems it is designed to solve. In a new environment or circumstances, it may or may not be appropriate. Appropriateness is here defined as problem solving. That it may not be effectively problem solving in a new environment does not make the technology inappropriate except to a range of problems. In fact, however inappropriate a technology may be to a set of problems, if it has been highly successful in solving similar problems elsewhere, the technology probably embodies scientific and technical principles and an accumulated body of knowledge and experience which, properly understood, modified, and adapted, can be useful in other contexts.

With its own combination of problem-solving technology, European agriculture became the most productive in the world. Quite clearly the problem was not the soil or the climate, just as the later Middle Ages with the Black Death, Europe was not unhealthy because of the climate. As one geographer, Preston James, put it, "fertility is not a property of the soil but of the uses we put it to." (quote from memory). Rather, the problem was proper technology. Centuries

later, when Europeans came to the New World, they brought their technology with them. It did not work the way it did at home. The new Americans combined this technology with Indian agricultural technology. In the 18th century, Jefferson in his Notes on Virginia, had to defend the New World against European intellectuals who thought the climate inferior for agriculture. Similarly, when Europeans acquired colonial possessions, they sometime treated technology as problem solving. Agricultural research was a means of growing essential commodities such as cotton in the colonies. Unfortunately, too often agricultural practices of the temperate zone were treated as absolutes, and attempts were made to impose them upon the colonies, sometimes with disastrous results.

Western views of the tropics, particularly the rain forest, have varied between extremes. First, there were those whose purple passages described the lush growth of the "jungle." Build a fence and before your eyes, the fence posts sprout. Others, noting the difficulties facing agriculture when rain forests have been cut, emphasize the thin soil cover and the threat to it of heavy rains and erosion of all kinds. It would seem that we really have not developed a highly productive method that uses the potential of the tropics. As the A.I.D. administrator said (Horizon, April 1983), what we need is not only technology transfer but technology generation in Africa. This is true for the tropics in general.

These principles were then applied to contemporary issues of technology transfer. We stressed how they were compatible with the four pillars of A.I.D. policy: technology transfer, institution building, private enterprise, and policy changes. We then showed how the guidelines embodied these principles and the four pillars (see accompanying document for details). We also attempted to show how the testing procedures in the guidelines linked the log frame to cost-benefit analysis. It also of course involved what we said about technology as ideas having measurable material manifestations.

We illustrated contemporary technology transfer with a variety of technologies. We used different ones for each seminar so as not to be boringly repetitive and also to allow responses to specific questions about the guidelines. We pointed out that good theories do not always give answers, but they should always pose the right questions. The one current technology transfer experience that we used most often involved the author's work on sugar cane crushing in Pakistan. We illustrated the difference between transferring a technology that is dynamic and one that is static. In others, we asked the question as to whether a technology will facilitate further technological change or hinder it.

Overall, the seminar presentation summarized above, taken together with the contributions of Jim Ray and Hank Miles, was part of a package of activities that successfully explained a new procedure for project evaluation to A.I.D. personnel. The above ideas also reflect the intellectual contribution made by the author in developing the guidelines, analyzing their applicabilities in previous projects, and refining and improving them for future use.

5.0 Appropriate Technology

Definition - A definition of the basic terms used seems in order. We can begin with some (two) dictionary definitions as a point of departure.

> Merriam Webster (3rd edition) definition of technology: "2a - the science of the application of knowledge to practical purposes . . . 3a - the totality of the means employed by a people to provide itself with the objects of material culture."
>
> American Heritage: "2. Broadly, the body of knowledge available to a civilization that is of use in fashioning implements, practicing manual arts and skills and extracting or collecting materials."

These definitions that have been selected both have a characteristic that is frequently omitted in common parlance. The implicit definition of technology, as it is sometimes used, tends to refer to specific material instrumentalities. It is at other times broadened to include managerial capability or other non-material characteristics. The above definitions (and they by no means exhaust these or other dictionaries) emphasize the entire range of practical knowledge and its potential material embodiment in tools and other instruments. Applied or practical knowledge must be applied to something and it is not certainly presumptuous to suggest that by these definitions, technology is the ability to solve problems. The technology of ideas or tools is defined by their ability to solve problems and, of course, problems and the priority ranking of problems is defined by society. Such a broad definition of technology is operational in that it describes the range of phenomenon that we should consider when we speak of using technology for development.

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5.1 Criteria for Assessing AID Technology Projects

Agricultural Extension Programs ought to be distinguished from technology programs. Possibly the term Appropriate Technology might need to be used because of external pressures. Some code word, however, such as extension, ought to be included to differentiate it from other technology programs. By an extension program we mean a situation where there is a known technology producing at a high level that is readily usable in the context of the project without the need for major adaptation. Of course, virtually all technologies must be adapted to fit new conditions. Soils vary from farm to farm, ore for smelting are different, and each batch of petroleum has characteristics that must be accounted for in the refining processes. Across the board in modern technology, these adaptations have been so routinized that they have become part of the technology. The difference between this kind of adaptation and that frequently required when a technology is diffused to a different culture or environment is so great as to be a difference in kind, and confusion of the new can lead to asking the wrong questions.

development requires continued technology transfer. Much of this perspective seems to be derived from the shared outlook with the ecology and limits to growth movements. Any programmatic philosophy that restricts or eliminates scientific and technological development at the higher echelons in order to concentrate it at the bottom would break the vital linkages that both sustain local technologies and provide the basis for further improvement of them.

One does not wish to create straw men, but it is difficult to interpret some of the most popular writers on small scale technology other than as advocates of this technology to the exclusion of others. One could litter this report with quotes from the late Schumacher or the still very active Amory Lovins who starkly states a dichotomy and the necessity to choose one or the other. (Lovins is currently best known for his advocacy of decentralized "soft" energy, i.e., solar, as opposed to other forms of energy such as nuclear energy.)

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Agricultural Extension Programs ought to be distinguished from technology programs. Possibly the term Appropriate Technology might need to be used because of external pressures. Some code word, however, such as extension, ought to be included to differentiate it from other technology programs. By an extension program we mean a situation where there is a known technology producing at a high level that is readily usable in the context of the project without the need for major adaptation. Of course, virtually all technologies must be adapted to fit new conditions. Soils vary from farm to farm, ores for smelting are different, and each batch of petroleum has characteristics that must be accounted for in the refining processes. Across the board in modern technology, these adaptations have been so routinized that they have become part of the technology. The difference between this kind of adaptation and that frequently required when a technology is diffused to a different culture or environment is so great as to be a difference in kind, and confusion of the new can lead to asking the wrong questions.

6.0 PRINCIPLES OF TECHNOLOGY

The following list of basic principles of technology form the intellectual assumptions consistent with the questions in the evaluation scheme. They have been, implicitly or explicitly, part of the author's work on technology over the last two decades. This particular set is taken verbatim from the summary of Chapter I in a book that I am writing. No attempt is made to hide this by excising telltale references to earlier parts of the chapter or to subsequent chapters. A rough draft of this chapter is available on request from Hank Miles. It is not included in the packet of materials sent to all participants.

6.1 Summary: Operational Principles of Technology

The purpose of historical inquiry on technology was to attempt to identify those operating principles that have governed technological evolution. It is our contention that consistency with these principles is necessary for successful technology transfer and economic development. They will be in one way or another embedded in the rest of this book. We consider them fundamental, both in planning and in implementing technology projects and as a set of criteria for evaluating completed projects. In the final chapter, we will take those summary principles and combine them with the empirical and analytical results of current efforts in science and technology for development, to create a set of guidelines or recipes for applying theory to the task of project development.

The basic characteristics of technology are:

1) Technology or human tool using is primarily an ideational process. It is the use of ideas to transform the material and non-material world.

2) Technology is behavioral. The very existence of tools implies skills both in tool creation and in tool use. Skills are forms of human behavior.

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3) Technology becomes organizational and institutional. Humans live in groups, and much of their technology, going back to large-scale hunting, requires organized group cooperation for effective implementation.

4) Technology as ideas (or knowledge) and as material artifacts is transmitted through culture. Though analytically separable, technology in use becomes part of the general belief system of those who use it. As such, the dynamic nature of technology (points 5 & 6 below) can come into conflict with the restrictive institutional beliefs and practices.

5) Technology is cumulative and combinational. Once the process of technology is under way, it gains momentum from the ability to combine, recombine, and modify existing technology. In the same sense that biologists say all life comes from previous life, and anthropologists say that all cultures come from previous cultures, we can state that all technologies come from previous technologies. Though, in terms of the archeological and industrial record, what appears to be combined are the material artifacts; the dynamics of the process comes from combining the ideas of the artifacts.

6) Technology is an interactive process. Just as there are feedback loops between human evolution and tools (as described above), there are feedback loops with other social activities. If a distinction is made between science and technology (which we do not fully accept, though most writers on the subject do), then we can observe a continuous feedback loop. Scientific inquiry establishes principles that are applied in technology. Technology provides the instrumentation that facilitates scientific advancement.

7) Technological change is an accelerating process. The more technology there is, the even greater are the possibilities for new combinations and advances and for positive feedback loops between science (and knowledge in general) and technology. Goldschmidt refers to "an exponential quality; that is, the rate at which growth takes place increases with each successive

increment of advancement." He considers it "mathematically inevitable that the opportunity for new techniques increases geometrically as the number of basic ideas increases arithmetically." He considers it "mathematically inevitable that the opportunity for new techniques increases geometrically as the number of basic ideas increases arithmetically." (Goldschmidt, op.cit., pp. 112-113). The historical record in the timescale figures that we have given certainly bear out the contention of exponential growth. It is a major contention of this book that some theories of technology and the projects thereby derived neglect the potential of technology and thus severely limit the potential gains from technology transfer.

8) Technology is a problem solving process. Technology is technology in the context of its use. Its use in the wrong context does not deny its efficacy in appropriate circumstances. By definition, all technology, if it is truly technology, is appropriate to some problem solving endeavor. The selection of technology depends upon cultural, environmental, and economic criteria that define a problem and the characteristics of its solution.

9) Technological innovation has long term consequences (the unintended consequences described above) that, from the viewpoint of subsequent generations, are more important than the short term problem solving that was the original intention of the technological change. Both in the short and long terms there are chance or fortuitous discoveries. Serendipity is the name given for the discovery that emerges by chance when one looks for one thing and finds another. As one great scientist said, "chance happens to the prepared mind" in that accidental discoveries only happen because someone had the intelligence to interpret the results as being useful in another context.

10) Because technology is combinational, it is not surprising that people working from the same technological and scientific base frequently create essentially the same invention (i.e. solve the same problem) at the same time. For the same reasons, simultaneous discovery is also a frequent phenomenon in scientific inquiry.

11) Technology, since it involves behavior, is likely to bring about cultural change. Similarly, culture is likely to force a modification of technology in the process of diffusion. Cultural change does not necessarily mean cultural destruction, in that it provides new and more expanded means for expressing traditional themes in art, ritual, and other human endeavors.

12) The cumulative body of knowledge, instruments, and human skills that we call technology is essentially a seamless webb. The source of an instrument or innovation in one area of endeavor can be derived from what superficially appears to be a totally unrelated area. We shall illustrate this point further in the chapter on arts and technology.

13) Adaptation of technology to new environmental circumstances is in itself a form of invention. Socially and linguistically we call large, apparently discrete technical changes, inventions. A closer, detailed analysis of the inventive process reveals the fact that a series of smaller, less discrete changes preceded the more noticed, larger changes. A more indepth study of the inventive process of printing would clearly indicate this. In most instances, adaptations are comparable to small, innovative changes in the inventive process.

14) The separation of a technology from the major areas of technological change, whether by geography, culture, or political isolation, tends to slow innovation, if not bring about stagnation. Linkage to other technologies is vital, linkage necessitating not only contact but also some compatibility in the level of technological achievement. This issue of linkage and continued technological development will be central to our analysis of appropriate technology.

15) Technology (and science) create resources. Resources are neither natural nor necessarily finite.

16) Historically, more often than not, successful technology transfer has involved borrowing technology at its then highest level.

17) Terms such as "Western technology" can only have a very restricted historical use. "Modern technology" can have a universal meaning as the set of knowledge and ideas, skills, tools, and machines that are the most efficient and effective at problem solving. Similarly, "modernization," a term frequently in disrepute as being ethnocentric, can have a transcultural meaning as the societal and cultural ability to use modern technology.

18) Technology transfer is incomplete if particular techniques are diffused out of context from the larger dynamics of the process. The presence or absence of a particular tool or machine is not evidence for technology transfer.

19) One of the frequent mistakes of analyzing old and new technologies is that they are frequently compared in terms of how well they perform established tasks without recognizing that new technologies almost always allow people to do new things as well as old ones better.

20) In choosing between technologies, the borrower must recognize that the context is not the world as it was but the world as it is and is becoming with most competitors (both economic and military) using the most efficient and effective technologies.

21) Technology, as noted above, is an evolutionary process. Technologies are predicated from the prior development of other technologies. This is the process in aggregate. For a particular economy or people, the process of technological evolution need not be replicated. Borrowing peoples may skip stages by borrowing technology at its highest level, as noted above. As a universal process, technology is evolutionary. As a particular process, technology is revolutionary. The dynamic accelerated growth that characterizes universal technological change may even be more greatly accelerated by particular peoples' jumping stages of technological development. The very rapid growth of technology borrowing countries, particularly the extraordinary unprecedented

post-World War II growth of countries such as the Republic of Korea, testify to this process.

22) All technology is both universal and particular. It is universal in that it is based unpon the principles of nature and is characteristic of all people. It is particular because as a problem solving process each peoples has a unique set of environmental and culturally-defined problems to be solved. Because technology is universal, it is ironically and paradoxically also alien because, for any particular people, the majority of their technology originated elsewhere. Simultaneously, technology as problem solving is entirely indigenous in that technology must be adopted to meet local conditions and this process of adaptation makes it one's own. This apparent paradox of universality and particularity, when indigenous, when properly understood and explained, can facilitate technology transfer. Too often the alien character of technology for a recipient peoples is stressed, i.e. called Western technology, when it is also a universal technology that is the heritage of all human kind. Similarly, the Appropriate Technology movement stresses the particular character of technology and thereby ignores the enormous benefits of its universality.

23) Invention, as Veblen stated, is truly the mother of necessity. We adopt our lifestyle, population, and other aspects of our condition to new technologies. The agricultural systems of the world that create the means to support 4 billion people are necessary if there is not to be mass starvation. The technologies that allowed urban growth are now necessary for their survival. Individuals may return to previous technologies but rarely if ever does the group have that option. Going back to earlier technologies has been widely advocated as a development strategy, but no evidence has been offered as to its aggregate validity.

24) There are gains and losses to evolutionary and technological change. The human record shows that the gains have been far greater than the losses. The claims made for alternate technologies (and against modern technology) actually apply to modern technology. Nature is only a virtue in developed countries where technology has pratically insulated the population from its worst ravages

such as drought, famine, and plague. Modern technology is truly technology for the masses, given people longer lives, more choices, and greater control over their destiny. The list of the benefits of modern technology is as long as the criticism against it.

25) The free market place of ideas, democratic institutions of all kinds and free economic markets are all vital mechanisms in developing, transferring, and sustaining technology. The dynamic process of combining technologies to create new technologies or borrowing technology is greatly facilitated by freedom of thought and freedom of action. Jacob Bronowski, in his masterpiece, Science and Human Values, argues that the basic principles of scientific inquiry as refined in the last few centuries are essentially the same principles of democracy — free and open inquiry are equally functional for science, for technology, and for democracy.

26) Technologies coexist. (a) New technologies are better only for a range of problems and circumstances but not all. (b) Prior technologies can continue to experience improvements. (c) New technology generally is being improved in a way that cumulatively may be more significant than the "original invention. (d) a/b do not negate the principle that some technologies become obsolete and are a technological dead end.

27) Reliability can be substituted by redundancy. Modern technology generally have greater reliability (i.e., redundancy) than previous technology. Evidence is overwhelming from data on famine, loss of life to natural disaster, etc. Most critics of modern technology cite breakdown, that are not substantially life threatening (New York City power failure) or theoretical possibilities.

28) Technological interdependence or complimentarity in complex technology means that some improvements in the technology requires complimentary advances in several areas. For example, fast moving vehicles, cars,

trains, planes) need braking systems. Tool making has always involved the property of materials. In modern technologies, materials, strength, purity, heat resistence, etc., have to be created so that proposed system can function.

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7.1 Some Basic Theories of Economics and Technology and Author's Works Associated With Them

a) Factors of Production - Labor Surplus. In the 1950's, W. Arthur Lewis established the basic model where there was surplus labor in agriculture (i.e., marginal product of labor was zero), which could be used with inexpensive basic technology (such as picks and shovels) to create the capital (such as roads) to build a more advanced society. In productive enterprises wages would be at subsistence, profits would be high, and therefore capital would accumulate. As development progresses, wages would increase, and more advanced technology would be used. See W. Arthur Lewis, "Economic Development with Unlimited Supplies of Labor," The Manchester School of Economic and Social Studies, XXII, No. 2 (May 1954), pp. 139-191. For a similar but more sophisticated theory see John C. H. Fei and Gustav Ranis, Development of a Labor Surplus Economy: Theory and Policy, Homewood, Illinois: Richard D. Irwin, 1964. Since 1964 Ranis has written extensively on Taiwan as the premier example of successful economic development, following the policy implicit in the Fei-Ranis model. Erich Schumacher's economic premises underlying his widely acclaimed book, Small is Beautiful: Economics as if People Mattered, New York: Harper & Row, 1973, are in effect an oversimplification of Lewis, Fei, and Ranis. However, whatever one may think of the theoretical validity of Schumacher's work (and others such as Ivan Illich, Tools

for Conviviality, New York: Harper & Row, 1973), those stimulated by his thinking have done an enormous amount of good work in finding or creating appropriate technologies. In this regard, there seems to be an almost endless number of appropriate technology magazines and journals, such as Vita News and Appropriate Technology. Theodore W. Schultz, in his book, Transforming Traditional Agriculutre, New Haven Connecticut: Yale University Press, 1965, questions whether there is a labor surplus in agriculture. If there was a labor surplus meaning that the marginal product of labor was zero, then one would expect that population decline would not lead to a fall in agricultural output. Schutz presents evidence that it does.

b) Resources and the Theory of Technological Choice - A. K. Sen, Choice of Techniques, London: B. H. Blackwell, 1968 is a basic theoretical work, grounded on the classical and neoclassical theory in economics, on the factors involved in choosing technology. Sen is theoretical to the point that it is difficult to find very much that is concrete and empirical in his work. C. E. Ayres, The Theory of Economic Progress, Chapel Hill: University of North Carolina Press, 1944, created a comprehensive theory of technological change that arises out of Veblenian thought and the American school of institutional economics. Ayres seeks to ground his theory in historical fact and in so doing is willing to explore issues of values in cultural change. Ayres has a theory of resources in which resources are created by technology. This theory was in part derived from the work of Erich

Zimmermann, World Resources and Industries, New York: Harper & Brothers, 1951. Important work on the practical economics of resources was done by Harold J. Barett and Chandler Morse, Scarcity and Growth: The Economics of Natural Resource Availability, Baltimore: Johns Hopkins Press for the Resources for the Future, Inc., 1963. Their arguments on resource availability and those of Ayres and Zimmermann on the technology of resource creation stand in opposition to those who argue that there is a threat of resource exhaustion, such as Dennis Meadows (et al.), The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind, New York: Universe Books, 1972. There have been many attempts to measure the economic impact of technological change (and by implication, resource creation). For several decades, Simon Kuznets has pioneered economic measurement, and one of many important works of his is Modern Economic Growth: Rate, Structure, and Spread, New Haven, Conn.: Yale University Press, 1966. John W. Kendrick has done some of the best work on measuring growth and technological change in the United States. Among his writings is Output, Input, and Productivity Measurement, Princeton, New Jersey: Princeton University Press for the National Bureau of Economic Research, 1961. Some early efforts at thinking on the implications on standard economic theory of increasing data showing the important impact of technology can be found in Benton F. Massel, "Capital Formation and Technical Change in United States Manufacturing," Review of Economics and Statistics, 42, No. 2

(May 1960), pp. 182-188, and Robert Solow, "Technical Change and Aggregate Production Function," Review of Economics and Statistics, 39, No. 3 (Aug. 1957), pp. 312-320.

c) The Spread of Science and Technology and Industry to Third World Countries. A thoughtful and important work on the diffusion of science is George Basalla's "The Spread of Western Science: A Three-Stage Model Describes the Introduction of Modern Science into Any Non-European Nation," Science, 156, No. 3775 (May 5, 1967), pp. 611-622. My own work, Technology and the Economic Development of the Tropical African Frontier, Cleveland, Ohio: Case-Western Reserve University Press, 1969, attempts to look at historical patterns of technological development and diffusion in Africa as a basis for understanding current scientific and technological policy issues in African development. Vernon W. Ruttan and Yujiro Hayami have argued in books and articles that different factors of production give rise to different types of science and technology. In the United States, where land was abundant and labor relatively scarce, agricultural research and training was primarily in the area of labor saving mechanical technology. In Japan in the late 19th century, with its extreme scarcity of land, biological research fostering increased yields per acre was carried out. Following from this, they argued that the factor endowments of Third World countries make continued biological research the most promising for their agricultural development. Among their singular and joint efforts see Vernon W. Ruttan and Yujiro Hayami, Technology Transfer and Agricultural Development,

obvious or a truism) to carry out this task. It is doubtful, however, that any industrial nation such as the United States would have committed the resources to carry out this endeavor without being in a war or a cold war. At no previous time could the A-bomb have been developed, no matter how much it was "needed." Without war there is no telling how long its development would have been delayed. The factors of production arguments of Ruttan and Hayami are comparable to war in our analogy — they can only direct and focus emphasis on a flow of science and technology that already exists.

Much useful biological research is being carried out today as advocated by Ruttan and Hayami and by many others operating from different theories. However, as they recognize, the fruits of this research are as readily used (if not more so) in capital intensive agriculture as they are in labor intensive agriculture. For an excellent piece of research in agriculture, which, among the many things that it accomplishes, calls into question oversimplified theories of economic and technological change, see Derek Byerlee, Carl K. Eicher, Carl Liedholm and Dunstant S. C. Spencer, Rural Employment in Tropical Africa: Summary of Findings, Working Paper No. 20, the African Rural Economy Program, Department of Agricultural Economics, Michigan State University, East Lansing, Michigan, February 1977. Their work represents a basic approach of factually studying each task and environment, then selecting, adapting, or designing the technology to fit the problem. They avoid rigid aprioristic theory, but it does not mean that they lack an empirically testable theory or theories of development.

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Attachment A

TECHNOLOGY AND EVOLUTIONARY PRINCIPLES OF CHANGE

The mainstream of economics has long considered questions of technology as subsidiary to those of saving and capital formation. However, in the last two decades, the issues of technology transfer have become a major concern for those interested in the problems of economic development in less developed countries. Economists and others are now writing about scale of technology, appropriate technology, transfer of technology, and so on. This outpouring appears to consider technological diffusion as largely a post World War II phenomenon. Of course, such is not the case.

Throughout human history technological diffusion has been a regular and important element in the evolution of a people's technology. The populations of all cultures and places use a technology, although they, or their ancestors, originated only a small part. Technological borrowing incorporates the creativity of the rest of the world. The process of adaptation in technological borrowing is itself a form of inventive activity. Yet, little of the writing on technology transfer reflects any attempt to gain understanding from prior successes (and failures) in borrowing and using exotic technology.

In this chapter we argue that the history of technology is replete with insights which yield theories directly applicable to the current pressing problems of development. Using this historical base, we define the nature of technology in a way that generates useful and practical concepts for thinking about development and for carrying out programs and policies using technologies to raise the levels of living for the world's population. Toward the end, the

chapter suggests that some views of technology transfer are deficient in historical understanding and if carried through, have the potential for curtailing the long term processes of development.

Now that technology policy has become a central debated issue among economists and other practitioners of development, the scope of discourse has broadened enormously. Technology policy is no longer concerned almost exclusively with expanding economic output. Issues concerning the selection of technology and its impact upon women, minorities, local, regional and national identities, and upon the distribution of income have become as important as economic efficiency and increase in production. Concern has been raised about adverse cultural change, deleterious environmental impact, and irrevocable biological destruction.[1] The discussion of technologies has led to discourses on future lifestyles, new eras or ages of human kind, and the exploration of cosmic issues such as the nature of life and physical processes. There are calls for more spartan lifestyles, and the second law of thermodynamics (entropy) is used to argue that affluence must pass, as energy and raw materials for production inevitably and ineluctably decline. Emphasis is placed on renewability, consistency with nature, and living within environmentel limits.

Few would argue that it is not better to be discussing the non-economic implications of technological change than to treat technology as mere gadgetry and assume no other criteria for assessment other than economic efficiency and growth in output. However, many of these "large issues" of biology and physics

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[1]An examination of the more catastrophic views that have been voiced over the last two decades can be found in Chapter II.

(entropy) appear to be questionable as to immediate development decisions and technology choices.[2] The challenge to development theory and practice is serious and sufficiently widespread that it cannot be ignored or summarily dismissed. The following brief exposition on the origins and development of life is meant only to indicate that certain concepts about the use and development of technology are not inconsistent with life as we know it on this planet.[3] That many of the critical episodes in the early development of life bear remarkable (if not superficial) resemblance to contemporary problems may provide useful analogies for understanding but does not close out inquiry concerning the nature of our contemporary difficulties.

The earth was formed about 4.5 to 5 billion years ago, and life is believed to have begun on it between 3.2 to 3.8 billion years ago.[4] The "life process" can be defined as aiming at survival and doing this by extracting "energy from their environment" and using "that energy to make their own preservation more likely." "The entire life process is aimed at safe reproduction because any

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[2]Among the more recent books that attempt to use biology and physics to create a world view and to posit ineluctable forces that require small kinds of technology and development strategies are Jeremy Rifkin, Entropy: A New World View, New York: Viking, 1980, and Kirkpatrick Sale, Human Scale, New York: Coward, McCann and Geoghegan, 1980. A sample of the multitude of other sources arguing this position can be found in the chapter on catastrophes.

[3]The double negative, not inconsistent, is used deliberately. To say that development theory must be consistent with theory in biology begs the question as to the relevance of theory in one inquiry to that in another. Obviously development should not threaten the existence of human life or life in general. Development theory should also adhere to the basic criteria of the scientific method common to all scientific inquiry.

[4]Cyril Ponnamperuma, "The Quickening of Life," in S. Dillon Ripley (ed.), Fire of Life, New York: Smithsonian Exposition Books, 1981, p. 125; Harold L. Levin, The Earth Throughout Time, Philadelphia: W. B. Saunders, 1978, p. 249, and Mark Washburn, In the Light of the Sun, New York: Harcourt Brace Jovanovich, 1981, p. 147.

other target is self-destructive."[5] Another author notes that "life is also a chemical system that interacts with its surroundings; after life originated, it had a rapid, widespread, and irreversible effect on the atmosphere, the surface water, the soils, and the sediments."[6] The chemistry of life as we know it is based upon the almost unique bonding properties of carbon and its ability to form with other elements complex organic molecules.[7]

> "Reduced to a fundamental definition, life can be viewed as a system with four basic components. The first of these is proteins. Proteins are essentially strings of comparatively simple organic molecules called amino acids. Proteins act as building materials and as compounds that assist in chemical reactions within the organism. The second of the basic components is nucleic acids, such as DNA mentioned earlier and ribonucleic acid (RNA). Organic phosphorous compounds provide a third component of life. They serve to transform light or chemical fuel into the energy required for cell activities. The fourth essential for life is some sort of container, such as a cell membrane. The enclosing membrane provides a relatively isolated chemical system within the cell and keeps the various components in close proximity so that they may interact.[8]

The very nature of life itself necessarily creates stuff that we have come to call waste and/or pollution. "Pollution is not, as we are told, a product of moral turpitude. It is an inevitable consequence of life at work."[9] Life

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[5]Michael A. Seeds, Horizons, Belmont, California: Wadsworth Pub. Co., 1981, p. 346.

[6]Brian J. Skinner (ed.), Paleontology and Paleoenvironments, Los Altos, CA.: William Kaufman, Inc., 1981, p. 1.

[7]Nicholas Rosa, "The Origins of Life," Oceans, Vol. 15, No. 5, Sept.-Oct. 1982, pp. 36-37 and Seeds, op. cit., p. 346.

[8]Levin, op. cit., p. 250.

[9]J. E. Lovelock, GAIA, Oxford University Press, 1979, p. 27 and pp. 108-109.

takes energy from the environment and releases it in a degraded form, i.e., entropy. Though the energy that passes through life confirms the second law of thermodynamics (entropy) by passing out in a less usable form, life itself (as many have noted) is an island of anti-entropy in that it builds complexity. The very chemical processes of life involve the taking in of compounds from the environment, breaking them down, using parts and expelling others. These parts expelled can be defined as waste. Under other circumstances, the wastes of life can be, and in the past have been, a creative environmental factor for the further development of life.

The first life forms developed in an atmosphere that was a hydrogen-bearing-reducing environment with a trivial or no amount of oxygen in it.[10] The pre-existing "organogenic elements with which the earth was initially coated" were: "methane, ammonia, carbon monoxide, water, carbon dioxide, hydrogen sulfide, and of course, hydrogen."[11] Without an ozone layer to filter it, ultraviolet light was bombarding these molecules, converting them into amino acids, sugars, nucleic bases, and other carboxylic acids."[12] A number of famous experiments conducted this century have shown that organic compounds could have been formed from the action of ultraviolet light upon the early atmosphere of earth.[13]

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[10]Preston Cloud, "Evolution of Eco-systems," in Brian J. Skinner (ed.), Paleontology and Paleoenvironments, op. cit., p. 7; Lovelock, op. cit., p. 18; Fuller, op. cit., p. 467; and Washburn, op cit., p. 148.

[11]Melvin Calvin, "Chemical Evolution," in Brian J. Skinner, Paleontology and Paleoenvironments, op. cit., p. 21.

[12]Loc. cit.

[13]On the experiments of A. I. Oparin and J. H. S. Haldane and others, see David G. Smith (ed.), Cambridge Encyclopedia of Earth Sciences, New York: Crown/Cambridge University Press, 1981, pp. 349-352?.

These early life forms are part of the large category of procaryote. They were unicellular and reproduced by cell division. They were heterotrophic in that they could not manufacture their food and were forced to live off already existing organic materials. These organic compounds were converted into energy by chemical processes of fermentation. These life forms were anerobic, meaning that not only could they live without the presence of free oxygen; an oxidizing environment would have broken down the chemical composition of life as it then existed.

A system of life consisting entirely of heterotropes is inherently limited and theoretically doomed to extinction. No matter how large the pre-existing stock of organic compounds was (then food), the procaryotic life forms would have eventually exhausted them. Some new organic compounds were probably being created, and living cells were undoubtedly consuming other living cells, as they have been doing ever since. Further, any oxygen buildup in the upper atmosphere in the form of ozone would have begun to shield out the ultraviolet rays that created the organic soup that fed life as it then existed. Thus, the ozone layer that was later to become the protector of life was initially an agent for the destruction of the food supply.

The first food crisis was resolved by the evolutionary processes that led to the creation of photoautotrophs in the form of photosynthetic procaryotes, possibly as early as 3 billion years ago.[14] A photo-autotroph is a life form that can use the sun's light (in this case the most abundant wavelengths) to convert carbon dioxide and water into glucose (as a storehouse of life's energy)

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[14]Levin, op. cit., p. 252.

and oxygen. This process is written in most basic works on the subject as $6\ CO_2 + 6\ H_2O \xrightarrow{\text{sunlight}} C_6H_{12}O_6 + 6\ O_2$. When organisms take in oxygen to "burn" their food (glucose or the $C_6H_{12}O_6$ in the above equation), they reverse the process and acquire energy for living.[15] It is chlorophyll in the organism that retains light and allows its energy to be used.[16]

We humans frequently find that when we solve one problem we at the same time create another. Progress in the human endeavor is most meaningfully defined not in terms of the ultimate or final solution of problems but in creating smaller or less important ones than those we solve. In life, the development of photosynthesis among procaryotes meant the generation of more of that deadly, life-threatening substance, free oxygen. Initially, there were large amounts of oxygen acceptors such as ferrous iron that could serve as an oxygen sink, keeping atmospheric oxygen down to tolerable levels.[17] Eventually, the most readily accessible oxygen acceptors acquired a full complement of oxygen, and oxygen began to build up in the atmosphere. Meanwhile, procaryotic life was retreating to environments protected from death-dealing oxygen. The reducing environment became an oxydizing one. This process may have taken as long as a billion years.[18]

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[15]Various alternative fermentation processes were possible in the earlier life forms to break down the pre-existing glucose by fermentation to generate energy in an oxygen free environment.

[16]Robert Carola, "Sunlight to Sugar," in S. Dillon Ripley, Fire of Life, op. cit., pp. 128-132.

[17]Cloud, op. cit., p. 11; and Levin, p. 252.

[18]Cloud, p. 11.

About 1.3 to 1.6 billion years ago, a new life form appears, the eucaryotes.[19] The first eucaryotes were photo-autotrophes like some of the prokaryotes. Their most important characteristics in the context of this analysis were that they were aerobic organisms. The ozone layer that prevented the creation of organic soup now shielded and protected the new life form. The free oxygen in the environment that was destructive to procaryotes became a vital component of the new life processes.

If prevailing theories are correct, life on earth overcame the food crisis and then a toxic oxygen crisis by evolutionary changes. There is nothing in these theories that argues that the evolutionary changes had to occur. They did. If they hadn't, we wouldn't be here to write about them. And it is not beyond the realm of possibility that elsewhere in the cosmos (once or many times), similar biological challenges were faced with extinction occurring in some instances and diverse successful options pursued in other instances.

The emergence of photosynthesis and eucaryotes had other evolutionary advantages than mere survival. Photosynthesis is a more efficient converter of its fuel into energy.[20]

This greater energy efficiency created surplus energy and opened up new evolutionary possibilities.[21] Utilization of oxygen allowed for the

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[19]Cloud, p. 15.

[20]Greater energy efficiency is a defining characteristic of evolution to one author. "Since life thermodynamically is an open system, in all theories on its origin, the energy source gains first importance. Other things being equal ... evolution ... primarily should be proportional to the sum of energy turnover per mass unit." (author's underlining) Peter Decker, "Coupling to Solar Energy: Sensitized Photoreactions -- The Primary Source of Self Organization" in Yecheskel Wolman, Origin of Life, Dordrecht, Holland: D. Reidel Publishing Company, 1981, p. 329.

[21]Levin, pp. 252-253.

colonization of land. Sexual differentiation and mitotic cellular division opened possibilities for genetic variation and the acceleration of evolutionary change.[22] To survive (in some cases to the present), many procaryotes established symbiotic relationships with (or within) eucaryotes. According to Margulis, 'the aerobic metabolism and genetic systems of these 'higher cells' led to the eventual dominance of the most complex eucaryotes, the metazoans, and the green plants".[23] About 600 million years ago, eucaryotes with "hard coverings and skeletons in a number of animal groups" evolved and with them "the fossil record proliferates.[24] After about 3 billion years of evolution, life as most of us nonbiologists recognize it took hold in the form of multicellular plants and animals.

There are a number of lessons for development or at least insights into the process that we can derive from the study of the development of life:

1) Life as we now know it created the conditions for its own existence with the assistance of early life forms. This is, in part at least, the GAIA hypothesis of J. E. Lovelock.[25] As we shall note below, humans have complemented the life sustaining conditions through the development of technology that has turned environments into habitability for their kind. In most human habitats, the conditions for even bare existence, let alone the level of existence or the population density, are dependent upon human modification of

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[22]Washburn, p. 151; Levin, pp. 252-253; Cloud, p. 137; and Skinner, p. 1.

[23]Lynn Margulis, "The Origins of Plant and Animal Cells," in Skinner, p. 33.

[24]Skinner, p. 1.

[25]Op. cit.

the environment with technology.

2) What appears to be fixed, absolute limits to development can be overcome. There were food supply and pollution crises in the past. We observed how life overcame them and established a new framework for growth and change. Similarly, in the human endeavor, we will show throughout this book how science and technology have now and in the future overcome barriers to development. For the life process, we cannot assert that these limits necessarily had to be overcome, merely that they were. It took time (in some instances, eons) and possibly luck. For humans, technology has possibilities for future problem solving that are neither certain nor automatic. It requires the application of effort and intelligence. The only point here (which shall be reiterated later) is that apparent limits to growth should not be used as a device to close out inquiry or foreordained technology and development strategies.

3) Entropy or the Second Law of Thermodynamics applies only to closed systems. Thus, life as a whole is definably an island of anti-entropy. As long as there is available energy outside the life system, then there is the continued possibility to move in the direction of greater complexity and diversification. Obviously, all technologies, large scale or small, are subject to the laws of thermodynamics. Clearly, if current theories are correct, entropy as applied to the known universe will mean playing out the available energy sources in the far distant future. Entropy in this larger sense cannot be used as an argument for certain kinds of technologies over others. As Lovelock has correctly and beautifully stated, "the death sentence of the Second Law applies only to identities, to closed systems, could be rephrased: 'Mortality is the price of identity' ... In the end, the sun will overheat and

all life on earth will cease, but that may not happen before several more eons have passed. Compared with the lifetime of our species, let alone that of an individual human being, this time span is no tragic brief spell, but offers almost an infinity of opportunities to terrestrial life."[26]

4) The life process itself produces waste. Again, as Lovelock so poetically states, "The first appearance of oxygen in the air heralded an almost fatal catastrophe for life" but "ingenuity triumphed and the danger was overcome ... by adapting to change and converting a murderous intruder into a powerful friend."[27] John Dewey has described a similar process in the human enterprise: "Man who lives in a world of hazards is compelled to seek for security." One course "is to invent arts and by their means turn the powers of nature to account; man constructs a fortress out of the very conditions and forces which threaten him."[28] Science and technology are the means by which humans turn adversity to opportunity. Again, we would not want the statement on the possibility of solving today's environmental problems through technological change to give rise to complacency or the polyanish belief that technology will automatically solve our problems. While the "blind" forces of evolution may have solved the problems of eons ago, today our time frame is shorter and concerted organized intelligence must rise to the tasks at hand.

5) While the life process on earth may have created the conditions for

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[26]Lovelock, p. 125.

[27]p. 31.

[28]Dewey, <u>The Quest for Certainty</u>, New York: Capricorn Books, 1960, reprint, p. 1.

its own existence, "nature" as popularly used (presumably meaning the ecosystem apart from humans) is not a "friend" to any particular species or group of organisms. Again, from Lovelock we learn that "by far the most poisonous substances known are natural products" with some of the most deadly being "entirely organic products and but for their toxicity would be suitable candidates for the shelves of the health food store."[29] Nature can mean climatic variability — drought, floods, disease, and other natural disasters. Nature is! And if we humans modify it to suit our purposes, as we do by merely existing, we must do so with care and with foresight, based upon our scientific knowledge.

6) There appears to be a similarity, probably superficial, between biological evolution (discussed above) and the technological evolution discussed at the end of this chapter. Certainly, one cannot rigidly apply the rules derived from the study of one of the processes to the other. However, the similarity does raise further questions as to the thesis of incompatibility between technology and continued human life. Both processes move from the simple to complex, though some simple forms continue to exist. Both processes seem to accelerate through time. Roughly 2 billion years or over half of life's existence was limited to simple procaryotes. Eucaryotes have existed for less than half, about 3/7's of life's existence. Over 2/3's of this time was prior to the creation of hard surface or skeletal creatures. This latter group, then, has only existed about 1/7 of life's time on this earth. Comparable ratios for human technologies will be given later in the chapter. And most evolutionary

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[29]Lovelock, p. 109.

processes appear to be largely irreversible.

7) That life created its own conditions for existence reinforces the essential irreversibility of the evolutionary process. Technology is also essentially irreversible in that we have adapted our lives to it (population density, etc.) and by having used certain resources have probably closed the option of ever trodding the same path of evolutionary change again. Like it or not, if we humans are to survive on this planet, it will be by carrying forward the science and technology that we have. As Ross puts it for biological evolution, the "building blocks" of life, i.e. methane, ammonia, etc., are "used up". "Conditions are not the same as when life arose the first time. The niche for naive life is closed and all life today is born of existing life."30 We might add that all technology is borne of existing technology and the niche for naive technology is closed.

We have thus far looked at various episodes in life's history in an attempt to gain understanding of current development processes and to raise questions about development theories based upon biological argument. The events which we have been discussing took place over the course of two billion or more years from the probable origins of life to the development of life forms with skeletons or hard exteriors about 600 million years ago. The episodes of relevance to our inquiry to which we now turn took place over the last few million years. These are the tools, language and the evolution of human beings. Some of the tool using and signaling behavior that we will be describing for animals other than humans may have origins much earlier than a few million years

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30Ross, p. 37.

ago, though all our evidence on this behavior is from recent observation. The human part of our story begins about 4 million years ago, tool using humans or proto-humans began about 2.5 million years ago and language development probably well within the last million years.

Animals of many species from insects to primates use tools just as they communicate with others of their species. A burrowing wasp disguises her nest by pounding the ground smooth with a pebble hammer that she holds in her mouth. Sea otters use rocks as anvils to help them open shells. And beavers, working in groups, construct large and intricate dams.31

The most striking observations of tool using animals are those made by Jane Goodall of East African chimpanzees.32 These chimpanzees use tools for eating, grooming and fighting. The chimpanzees' tool use is unlike other species' because the chimpanzees apparently are not using tools in the "stereo-typed sequence of movements" observed in other animals, but rather the young learn by observing their elders.33,34 A hungry animal picks up or breaks off a stick

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31Oakley, Kenneth P., "Skill as a Human Possession," in Singer, Charles, Holmyard, E.J., and Hall, A.C., eds., A History of Technology, London: Oxford University Press, 1954, pp. 1-37.

32Goodall, Jane, "My Life Among the Wild Chimpanzees," National Geographic, August 1963, pp. 272-308 (first observed use of tools by non-human animals). Goodall, Jane, Van Lawick, Hugo, "New Discoveries Among Africa's Chimpanzees," National Geographic, December 1965, pp. 802-831.

33Lancaster, Jane B., "On the Evolution of Tool-Using Behavior," American Anthropologist, February 1968, Vol. 70, No. 1, pp. 56-66.

34The behavior Goodall observed is not common to all chimpanzees. See Nishida, Toshisada and Uehara Shigeo, "Chimpanzees, Tools, and Termites: Another Example from Tanzania," Current Anthropology, October 1980, pp. 671-2. Nishida and Uehara note that some termite eating chimpanzees do not use probes. The use of probes seems to depend on the availability of tool material and the "termite life-style". Also see Kitahara, Frisch J., "Apes and the Making of Stone Age Tools," Current Anthropology, July 1980, p. 359.

or blade of grass and carries it some distance to a termite hill. There, after knocking off the top of the hill with his hand, the chimpanzee takes the stick and dangles it down an exposed tunnel. He draws it out and picks off the clinging termites for his dinner.[35] Later, the same chimpanzee may crumble and chew leaves into a spongy mass which he uses to sop water out of a stump for an after dinner drink.[36] These actions clearly involve intelligence and foresight. The rocks, the stick and the sponges are used as tools. Sometimes acquired before the end use is in sight, they make the jobs of getting food or protecting the young easier. However, it can no more be argued that these animals have a technology simply because they have tools, than it can be argued that they have a language because they signal to one another.

The vocal and nonvocal signalling systems of animals indicate both feeling and information. These are not language but "innate movements and sounds for expressing feelings ... [and] innate ways of reacting to these signals."[37] Bees dance not only to indicate a new nectar find, but also its location. The closer the nectar, the faster the dance. And any hive member witnessing the dance knows exactly what course to pursue.[38] Siamese fighting fish identify the sex of another by its reaction to the opening movements of what may be a dance of love or a dance of death "not simply by seeing it but by watching the

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[35]Goodall, 1963, op. cit.

[36]Goodall, 1965, op. cit.

[37]Lorenz, Conrad Z., King Solomon's Ring, New York: Time Inc., 1962, pp. 27-30.

[38]Hockett, Charles F., "The Origins of Speech," Scientific American, September 1960, pp. 89-96.

way in which it responds to the severely ritualized, inherited, instinctive movements of the dancer."[39]

Vocalizing animals call to each other in many ways: defiance, warning, or greeting. The termite fishing chimpanzee has a range of calls that the other chimps understand.[40] Many birds have complex codes that others in the species respond to even when they have not heard them before.[41] Such signals are automatic and unemotional, innate and not learned. They do not rise from the consciousness of the caller.

> All expressions of animal emotions, for instance, the "Kia" and "Kiew" note of the jackdew, are therefore not comparable to our spoken language, but only to those expressions such as yawning, wrinkling the brow and smiling, which are expressed unconsciously as innate actions and also understood by a corresponding inborn mechanism. The "words" of the various animal "languages" are merely interjection.[42]

These signals are signals because their context is already known. They are restricted to particular situations. Novelty, if it exists, consists of a limited range of information such as direction to food sources or location of dangers. Beyond this, these systems are closed. A new experience can not be shared.[43] Human language is open-ended; it is continuously able to generate

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[39]Lorenz, op. cit.

[40]Goodall, 1963, op. cit.

[41]Lorenz, op. cit., pp. 89-90.

[42]Ibid.

[43]Hockett, op. cit.

new combinations of ideas. Any sentence can by a combination of words never before used together and, yet, a group of listeners can understand it. Furthermore, language can be used reflectively. As linguists state it, only humans using language can talk about talking.

> So, when we talk about a language — English, French, Russian, Sanskrit — we refer to a process rather than to a thing .... It is best to regard the language as a growing corpus of words and structures which nobody can know entirely but upon which anybody can draw at any time — a sort of unlimited bank account. It is not just the sum total of what has been spoken and written; it is also what can be spoken and written. It is actual and potential. In another sense, it is a code always ready for individual acts of encoding.[44]

Taken alone, tools and signals are static. Humans use them and generate the dynamic processes of technology and language. A stick for the East African primate has an end-in-view and its usefulness essentially terminates there. When humans have a tool, they find new uses for it, or they combine it with other tools to serve new purposes. The usefulness of a tool goes on and on.

In the same way as language, technology is dynamic and open-ended. They are both subject to change and modification. When we confront a new problem, we can use existing words to create the sentences to describe it and discuss it, while we use existing tools to create the ones that will solve it.

The dynamics of tool using and of open-ended language are a function of the evolutionary process from which human beings emerged. During the course of this

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[44]Burgess, Anthony, Language Made Plain, New York: Thomas Y. Crowell Company, 1965, pp. 16-17. "Human language can be reflexive because the human brain is capable of "self examination." "The human brain is the only organ on earth that is aware of itself." Robin Marantz Henig, "Where Surgery Meets the Soul," a book review in The Washington Post Book World, Vol. XIII, No. 16, April 17, 1983, p. 1.

process, an interaction occurred between tool using and biological evolution in a feedback mechanism that provided a non-teleological direction to change. Currently, there is some dispute as to the age and significance of certain skeletonal remains. For the purpose of our analysis, we need not be concerned about larger structure or the time frame of this transition. If indeed Lucy is 4 million or more years old and if the find is an important differentiation from the primates, then tool using was not a critical differentiating causal factor.[45] If the important transitions came later, on the order of about 2 million years, then the interaction with tool using was an important component of this critical differentiation. Even those who argue for the early origins recognize the importance that tool using began to play in the evolutionary process about 2 million years ago.

The feedback mechanism as described by Sherwood Washburn is basically simple.[46] As proto-hominids began using tools, there was a selective survival advantage in the group that had greater biological capacities for tool using. These characteristics are many and include the size of the area of the brain that controls the hand (in particular the thumb).[47] As members of groups, or

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[45]On Lucy, see D. C. Johanson and M. A. Edey, Lucy: The Beginnings of Humankind, New York: Simon and Schuster, 1981. On some of the controversies of dating this discovery, see Roger Lewis, "Fossil Lucy Grows Younger, Again," Science, Vol. 219, No. 4580, 7 January 1983, pp. 43-44. See also Frances H. Brown, "Tula Borluff at Koobi Fora," correlated with Sidi Hakoma Tuff at Hadar, Nature, Vol. 300, No. 5893, December 16-22, 1982, pp. 631-633, and N. T. Boaz, F. C. Howell and M. L. McCrossum, "Faunal Age of the Usno, Shungua B. and Hadar Formations, Ethiopia," Nature, Vol. 300, No. 5893, December 16-22, 1982, pp. 633-635.

[46]See Sherwood Washburn, "Tools and Human Evolution," Scientific American, Vol. 203, No. 3, September 1960, pp. 63-75.

[47]See Washburn, loc. cit.

as groups within the larger population, that had greater capacity for tool using survived and bred, the population in general had a more favorable set of tool using traits. Any random changes that favored tool using would be likely to survive and spread throughout succeeding generations. As these traits were intensified, it would improve the population's ability to make and use tools. This greater physiological (which includes the brain or mental capacity) ability for tool using, combined with the nature of tool using itself (described later in this chapter), gave rise to new and improved tools. These improvements in tools and tool use then feedback to give further selective advantage to those members of the population with improved capabilities for tool using.[48]

As this interactive or feedback process continues, hominoids or proto-hominids evolve into hominids and the process of tool using takes on the open endedness of tool combining and becomes technology. Throughout this book we will stress the importance of understanding the context or ecology which a technology operates. The preceeding illustrates an important component of technology, which we sometimes forget because of its universality, the physiological characteristics of the creators and operators of the technology.

The larger area of the human brain that controls the hand, controls a truly marvelous mechanism. Bernard Campbell has a delightful description of the hand that deserves to be quoted at length:

> Not needing our hands for support, we have been able to use them for more complicated and more creative tasks. With twenty-five joints and fifty-eight distinctly different motions, the human hand represents one of the most advanced mechanisms produced by nature. Imagine a single tool that

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[48]An excellent description of this positive feedback mechanism with an equally outstanding diagrammatic illustration of it can be found in Bernard G. Campbell (ed.), Humankind Emerging, Boston: Little, Brown and Co., 1982, pp. 218-219.

> can meet the demands of tasks as varied as gripping a tool, playing a violin, wringing out a towel, holding a pencil, gesturing, and — something we tend to forget — simply feeling. For, in addition to its ability to perform tasks, the hand is our prime organ of touch. In the dark or around corners, it substitutes for sight. In a way, the hand has an advantage over the eye, because it is a sensory and a manipulative organ combined. It can explore the environment by means of touch, and then immediately do something about what it detects. It can, for instance, feel around on a forest floor for nuts and roots, seize them on contact, and pop them into the mouth; when your eyes read the end of this page, your hand can find the corner of the page and then turn it.
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> The hand itself may be a marvelous tool, but it is used to full value only when it manipulates still other tools. This capacity is a second-stage benefit of upright walking. With our erect posture, our hands are free; with hands free, we can use tools; with tools we can get food more easily and exploit the environment in other ways to ensure our survival. Humans are not the only animals that employ tools, but they are the only ones that do so to any great extent and with any consistency.[49]

Campbell also suggests that the larger brain size enhanced the capability for attention span and memory.[50] This greater capacity for memory would facilitate the cumulation of knowledge including the knowledge of tool making and tool using. Individual and group memory would be the key component in the cumulation of knowledge and culture until this process gave rise to extra somatic means of cumulation in the form of writing.[51]

The "total life-way" of tool using human being created what C. Loring Brace

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[49]Ibid, p. 47.

[50]Ibid, p. 311.

[51]It has been argued that the large human brain is "energetically expensive", and that its evolution was only possible because of a generalized and energy rich diet that resulted from simple technologies such as the digging stick to gain access to "energy-rich tubers" and from hunting. Roger Lewin, "How Did Humans Evolve Big Brains?" Science, Vol. 216, May 1982, pp. 540-541.

calls a "cultural ecological niche".[52] This complex of humans and tool using is an extraordinarily successful adaptation. The dynamics of culture and the tool using part of this complex has allowed humans to spread across the globe and live in a vast array of climates and conditions without the necessity of biological evolution. This global dispersion has been taking place for well over 100,000 years and in a manner that is unique in life history, without speciation. Based upon the "competitive exclusion principle" (i.e. "that no two organisms can occupy the same ecological niche"), Brace argues "that there has been only one hominid species at one time, and that the hominids of different time levels are linearly related."[53]

Thus far we have concentrated on the interaction between tools and human evolution. The very concept of evolution has generally implied continuous change though there is now a school of evolutionary theorists who believe in periods of rapid changes and long periods of species stability.[54] Whether and to what extent humans are still evolving has become clearly secondary to the question of technological evolution and cultural change. Once primate evolution crossed certain thresholds, their further biological change became increasingly less significant in explaining the development of human cultures, technology and civilization. By the time of the emergence of Homo sapien/sapien (circa 50,000?? years ago), further biological evolution is of virtually no

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[52]C. Loring Brace, The Stages of Human Evolution: Human and Cultural Origins, Englewood Cliffs, New Jersey: Prentice-Hall, 1967, p. 56.

[53]Loc. cit.

[54]See Steven M. Stanley, The New Evolutionary Timetable: Fossils, Genes and the Origin of Species, New York: Basic Books, 1981. See also the regular column of Steven Jay Gould in Natural History magazine. Their theory of rapid change is called Punctuational Evolution.

significance for cultural and technological evolution.

Human culture has been called a superorganic phenomenon to emphasize its distinctness and independence from organic evolution.[55] Some have taken what they perceive to be the laws of biological evolution and applied them to cultural evolution.[56]

There are those who object to these conceptions of cultural evolution but nearly all anthropologists accept the idea that cultural development and differentiation is not dependent upon further human evolution and probably has not been for at least the last 100,000 years or more. In fact, Robert Lowie quoted E. B. Tylor on culture being "capabilities and habits acquired by man as a member of society", and Lowie had culture include "all these ... in contrast to those numerous traits acquired otherwise, namely by biological heredity."[57] However, as we shall note below and throughout the text, the development of culture and technology involves continuous interaction with the biological realm in general and with evolutionary change, in particular, of plants and animals.

One anthropologist, Walter Goldschmidt, has defined technology as the "learned means by which man utilizes the environment to satisfy his animal wants and cultural desires." It is then, in effect, a problem solving process.[58] We

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[55]See A. L. Kroeber, "The Superorganic," American Anthropologist, Vol. 19, No. __, April-June 1917, pp. 163-213.

[56]See Leslie O. Whites, The Evolution of Culture, New York: McGraw-Hill, 1959, and Marshall D. Sahlens and Elman R. Service (eds.), Evolution and Culture, Ann Arbor: University of Michigan Press, 1960, for two early and basic examples of a voluminous literature.

[57]Robert Lowie, An Introduction to Cultural Anthropology, New York: Rinehart and Co., 1940, p. 3, italics ours.

[58]Walter Goldschmidt, Man's Way: A Preface to the Understanding of Human Society, New York: Holt, Rinehart and Winston, 1967, p. 110.

will use that as a preliminary definition. As we discuss particular technologies throughout this chapter, we will refine, extend and clarify this definition. Tool use, like signaling, is widespread in the animal kingdom. The uniqueness to humans of technology is that it is productive, open ended, and therefore inherently developmental.

How long humans have been humans is a matter of definition and of scientific debate. The numbers can range from 500,000 years if one uses evidence of language to several million years if one uses minimal physiological criteria. Cohen refers to the "four million year history of Homo sapiens."[59] Most of the larger figures refer to the formation of the family Hominidea (i.e. Hominids), and as a subgroup of the super-family Hominordea (i.e. Hominoids).[60] Further, for 99 percent of his existence, man (i.e. hominids) has been hunter and gatherer "tied to the seasons of vegetative food or movement of game" and with the exception of fire, had "no power beyond that of his body."[61] According to Lee and DeVore

> Cultural Man has been on earth for some 2,000,000 years; for over 99% of this period he has lived as a hunter gatherer. Only in the last 10,000 years has man begun to domesticate plants and animals, to use metals and to harness energy sources other than the human body.... Of the estimated 80,000,000,000 men who have ever lived out a life span on earth, over 90% have lived as hunters and gatherers; about 6% have lived by agriculture and the remaining few percent have lived in industrial societies. To date, the hunting

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[59] Mark Nathan Cohen, The Food Crises in Prehistory: Overpopulation and the Origins of Agriculture, New Haven: Yale University Press, 1977, p. 5.

[60] Many of the quotes below appear to use the terms Hominid and Human interchangeably.

[61] Brian M. Fagan, People of the Earth, Boston: Little, Brown & Co., 1980, p. 148; (first quote) and Robert F. G. Spier, From the Hand of Man: Primitive and Preindustrial Technologies, Boston: Houghton, Mifflin & Co., 1970, p. 9.

> way of life has been the most successful and persistent adaptation man has every achieved.[62]

Whatever number is used as a base, the vast majority of the time that humans have had tools they consisted largely of basic stone tools that define what we call the Paleolithic and the generally very short period of the Mesolithic. Humans are considered to have been tool users for at least 2½ million years.

At one time, archaeologists referred to eoliths (or dawn stones).[63] Eoliths were presumably stone tools that were difficult to distinguish from markings of stones from streams or glacial creep. Another author distinguishes between naturefacts and artifacts. Naturefacts are "objects extracted from their natural setting and subsequently used without modification."[64] "Artifacts are forms created by withdrawing materials from their natural setting and modifying them in trifling or remarkable ways."[65] Most of what we observe as tool using among non-humans are naturefacts. Naturefacts may have been the first tools used by humans but virtually by definition, it's next to impossible to verify or falsify this speculation. The tool evolution that we are

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[62]R. B. Lee and I. DeVore, "Problems in the Study of Hunters and Gatherers," in R. B. Lee and I. DeVore, Man the Hunter, Chicago: Aline Press, 1968. Quoted in Jack R. Harlan, Crops and Man, Madison, Wisc.: American Society of Agronomy, Crop Science Society of America, 1975, p. 4.

[63]See Robert J. Braidwood, Prehistoric Man, Glenview, Ill.: Scott, Foresman & Co., 1964, p. 33. This term is no longer widely used.

[64]Wendell H. Oswalt, Habitat and Technology: The Evolution of Hunting, New York: Holt, Rinehart and Winston, 1973, p. 14.

[65]Ibid, pp. 17-18.

describing below is artifactual in character because all involve ideas that are used to transform the material world and not merely extracted from it.

Andre Leroi-Gourham describes a series of stages in human tool making.[66] The first two stages of this taxonomice scheme consist of core stone tools (pebble tools as they are called) and flaked stone tools. Both of them are made and not merely found.[67] The third stage of Leroi-Gourham's classification is seen as "a major step in the history of the human race ... for it served as the foundation for the conditions of technological development until the appearance of metallurgy."[68] In this stage, the techniques of the previous two stages are combined in that a stone core is first worked and prepared and then the desired tool is flaked off from it. "Production begins with a core, or nucleus of raw materials, as before, and its end result is a kind of surface that is dissymmetrical in thickness and has the shape of a tortoise's shell."[69] In the fourth stage, these techniques are used to create a wide range of tools, i.e. "scrapers, grovers, drills, and blades."[70]

In the third and fourth stages, tool using gives rise to technology (by our definition). Tool making becomes combinational and more rapidly cumulative.

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[66]Andre Leroi-Gourham, "Primitive Societies," in Maurice Daumas, A History of Technology and Invention: Progress Through the Ages, Vol. I, The Origins of Technological Civilization (translated by Eileen B. Hennessy), New York: Crown Publishers, 1969, pp. 21-25.

[67]See Robert J. Breidwood, Prehistoric Man, Glenview, Ill.: Scott, Foresman & Co., 1964, p. 33.

[68]Ibid., p. 22.

[69]Loc. cit.

[70]Ibid., p. 24.

The tool making techniques "require a well developed feeling for the material, some preconceptions of the desired result, and a manual skill that would not be deduced from an examination of the maker's cranium."[71] Leroi-Gourham's observation here brings out two other characteristics of technology. One that all tools and technologies involve ideas or "preconceptions" and that even seemingly simple stone tools involve a complex interaction between skills, ideas and materials. It is the replication of preconceptions in a series of tools that allows archaeologists to define tool traditions.[72]

The "mastery over materials" characterized what is called the Upper Paleolithic. New materials were used in tool making.[73] "Artifacts of complicated forms were wrought in bone antler and ivory by a combination of sawing, splitting, grinding and polishing. By now, tools were not only used to make implements in the sense of end products, such as meat knives or spears, but many tools were made which were tool-making tools. This is good evidence that the hunter-craftsman was showing considerably greater foresight, and no longer worked merely to satisfy immediate ends."[74] Just as earlier different ways of making tools were combined to make better tools, new tools were created as composite tools or as a combination of existing tools. The use of those new

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[71]Ibid., p. 23.

[72]See Braidwood, op. cit., p. 40.

[73]Fagan, op. cit., p. 101; and Kenneth P. Oakley, "Skill as a Human Possession," in Charles Singer, E. J. Holmyard and A. R. Hale (eds.), A History of Technology, Vol. I, From Early Time to Fall of Ancient Empires, New York and London: Oxford University Press, 1954, p. 32. Quote from Oakley.

[74]Oakley, op. cit., pp. 32-33.

tools involved the application of new principles of mechanics and power. According to Kenneth Oakley:

> Originally all tools were grasped in the hand; the first step towards a mechanical device was hafting. In Upper Paleolithic times, man were beginning to apply mechanical principles to the movement of tools and weapons. Spears were launched with throwers which, working on the lever principle, increase the effective propelling power of a man's arm. The bow was invented late in this period, probably in North Africa. It was the first means of concentrating muscular energy for the propulsion of an arrow, but it was soon discovered that it also provided a means of twirling a stick, and this led to the invention of the rotary drill ....

A greater variety of tools allowed for more intensive exploitation of new environments.[75] Clothes made from skins and fire allowed humans to move out of the tropics into the colder climates of the Late Pliestocene. This northward movement began earlier with the transition from core tools to flake industries.[76] A variety of materials became resources for human use.

> Bone and ivory bodkins, bone needles with eyes, belt-fasteners, and, rarely, even buttons have been found in Upper Paleolithic sites. Carved representations of clothed figures ... show that these hunters wore sewn skin garments with fitting sleeves and trousers. These greatly increased their efficiency in the very cold winters that they had to endure.[77]

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[75]For an analysis of the way that new tools allowed humans in Africa to expand to new environmental frontiers, see Thomas R. De Gregori, Technology and the Economic Development of the Tropical African Frontier, Cleveland, Ohio: Case Western Reserve University Press, 1969, pp. 83-181.

[76]Graham Clark and Stuart Piggott, Prehistoric Societies, New York: Alfred A. Knopf, 1965, pp. 59-60. See also Francois Bordes, The Old Stone Age, New York: McGraw-Hill, 1968, p. 133.

[77]Oakley, op. cit., p. 33.

A more intensive exploitation of the environment allows for a population build up and the creation of more permanent settlement patterns. Mesolithic industries included a variety of tools for gathering food. One of the defining characteristics of this period is the abundance of microliths which could be used in a variety of composite tools for hunting and gathering. Settled communities are a more efficient means for assembling, cumulating and diffusing technology.

> Gradually we begin to see the build-up toward the first basic change in human life. This change amounted to a revolution just as important as the Industrial Revolution. In it man first learned to domesticate plants and animals. They began producing food instead of simply gathering or collecting it. Some of the tools we tend to assume were used for agriculture may actually have been developed by collectors for collecting.[78]

Though the transition from hunting and gathering seems in retrospect was gradual, from the perspective of that which preceded, the pace of change was explosive. There was at least a million years (and possibly four million years) of human history until the period that we call the Upper Paleolithic began about 35 to 40 thousand years ago. Using the figure of a million years for human history, 98 percent of the time humans have been on earth, we have been hunters and gatherers.

> About 20,000 years ago people began to shift from a hunting and gathering way of life to a more specialized economy, including the use of both storage pits and ground stone

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[78]Braidwood, op. cit., pp. 97 and 199.

tools used to crush pigments and tough grass seeds.[79]

About 10,000 years ago the world's population of about 10 million people (possibly as high as 15 million) were almost all dependent upon hunting and gathering. "By 2,000 years ago the overwhelming majority of people lived by farming."[80] As Kenneth Oakley put it, homo sapien "ceased to be a rare species". There were then between 100 and 200 million people on earth. In 1500 more years, population grew to about 350 million and agriculture had spread to most areas manageable by the technology of the time.

> By the beginning of the 20th century (1900 A.D.) when modern ethnographers had begun their observations, the world population had jumped to about 1.6 billion and the hunters and gatherers decreased to less than 0.001%. The present population is racing toward 4 billion, with the hunter-gatherer population heading toward extinction.[81]

Agriculture was made possible by advancements in technology and concentration of technology. Similarly, agriculture allows for the further increase in population.[82] Some archaeologists argue that it was overpopulation relative to hunting and gathering technology that forced the near universal transition to agriculture.[83] However, these explanations seek the "why" of

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[79]Fagan, op. cit., p. 153. Fagan here is drawing on the work of Frank Hole and Kent V. Flannery.

[80]Cohen, op. cit., p. 5. See also Fagan, op. cit., p. 149.

[81]Harlan, op. cit., p. 6.

[82]Robert J. Wenke, Patterns in Prehistory Mankind's First Three Million Years, New York: Oxford University Press, 1980, p. 268.

[83]See Cohen, op. cit.

domestication. How it happened still depends upon technology. Not only does the direct process of agriculture (i.e. tending the fields) require a more sedentary life-style, but all its consequence further restricts mobility. Properly done, agriculture requires a wider range of tools than would be possible to carry about. And "moreover, storage technology is required" for "where could one go with a metric ton or so of clean wheat seed, no matter how nutritious?"[84]

Braidwood suggested that a "man who spends his whole life following animals just to kill them to eat, or moving from one patch to another, is himself really living just like an animal".[85] Hunting and gathering set "narrow boundaries to development".[86] Wenke argues that "the correspondence between agriculture ... and civilization is absolute".

The development of agriculture requires methods of storage. Many of the foodstuffs require processing and cooking for digestibility. Pottery is useful in both these endeavors, though not essential. Pottery was independently developed in many locations. It is described by one author as a "hallmark of the Neolithic period".[87] "Pottery or ceramic ware is one of the first synthetic materials created by man. It owes its existence to the irreversible change brought about when clays are heated to drive off the water".[88] The use

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[84]Wenke, op. cit., p. 275.

[85]Braidwood, op. cit., p. 113.

[86]Piggott, op. cit., p. 130.

[87]Spier, op. cit., p. 41.

[88]Ibid., p. 101.

of stone, wood, bone, vegetable fibers, and a host of other items involves changing the shape of the material to use it as a tool. The use of fire allows humans to transform the internal structure and composition of materials to make them more useful to themselves. Previously, resources were found; now they are also made. Pottery making reflects some of the open-endedness of technology. It also opens the possibilities for continued improvements in the materials themselves. Ceramics today have many traditional and new, sophisticated uses, from cooking to spacecraft, and research continues on material improvements and new uses.

Materials transformation has become the basis for subsequent periods for our naming of stages of human technological achievement, i.e., the Bronze Age, the Iron Age. Though metals were probably first used as found, in comparatively pure nodules, such as copper, the smelting of ores was soon necessary if their use was to be sustained. Transforming ores into metals is transubstantiation. We know today the nature of the transformation process; is it any wonder that those closer to its origins thought they could also transmute "base metals" into gold? As with the development of ceramics and pottery, the development of metals inaugurated an open-ended process that allowed for the creation of new forms, continued improvements in the quality of the materials used, and the opportunity to turn an even greater part of the universe's materials into resources. Those materials, furthermore, can be combined with a variety of others to create even more useful materials. The quality of the stone strongly affects the quality of stone tools, but the quality of the ores has progressively less to do with the quality of the metal tools than do the science and technology of production.

Raw materials and other aspects of the environment become resources when humans acquire the ability, or the science and technology, to exploit them. Certain rocks become resources when the knowledge and skills to make stone tools evolves. Roots become food resources when stone tools to dig into the hard ground are available. Large game become resources when hunting tools (such as bows and arrows) and social organizations emerge. Certain seeds become resources as humans develop tools and techniques for more efficient intensive harvesting. The resource character of these seeds is enhanced as the evolutionary changes of domestication increase their yield. Various types and kinds of ores, too, become resources -- natural resources, as we unfortunately call them -- as we continue more efficiently to learn to extract from them what we wish to use. Technology, then, creates resources.[89]

Many of the important inventions of human history in the domestication of plants and animals appear to have taken place independently in many different places. However, often the same item may have been invented, no one can assert that all peoples developed all of their technology. This straw man is raised simply to state the point that throughout human history people have borrowed technology from their neighbors. Consequently, the diffusion of technology (or technology transfer) is essentially as old as technology itself. Furthermore, every tool involves a human skill. Skills involve people doing things, which is behavior. Some tools-in-use, such as those used in paleolithic hunting of large animals, involved group behavior and therefore social organization. One need not have a determinist model of technology and social organization to recognize

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[89]This point will be explored in more detail in Chapter III on minerals and Chapter IV on agriculture. Also discussed is the way that the technology of creating fire made many harmful plants into useful food stuffs.

that, though there may be a range of possible behaviors and social organization, tool using nevertheless implies in a broad sense forms of behavior and organization. People also developed belief systems which include ideas about technology and social organization.

With the growth of sedentary communities, there is a parallel growth in technologies peculiarly adapted to the particular environment of the group. Of course, from the beginning people developed or adapted technologies to solve their problems. The forest or the savanna, the tropics or the colder climates, each gave rise to different technology or variations on the same technology (depending on one's definition). Tools-in-use, then, can be related to the environments in which they are used.[90]

Technologies can transfer by many different means. People can borrow and adapt technology from their neighbors. Or migrating or conquering people can carry it to new areas. People tend to carry as much of their cultural baggage with them, which includes their social organizations and belief systems. Settled communities that more intensely exploit their environment give rise to larger population concentrations. Larger populations increase the likelihood of larger armies. Advances in technology, such as metallurgy, create the possibility for better weapons. Larger armies and better weapons facilitate conquests. By no means is it true that people with superior technology for economic exploitation are always the military victors. Whoever the victors are, there has been a relentless conquest by agricultural technology over hunting and gathering technologies. Superior technologies tend to conquer, even when the

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[90]See, for example, DeGregori, op. cit., pp. 83-129.

carriers of it lose the particular war.

The diffusion of technology, along with beliefs and social organizations, can create problems. Techniques in agriculture, for example, suited to one environment, may not be operational for another. The basic problem-solving character of technology is not always fully understood. This occurs over and over in human history. The Romans brought Mediterranean agriculture north of the Alps, complete with latifundia, a Roman style of life.[91] Europeans brought their agricultural practices to North America. In both these instances, when the technology failed to perform as it did in the homeland, the environment was deemed to be inherently and eternally inferior for agriculture.[92] In these two cases we know from subsequent events that, with proper adapatation of alien technology and its combination with indigenous technology, both areas — Europe north of the Alps and North America — became among the most agriculturally productive in the world. Europeans also sought to diffuse their technologies to areas of colonial conquest in Africa, Asia, and South America. Again, the environment was blamed for any shortcomings in the performance or output. Subsequent refutations of these interpretations have in recent years gone to the other extreme of blaming some entity called "technology" or "Western technology".[93]

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[91]See Peter Brown, "The Later Roman Empire," The Economic History Review, second series, Vol. XX, No. 2, Aug. 1967, pp. 336-337; and Thomas R. DeGregori, Technology and Economic Change: Essays and Inquiries, Comox, British Columbia: Peter McLoughlin Associates, Ltd., 1974, pp. 5-6.

[92]See Thomas Jefferson's, Notes on the State of Virginia, New York: Harper & Row, 1965, pp. 42-66, for a list of the 18th century European criticisms of North America's environment, and his defense of it.

[93]This issue will also be examined in more detail in Chapter IV on agriculture and Chapter VIII on appropriate technology.

Thus far we have concentrated on peoples using technology or using the wrong technology. We have not discussed the institutional factors that cause people not to use a technology. One institutional factor in not using a technology is that people do not want to use it. It is not a question of whether a new technology will solve a particular problem better, but it is just that the belief system forbids it. Thus, in the United States today there are groups that will not use motor vehicles and others that will not use medicine or allow surgery. Such groups are replicated through history and around the globe. The efficacy of the technology is irrelevant; their religion forbids its use. There is another category of not using technology that is far larger. As we have noted, the use of technology involves the creation of social institutions that define and validate its use. The very complex ideas and beliefs involved in using a technology in time can be the basis for denying the superior efficacy of a new technology.[94] Elsewhere, one author has argued that advances in technology and in science tend to develop on the periphery of civilization where these institutionalized idea systems are less well established and therefore less able to resist pragmatic adjustments and changes.[95] Under these circumstances technology transfer to new areas frequently not only allows the recipient to catch up, but also allows the borrower to use it as a basis for surpassing the lender.

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[94]It should be noted that, even for the first category, the belief system prohibiting use of a technology sometimes argues that their way is technically more efficient as well as being morally superior.

[95]See both works by DeGregori, Technology and Economic Change and Technology and the Economic Development of the Tropical African Frontier, cited above.

Though we are concerned in this book almost exclusively with the technology of production of economic goods, we will use the technology of warfare as an illustration of institutional resistance to technological change. Whatever the conservative impulses are in a culture, to lose a war is potentially to lose everything. Consequently, in virtually all instances, people would not knowingly preserve a military technology that would bring them defeat. If we find repeated instances of such behavior, then the likely answer must lie in an institutionally conditioned blindness to the possibilities of new technology. A cursory view of some selected aspects of Western military technology will illustrate this interrelationship between technology and institutional myopia.96

In the early phases of Middle Eastern civilization, military supremacy was predicted upon bronze, then iron, then chariot warfare, and afterwards, the phalanx with iron spears and shields. Bronze and chariot warfare limited fighting primarily to an elite (since bronze was of limited availability and chariots and horses were expensive), while iron was more widespread and cheaper and favored a highly organized yeomanry, as in Classical Greece. When the Athenian power base became heavily maritime, a new social importance accrued to the urban lower classes who manned the oars. Not only did these changes in technology bring social changes, but they also left in their wake a series of defeated peoples who could not respond to change.

The foot soldier in the form of the Roman legionnaire with his sword and

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96Most of the material for the following paragraphs is drawn from Oriol Pi-Sunyer and Thomas R. DeGregori, "Cultural Resistance to Technological Change," Technology and Change, Vol. V, No. 2, Spring 1964, pp. 2[illegible]-274, and, by the same authors, "Technology, Traditionalism, and Military Establishments," Technology and Change, Vol. VII, No. 3, Summer 1966, pp. 402-407.

shield was challenged by light horse cavalry during the Germanic conquest. The issue was not clearly decided until the eighth or ninth century, with the development of the stirrup, horseshoe, and heavy shock cavalry. To some observers, heavy cavalry and the three-field system were primarily responsible for the development of feudalism. Yet in 1066, two centuries after the development of shock calvary, Harold's troops rode into the Battle of Hastings on stirruped horses, dismounted, and were defeated by the Normans.[97] For nearly three more centuries, stirruped cavalry was the most efficient form of warfare and inculcated into European social consciousness attitudes toward the horse and nobility that persisted until very recent times.

In the fourteenth century, the English long bowmen and the Swiss pikemen drove heavy cavalry from the field, though the latter continued to appear and to suffer defeats for at least another century. In the nineteenth century a series of inventions — the repeater rifle, the Gatling Gun, and barbed wire — made cavalry clearly obsolete as a battlefield instrument, a judgment that was confirmed by the trench warfare of World War I. In the same century the two most famous cavalry charges, Balaclava and Sedan, were colossal failures.

Despite all of this, in the pre-World War II period the major powers (except the two losers, Germany and the Soviet Union) were preparing to fight the next war on horseback, and for the Poles it was even more tragic, as they sent a unit of lancers to meet the German invaders. There was no lack of empirical evidence that the internal combustion engine (along with the other

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[97]Lynn White, Medieval Technology and Social Change, Oxford: At the Clarendon Press, 1962, pp. 36-37.

previously mentioned inventions) had doomed the horse; the brief tank warfare in World War I, the many interwar years manuevers, the German tanks in Spain and the Soviet tanks in Outer Mongolia had all demonstrated this point. The retention of the horse and the near national catastrophes that it created were the results of sentiments of nobility, honor, and chivalry that harked back deep into the Middle Ages. In describing similar attitudes in the British Navy, B.H. Liddell Hart likened an Admiral's attitude toward his ship to that of a Bishop to his cathedral.98 Such sentiments may win the praise of the faithful, but they do not defend a nation.

The classic 1930's statement confusing the spiritual value of the horse with its military technical efficacy was made by British Field Marshall Haig - "that as time goes on you will find as much use for the horse — the well bred horse — as you ever have done in the past".99 This digression on the horse should not lead us to believe that this attitude toward the horse as a military instrument was not inherent in the horse itself. Exactly the opposite attitude and pattern emerged in China. There the horse was identified with "barbarians". There, for over a millenium, Chinese leaders knew that they must raise and use the horse as a battlefield instrument if they were to succeed in defense against mounted invaders. Try as they might, they could never disassociate the horse from the "barbarians" who brought it and developed that close man-animal relationship necessary for its effective use.100

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98B.H. Liddell Hart, The Liddell Hart Memoirs, Vol. 1, 1898-1938, New York: G.P. Putnam's Sons, 1965, p. 326.

99Ibid., p. 100.

100H.G. Creel, "The Role of the Horse in Chinese History," The American Historical Review, Vol. LXX, No. 3, April 1965, pp. 647-671.

The vast majority of the technology of any people was developed by others. We are all or have been borrowers of technology. Technology transfer is a regular facet of human history. The study of some of the more dramatic of these transfers, though not providing all the answers for present problems, can nevertheless give us insight into some of the most important characteristics of technological diffusion.

Northern Europe and later North America built industrial economies based on science and technologies that originated in other areas. The religion, science, and technology of medieval Europe were fundamentally alien to that region. Their origins were in the Middle East. For several thousand years there was a continuous, fruitful interchange of tools and ideas in area that included the Indian subcontinent on the east and stretched to and later included the Hellenic peoples in the west. This civilization spread across the countries on the shores of the Mediterranean Sea. Politically, it became dominated by Rome.

Small elements of these great civilizations were filtering northward into Europe. While there were great civilizations in India, in the Middle East, and in the Eastern Mediterranean, Northern Europe was in comparative darkness. With Roman conquest north of the Alps came a significant increase in the northward movement of Mediterranean technology. This movement is interesting and significant because virtually every error in technology transfer (or attempts at it) during the period of European colonialism, and since independence, was a replication of those made during Roman colonialism.

Many Roman writers thought that Northern Europe was essentially uninhabitable. Among other reasons, it was too cold. Rome had taken Mediterranean agricultural practices, crops, architecture, and style of life and

had attempted to transplant them in a different climate and geographical environment without modification. No wonder, then, there was an apparent "failure of technology". In fact, it was neither the inadequacies of the peoples or environment of Northern Europe nor was it a failure of technology. The fault was in the character of the diffusion process.

The diffusion of science and technology to North America is comparable to the flow from Rome into Northern Europe. In the eighteenth century, Europeans debated the habitability of North America. Though they did not question the physical heritage of their kith and kin who were conquering the continent, some argued that the climate stunted the growth of humans, other animals, and plants. It is clear from subsequent history that Northern Europe and North America had great potential for agriculture and industry, provided the right technology was used.

The key to the development of both areas was the shifting of decision making power from alien colonial authorities. The new technology that evolved was a synthesis of indigenous technology, exogenous technology that was modified and adapted to solve the particular problems of the new environment, and, in some instances, a direct borrowing of exogenous technologies that needed no adaptation. What is important is that, in this synthesis, the people of these areas made the technology part of their culture. Tools and technologies are more than mere gadgets or physical instruments; they are the embodiment of ideas. If these ideas become a vital part of a culture, then there is more than an assemblage of tools — there is a continuous dynamic evolving process of change, technological borrowing and development. Technology evolves as the combination of existing tools and technology. Therefore the more tools, the

more possibilities for combinations and acceleration of development.

The evolution of printing by moveable type in fifteenth century Europe is an example of technological change resulting from a synthesis of indigenous traditions and adaptation of exogenous technology.[101] It also demonstrates the worldwide nature of technology, as most of the "indigenous" elements of European printing were the product of earlier diffusion of technology from other areas. Printing by moveable type involves the arts of printing, papermaking, metal working, a phonetic alphabet, and an ink that would adhere to a metal typeface and to paper.

Evidence of printing can be found as early as the seventh century in Korea and the ninth century in Central Asia. Possibly, there were earlier origins, from the practice of taking rubbings from stone in China. Paper began from the felting process of making tents and garments in Central Asia and the use of these techniques to make rice paper in China. Paper making diffused into Persia in the ninth century and into Italy in the eleventh century.

Printing by moveable type is superior to other forms of printing if one has a phonetic alphabet. The phonetic alphabet was part of Europe's heritage from the Middle East that was brought north of the Alps by the Roman conquest.[102] Presses were independently invented in many different parts of the world. The

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[101]The material for printing by moveable type is largely drawn from Abbot Payson Usher, A History of Mechanical Invention, Boston: Beacon Press, 1959, Ch. X. Though it is over two decades old, the book is neither dated nor has it been surpassed for its analytical insight into the inventive process.

[102]The phonetic alphabet is an instance of pre-adaptation. It is a trait that was developed for its own purposes — writing — that was not overwhelmingly superior to other competitive techniques used for that purpose. It was, however, almost uniquely adapted to an invention that did not occur until over two thousand years after its beginning. Pre-adaptation is a phenomenon of both biological and technological revolution.

European press descended from the olive presses of the Grecian world. Metalworking had come to Europe from the Middle East two thousand years previously and had taken root and developed to a high art. Ink from linseed oil was a purely indigenous invention derived from the flax used in textiles and was used in a rapidly growing tradition of oil painting.

Printing by moveable type was but one of the many European developments in science and technology that were largely derived from Asia and/or the Arab world.[103] Many of the important terms in European science and mathematics were derived from Arabic, reflecting the Arab influence and origins. Europe was fortunate in being a crossroad for the movement of tools and ideas. Each of these was absorbed into European culture, became part of their tradition, and was the basis for continued development that led to the scientific and industrial revolutions.

The diffusion into Europe of alien ideas and technologies was an important element in the intellectual upheaval and the cultural change in Rennaissance Europe. One might even be so bold as to say that the change was revolutionary. Certainly, what was to follow in the next centuries was deemed the Scientific Revolution and the Industrial Revolution. Europe (and many of the areas where the population is predominantly of European extraction) has been experiencing five centuries of fairly continuous scientific and technological change and cultural transformation. Yet, even in the most industrially advanced European countries large pockets of traditional culture, such as that of the peasantry of France, persist even with the intrusion of the automobile and television. And

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[103]It is interesting to note that Francis Bacon, the 16th and early 17th century English scientist, commented on five important inventions, including printing, all of which came from Asia. Francis Bacon, Nuvum Organum, Book I, Chicago: Henery Regnery, 1949, pp. 64-67.

who would argue that English or French cultures are any less English or French today than they were five centuries ago, just because they have undergone such enormous change? Industrialization has made France and England alike in many ways, but it has not obliterated those distinctive features of these cultures which are a source of pride and identity for its members and constitute a vital part of the heritage of all humans.

Rather than being destructive, technological change in Europe has stimulated its arts and culture.[104] Printing by moveable type was, as we have noted, developed in Europe in the middle of the fifteenth century. Before the end of that century, more books were printed in Europe than had been printed in the history of the human race. This is more than just a quantitative distinction, as great written works of many cultures were being printed and reprinted in translation. Printing was the key factor in the rapid growth of literacy, in the improvement of communication among scientists, and therefore it was important in the growth of science and in the development of literary forms. In fact, one could argue that the scientific and technological revolutions have enhanced all of the arts, both in their creations and in our ability to appreciate them.

The European experience in technological and economic development provides a useful experience in current attempts to foster economic growth and development. Europeans, when colonizing other parts of the world, made the same mistakes that the Romans made when they colonized Northern Europe. They attempted to transplant their technology in agriculture, in industry, and in

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[104]The point on the potentially positive interchange between technologies and the arts and culture will also be explored in more detail in Chapter ____ on technology and the arts.

education to their colonies without modification to fit the cultural and environmental conditions of the area. Many of these schemes failed. The climate and the peoples of the colonies were blamed. Just as Northern Europe was considered too cold by Romans to be inhabited in a civilized manner, the tropics, it was argued, were too hot and humid for long term economic development. There were also many successes in technology transfer as a result of culture contact between two peoples.

The failures of many projects of technology transfer in the colonial and post-colonial period have given rise to charges that technology has failed. Voices are raised on behalf of appropriate technology, or intermediate technology, or indigenous technology. Technology is a set of tools, machines, and ideas; it is a problem-solving process. When a set of tools designed to solve one set of problems are applied to different problems, it is understandable if they do not always work. It does not mean the technology failed, merely that the technology was incorrectly used.

The developed countries' experience with alien technology is not, however, a complete guide to the dilemmas of less developed countries. Countries like England and the United States have had a couple of centuries to industrialize and absorb the changes that come in its wake. The less developed countries do not choose and in reality cannot afford the luxury of this slow rate of economic growth. The pace of change today can be destructive without giving cultures the opportunity for creative, constructive response. The pace alone is threatening. In addition, the many facets of modern communication, such as films, radio, television, magazines, and consumer goods, bring slickly packaged chunks of exotic culture. These influences limit or at least make infinitely more

difficult the task of leadership in providing repsonses to change that preserve and sustain local cultures. There is insufficient ground for despair or pessimism. Technology is not inherently destructive as many claim. Quite the contrary is true. The challenge to the sensitive, intelligent leaders and to the population of less developed countries is enormous. Exotic influences, though, are not going to evaporate without a trace, and the possibilities for personal and cultural enhancement are virtually limitless.

For many parts of the world, "Western" science and technology may seem "alien", but in reality it is their own ideas and tools coming back home to them in another form. For it was "Greek", "Arab", "Indian", and "Asian" science and technology that formed the basis for European development. In a larger sense, exotic technology is coming home to all people, for it is the heritage of all mankind. Science and technology are both universal and particular. They are universal in the sense that the principles of physics (for example) and the engineering principles involved in technology transcend national boundaries. Scientists and engineers working within a discipline have means of communication that are not in any way limited by race, culture, religion, or environment. And, with the use of mathematics and translation, language is almost no barrier. Many, if not most, scientists strongly object to any national or cultural qualifying adjective to science. Yet, though science and technology are universal, there are also particularistic aspects to them. Science is a body of ideas, some only distantly practical, if at all, while others are directly useful in the human enterprise. Technology is fundamentally problem-solving. The particularity of science and technology derives from the fact that each country has its own complement of problems and therefore must, in its science

and technology policy, draw and create from this common fund of knowledge the most useful and relevant ideas and tools. What is needed are national science and technology policies that facilitate the organic growth of science and technology within a culture. The universality and particularity of science and technology can be the basis for finding unity in diversity and diversity in unity. Modern science and technology have given us that visual picture of our unity and diversity in the magnificent photographs of the earth taken from the moon. Unity and diversity in all aspects of the human endeavor are necessary if we are going to share this globe and its heritage.

Concluding Observations

After four million years of homenid history and two and a half million years of tool using, have we humans reached the limits of our environment beyond which even further evolution or technological change cannot carry us? The answer is emphatically no! The fundamental purpose of most of the succeeding chapters is to explore the ways that further scientific and technological change can continue to expand human horizons and opportunities. Cohen and others argue that humans reached the limits of their environment 20 to 40 thousand years ago, as defined by hunting and gathering technology.105 The food crisis, as he calls it, forced humans to devise new means of agriculture to solve the problems wrought by overpopulation, relative to a technology of food supply. Another author, Ester Boserup, has argued that overpopulation relative to food supply has been a continuing force for agricultural innovation throughout history.106

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105See Cohen, op. cit.

106Ester Boserup, The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Pressure, Chicago: Aldine, 1965.

At the time hunting and gathering supposedly had reached environmental limits, the population is estimated to have reached 10 to 15 million. Perhaps this was not in fact the actual limit of this technology. Malcolm Slessor has calculated that the "productivity of a natural eco-system is around 6 kg. per hectare per year of protein suitable for humans ... obtainable from the better land on the earth's surface".[107] Assuming that hunters and gatherers could harvest and utilize 100 percent of this, the world's ecosystem could support possibly 200 million people. This figure is one-twentieth of the current world population. Even if we don't accept the 10 to 15 million population as being the hunting and gathering limit, it was probably quite close to the exploitable portion of the natural ecosystem. Clearly, we are by irreversible necessity committed to a post-agricultural revolution technology. Further, it demonstrates the way in which changes in technology can dramatically change the economically exploitable limits of our environment.

Are the soil, water, sunshine, air and all materials that humans use on this globe to create and sustain life sufficient to the demands that must be made if human life is to continue? In the chapters on catastrophism and the limits to growth, we will actually define these limits and indicate that we are far from reaching them. That does not mean that we will automatically come up with the advances in science and technology needed to transform the earth and improve the life of a growing population. As with technological change throughout human history, it is not automatic but requires thoughtful intelligent action directed toward problem-solving. As we look back at the

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[107]Malcolm Slessor, "Energy Requirements of Agriculture," in Food Agriculture, the Environment, edited by John Lenihan and William W. Fletcher, New York: 1976, p. 1.

history of human problem-solving, we get a better understanding of the process so that we are better able to act intelligently in terms of problem-solving and expand our time horizons to predict and account for longer and longer term consequences of current actions. We have taken the first hesitant steps into space. As we shall demonstrate below, long before we have exhausted terrestrial life-sustaining resources, we will have the capability of exploiting the virtually unlimited resources of our planetary system and beyond. This reality, though, is far beyond the more urgent and immediate needs of economic development and the elimination of poverty that face us and are the subject of this book.

We have spoken of life, language and technology as being dynamically open systems. In technology, the dynamism comes from ideas. Douglas Hofstader compares language and ideas to dynamic evolutionary life processes. He speaks of "virus-like sentences and self-replicating structures". Like life forms, successful ideas gain an ecological niche in "idea space". Quoting R. W. Sperry, he finds that "Ideas cause ideas and help evolve new ideas". Just like there is a biosphere there is also an ideosphere. And ideas have "spreading power", what we in our context might call technology transfer. Just as life and other self-replicating systems can be understood in terms of their ability to survive, so also do ideas have a "performance value" which "depends upon the change it brings to the behavior of the person or group that adopts it."[108] Technologies as educational processes must be sustained by the performance value of the ideas embodied in them. Technology must allow people to change their

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[108]Douglas R. Hofstader, "Mathematical Themes: Virus-like Sentences and Self-replicating Structures," Scientific American, Vol. 248, No. 1, January 1983, pp. 14-21.

behavior and improve the quality of their life. Technology as an idea system, like the life system from which it is derived and compared, must have the survival value of sustainability in and through the life processes of the humans who use it. Technology and technology transfer then have empirical, testable, measurable consequences.

As Lee and DeVore note, strategraphically the origin of agriculture and the present "will appear as essentially simultaneous".[109] "If we fail, then, it will be a tragedy, not only for all those alive, but it will be a failure of civilization itself and an implicit argument that human life beyond hunting and gathering is inherently unstable." Tool using, as C. Loring Brace argues, has created for humans a unique ecological niche. For 125,000 years, we have spread across the globe into every known climate (and now into space) without biological adaptation of the species.[110] Technology has been our means of adaptation and survival and can continue to be so. As with most human endeavors, the choice between success and failure is ours.

Summary: Operational Principles of Technology

The purpose of historical inquiry on technology was to attempt to identify those operating principles that have governed technological evolution. It is our contention that consistency with these principles is necessary for successful technology transfer and economic development. They will be both implicitly and explicitly embedded in the rest of this book. We consider them

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[109]Lee and DeVore, op. cit., p. 3.

[110]C. Loring Brace, op. cit., pp. 56-57.

fundamental, both in planning and in implementing technology projects and as a set of criteria for evaluating completed projects. In the final chapter we will take those summary principles and combine them with the empirical and analytical results of current efforts in science and technology for development to create a set of guidelines or recipes for applying theory to the task of project development.

The basic characteristics of technology are:

1) Technology or human tool using is primarily an ideational process. It is the use of ideas to transform the material and non-material world.

2) Technology is behavioral. The very existence of tools implies skills in both tool creation and tool use. Skills are forms of human behavior.

3) Technology becomes organizational and institutional. Humans live in groups, and much of their technology going back to large-scale hunting requires organized group cooperation for effective implementation.

4) Technology as ideas (or knowledge) and as material artifacts is transmitted through culture. Though analytically separable, technology in use becomes part of the general belief system of those who use it. As such, the dynamic nature of technology (points 5 & 6 below) can come into conflict with the restrictive institutional beliefs and practices.

5) Technology is cumulative and combinational. Once the process of technology is under way, it gains momentum from the ability to combine, recombine, and modify existing technology. In the same sense that biologists say all life comes from previous life and anthropologists say that all culture comes from previous cultures, we can state that all technology comes from previous technology. Though in terms of the archeological and industrial

record, what appears to be combined are the material artifacts, the dynamics of the process comes from combining the ideas of the artifacts.

6) Technology is an interactive process. Just as there are feedback loops between human evolution and tools (as described above), there are feedback loops with other social activities. If a distinction is made between science and technology (which we do not fully accept, though most writers on the subject do), then we can observe a continuous feedback loop. Scientific inquiry establishes principles that are applied in technology. Technology provides instrumentation that facilitates scientific advancement.

7) Technological change is an accelerating process. The more technology there is, the even greater the possibilities for new combination and advances, and for positive feedback loops between science (and knowledge in general) and technology. Goldschmidt refers to "an exponential quality; that is, the rate at which growth takes place increases with each successive increment of advancement". He considers it "mathematically inevitable that the opportunity for new techniques increases geometrically as the number of basic ideas increases arithmetically".[111] The historical record in the timescale figures that we have given certainly bear out the contention of exponential growth. It is a major contention of this book that some theories of technology and the projects derived from them neglect the potential of technology and thereby severely limit the potential gains from technology transfer.

8) Technology is a problem-solving process. Technology is technology in the context of its use. Its use in the wrong context does not deny its efficacy

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[111]Goldschmidt, op. cit., pp. 112-113.

in appropriate circumstances. By definition, all technology, if it is truly technology, is appropriate to some problem-solving endeavor. The selection of technology depends upon cultural, environmental, and economic criteria that define a problem and the characteristics of its solutions.

9) Technological innovation has long-term consequences (the unintended consequences described above) that, from the point of view of subsequent generations, are more important than the short-term problem-solving that was the original intention of the technological change. Both in the short and long term, there are chance or fortuitous discoveries. Serendipity is the name given for the discovery that emerges by chance when one looks for one thing and finds another. As one great scientist said, "chance happens to the prepared mind" in that accidental discoveries only happen because someone had the intelligence to interpret the results as being useful in another context.

10) Because technology is combinational, it is not surprising that people working from the same technological and scientific base frequently create essentially the same invention (i.e., solve the same problem) at the same time. For the same reasons, simultaneous discovery is also a frequent phenomenon in scientific inquiry.

11) Technology, since it involves behavior, is likely to bring about cultural change. Similarly, culture is likely to force a modification of technology in the process of diffusion.

12) The cumulative body of knowledge, instruments and human skills that we call technology, is essentially a seamless webb. The source of an instrument or innovation as one area of endeavor can be derived from what superficially appears to be a totally unrelated area. We shall illustrate this point further

in Chapter ____ on the arts and technology.

13) Adaptation of technology to new environmental circumstances is in itself a form of invention. Socially and linguistically, we call large, apparently discrete technical changes, inventions. A closer, detailed analysis of the inventive process reveals the fact that a series of smaller, less discrete changes preceded the more noticed, larger changes. A more in-depth study of the inventive process of printing would clearly indicate this. In most instances, adaptations are comparable to small, innovative changes in the inventive process.

14) Technologies that are separated from major areas of technological change, whether by geography, by culture, or by political isolation, tend to slow innovation, if not bring about stagnation. Linkage to other technologies is vital, linkage that necessitates not only contact but also some compatibility in the level of technological achievement. This issue of linkage and continued technological development will be central to our analysis of appropriate technology.

15) Technology (and science) create resources. Resources are neither natural or necessarily finite.

16) Historically, more often than not, successful technology transfer has involved borrowing technology at its then highest level.

17) Terms such as "Western technology" can only have a very restricted historical use. "Modern technology" can have a universal meaning as the set of knowledge and ideas, skills, tools, and machines that are the most efficient and effective at problem solving. Similarly, "modernization", a term frequently in disrepute as being ethnocentric, can have a transcultural meaning as the

societal and cultural ability to use modern technology.

18) Technology transfer is incomplete if particular techniques are diffused out of context from the larger dynamics of the process. The presence or absence of a particular tool or machine is not evidence for technology transfer.

19) One of the frequent mistakes of analyzing old and new technologies is that they are frequently compared in terms of how well they perform established tasks without recognizing that new technologies almost always allow people to do new things as well as old ones better.

20) In choosing between technologies, the borrower must recognize that the context is not the world as it was but the world as it is and is becoming with most competitors (both economic and military) using the most efficient and effective technologies.

21) Technology, as noted above, is an evolutionary process. Technologies are predicated upon the prior development of other technologies. This is the process in aggregate. For a particular economy or people, the process of technological evolution need not be replicated. Borrowing peoples may skip stages by borrowing technology at its highest level, as noted above. As a universal process, technology is evolutionary. As a particular process, technology is revolutionary. The dynamic accelerated growth that characterizes universal technological change may even be more greatly accelerated by particular peoples' jumping stages of technological development. The very rapid growth of technology-borrowing countries, particularly the extraordinary unprecedented post-World War II growth of countries such as the Republic of Korea, testify to this process.

22) All technology is both universal and particular. It is universal in that it is based upon the principles of nature and is characteristic of all people. It is particular because as a problem solving process each people has a unique set of environmental and culturally-defined problems to be solved. Because technology is universal, it is ironically and paradoxically also alien because, for any particular people, the majority of their technology originated elsewhere. Simultaneously, technology as problem solving is entirely indigenous in that technology must be adapted to meet local conditions and this process of adaptation makes it one's own. This apparent paradox of universality and particularity, alien and indigenous, when properly understood and explained, can facilitate technology transfer. Too often the alien character of technology for a recipient people is stressed, i.e. called Western technology, when it is also a universal technology that is the heritage of all human kind. Similarly, the Appropriate Technology movement stresses the particular character of technology and thereby ignores the enormous benefits of its universality.

23) Invention, as Veblen stated, is truly the mother of necessity. We adopt our lifestyle, population, and other aspects of our condition to new technologies. The agricultural systems of the world that create the means to support 4 billion people are <u>necessary</u> if there is not to be mass starvation. The technologies that allowed urban growth are now <u>necessary</u> for their survival. Individuals may return to previous technologies but rarely if ever does the group have that option. Going back to earlier technologies has been widely advocated as a development strategy, but no evidence has been offered as to its aggregate validity.

24) There are gains and losses to evolutionary and technological change.

The human record shows that the gains have been far greater than the losses. The claims made for alternate technologies (and against modern technology) actually apply to modern technology. Nature is only a virtue in developed countries where technology has partially insulated the population from its worst ravages such as drought, famine, and plague. Modern technology is truly technology for the masses, giving people longer lives, more choices, and greater control over their destiny. The list of the benefits of modern technology is as long as the criticism against it.

25) Technologies co-exist. (a) New technologies are better only for a range of problems and circumstances but not all. (b) Prior technologies frequently continue to experience improvements. (c) New technologies will often be undergoing further continuous changes that may be more significant than the original "invention". (d) a and c do not negate the principle that some technologies become obsolete and are a technological dead-end.

26) Reliability can be substituted for redundancy. Modern technologies have greater reliability (i.e., redundancy) than previous technologies. Evidence is overwhelming from data on famine and loss of life to natural disaster. Most critics of modern technology cite breakdowns that are not substantially life threatening (New York City power failure) or theoretical possibilities.

27) Technological interdependence or complementarity in complex technologies means that some improvements in a technology require complementary advances in several areas. For example, fast moving vehicles (cars, trains, planes) require braking systems. Tool making has always involved the property of materials. In modern technology, material properties (i.e., strength,

purity, heat or corrosion resistance, etc.) have to be created so that the proposed system can function.

28) The vital complementarities involve ideas and skills as noted above. Advances in the physics, engineering and science of materials and many other intellectual and applied inquiries are the foundation for the creation of the materials of modern civilization. As important are the advances in the skills necessary to operate the systems. Contrary to popular wisdom that we are losing our skills, modern technology has required that an ever increasing proportion of our society be involved in intellectual and skilled endeavor.

29) Though there is an important sense in which modern weaponry and communications have linked the globe, tied to one another's fate for good or for evil and has facilitated the growth of large centralized states, groupings of states and international organizations, there is also a sense in which modern technology is decentralizing. Very simply, it has given individuals and groups of individuals greater choice in the larger circumstances of their life and in the day to day range of choices available to them.

30) Last but not least, the free market place of ideas, democratic institutions of all kinds and free economic markets are all vital mechanisms in developing, transferring, and sustaining technology. The dynamic process of combining technologies to create new technologies or borrowing technology is greatly facilitated by freedom of thought and freedom of action. Jacob Bronowski, in his masterpiece, Science and Human Values [New York: Harper, Torchbook, 1959], argues that the basic principles of scientific inquiry as refined in the last few centuries are essentially the same principles of democracy — free and open inquiry are equally functional for science, for technology, and for democracy.

Attachment B

APOCALYPSE YESTERDAY

"There is a question in the air, more sensed than seen, like the invisible approach of a distant storm, a question that I would hesitate to ask aloud did I not believe it existed unvoiced in the minds of many: 'Is there hope for man?'"[1] Thus, Robert Heilbroner, one of the most intelligent, sensitive, and perceptive economists in America today, begins his book, An Inquiry into the Human Prospect. Paul Ehrlich, probably the best known prophet of doom in the 1960s and 1970s, is more emphatic than Heilbroner. He opens his book, The Population Bomb, with the assertion: "The battle to feed all of humanity is over. In the 1970s and 1980s hundreds of millions of people will starve to death in spite of any crash programs embarked upon now."[2] Ehrlich and many of his illustrious contemporaries use the image of the Four Horsemen of the Apocalypse: War, Famine, Pestilence, and Death.[3] The very use of the apocalyptic metaphor by some authors for their prophecies implies that they have some concept of the long history of similar prophecies. These current prophecies differ, however, in that they are being made by scientists, using

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[1]Robert L. Heilbroner, An Inquiry into the Human Prospect (New York: Norton, 1974), p. 13.

[2]Paul R. Ehrlich, The Population Bomb (New York: Ballantine Books, rev. ed. 1971), p. xi.

[3]Ehrlich, p. 45. See also William and Paul Paddock, Famine 1975! America's Decision: Who Will Survive (Boston: Little, Brown, 1967), p. 61, quoting U.S. Secretary of Agriculture, Orville Freeman.

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scientific evidence.[4] It is reasonable, then, to use the scientific method of empirical testing on some of these authors' projections to give us at least a partial basis for assessing their recent pronouncements. As Garrett Hardin states, "To have any science at all we must generate falsifiable statements and have nothing to do with statements that are not falsifiable. Science is inherently vulnerable. It is proudly so."[5] Hardin further argues that "science does not admit invincible assertions into its sanctuary."[6] Thus, I will use the methods of scientists to test the validity of their apocalyptic dicta.

Fortunately for our inquiry, some of the 1960s and early 1970s prophets of doom were highly specific as to the nature and time of the forthcoming disasters. Occasionally they hedged their bets by phrasing their forecasts as scenarios. Ehrlich, in one of his "scenarios" printed in 1969, specifies a series of catastrophes that were to be the lot of mankind during the 1970s. "The end of the oceans came late in the summer of 1979 and it came even more rapidly than the biologists had expected."[7] "By September 1979, all important animal life in the ocean was extinct."[8] "Earlier in the year, the bird

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[4]See, for example, Stephen H. Schneider, The Genesis Strategy: Climate and Global Survival (New York: Plenum Press, 1976), pp. x-xi.

[5]"Vulnerability -- the Strength of Science," in Garrett Hardin, Stalking the Wild Taboo (Los Altos, Ca.: William Kaufman, 1978), p. 77.

[6]Garrett Hardin, The Limits of Altruism: An Ecologist's View of Survival (Bloomington: Indiana Univ. Press, 1977), p. 1.

[7]Paul R. Ehrlich, "Eco-Catastrophe," Ramparts, 8, No. 3 (Sept. 1969), 24-29, reprinted in Current, 3 (Oct. 1969), 23-32.

[8]Ehrlich, "Eco-Catastrophe," 30-31. One month after this catastrophe was to occur, Paul Ehrlich accepted a $10,000 prize for the best essay on the future. Three years later, the same prize was won (now $30,000) for an essay that

population was 'decimated'."[9] Along the way, fifty million a year were dying of malnutrition, famine gripped many countries, the green revolution was a failure as yields were falling, 200,000 a year were dying of pollution, the midwest part of the United States was turning into a desert, diseases of all kinds were on the increase, and chaos was spreading. Amidst all these crises was a baby boom in the United States.[10] Ehrlich concedes that it is "a pretty grim scenario," but, "unfortunately, we are a long way into it."[11] In his succeeding works, it is difficult to find any indications of policy or other changes that were made to ward off this catastrophe.

Ehrlich published his prophecies widely and in some surprising places like the Wall Street Journal and Reader's Digest.[12] He also called attention to other works of similar orientation such as Famine 1975! America's Decision: Who Will Survive, by William and Paul Paddock.[13] The Paddocks were as certain

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couldn't even get past deaths correct. The authors had 500 million people die of famine in 1973-74. This is quite an achievement since the deaths from all causes in each of those two years was about 50 million. The prize winning essay was published — Orville L. Freeman and Ruth Karen, "The Farmer and the Money Economy: The Role of the Private Sector in the Agricultural Development of LDC's," Technological Forecasting and Social Change: An International Journal (Special Issue — The Woodlands Conference on Sustainable Societies: Future Roles for the Private Sector), Vol. 22, No. 2, October 1982, page 184.

[9]Ehrlich, "Eco-Catastrophe," 30.

[10]Ehrlich, "Eco-Catastrophe," 24-28.

[11]Ehrlich, "Eco-Catastrophe," 30. Elsewhere, he finds a "net result of 1.2 billion deaths, one out of every three people, is not inconceivable." Ehrlich, The Population Bomb, p. 47.

[12]Paul R. Ehrlich, "Work Population: Is the Battle Lost?" Reader's Digest, 94, No. 2 (Feb. 1969), 137-140, and Paul R. Ehrlich, "The Countdown to Disaster," Wall Street Journal, 3, Dec. 1968.

[13]William and Paul Paddock, Famine, 1975! America's Decision: Who Will Survive (Boston: Little, Brown, 1967) and Paul Ehrlich, "The Coming Famine," Natural

of the coming catastrophe as Ehrlich. "Nothing can stop the locomotive in time. Collision is inevitable. Catastrophe is foredoomed .... Now it is too late."[14] There is little potential for agricultural increase; hybrid wheats are little used outside the U.S. (and presumably won't be); food production is static.[15] Famine — 1975; catastrophe — 1982.[16] The four horsemen are in their saddles and ready to ride.[17] Though world famine cannot be avoided, it can be "ameliorated".[18] Amelioration consists of saving ourselves and some others but not everyone. They state boldly, "Herewith is a Proposal for the Use of American Food: Triage."[19] Triage is based upon the French wartime medical practice of separating the wounded into three categories: 1) those who would survive without immediate medical assistance, 2) those who could survive but only with immediate medical attention, and 3) those who could not survive no matter what was done for them. Obviously, scarce medical personnel turned their attention to the second group, then to the first, leaving the third group to die. Triage as an international aid policy argues that certain nations or

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History, 77, No. 5 (May 1968), 6-15.

[14]Paddock, p. 9.

[15]Paddock, pp. 82-84, 78, 20.

[16]Paddock, p. 8.

[17]Paddock, p. 61.

[18]William and Paul Paddock, Time of Famines: America and the World Food Crises, a new edition of Famine, 1975! with a new introduction and postscript (Boston: Little, Brown, 1976), author's note.

[19]William and Paul Paddock, Famine, 1975!, pp. 207-209.

peoples are doomed and that food assistance merely delays and thereby worsens the inevitable catastrophe. Further, trying to save the many could imperil the future of the few. This view is essentially a variant of the famed Lifeboat Ethic, i.e., if too many are allowed on board, it sinks! There are, as Hardin says in another but similar context, limits to altruism.[20]

Nineteen seventy-five has come and gone, and so has 1982. It is difficult to find evidence for the Paddocks' predictions. Yet in their 1976 reprint (as Time of Famines), they confidently assert that "this volume demonstrates that it is possible to predict the course of at least some human events."[21] They made no changes whatsoever in their text to prevent any perceptions that the data were "massaged".[22] In their postscript they accuse their critics of being blindly optimistic, guilty of "boosterism worthy of Babbitt," and simply not knowing "what they are talking about."[23] They also found the world's population to be "growing at an accelerating rate," which it was not then and is not now.[24] Unequivocally, they maintain that "the Time of Famines is here."[25]

Scientists such as Ehrlich and Hardin or applied scientists with field experience such as the Paddocks (an economist and an agronomist) gave

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[20]Hardin, Limits to Altruism.

[21]William and Paul Paddock, Time of Famines, author's note.

[22]Paddock, Time, author's note.

[23]Paddock, Time, 252.

[24]Paddock, Time, 251.

[25]Paddock, Time, 252.

respectability to doomsday prophecies. Even more prestige was added when the Club of Rome asked a group of M.I.T. researchers led by Donella and Dennis Meadows to do a study of the human predicament using computers and the world dynamics approach of an M.I.T. engineer, Jay Forrester. Among the results was the widely publicized book, The Limits to Growth.[26] The tone of this volume is certainly not shrill, and their forecast for the apocalypse is on the order of 100 years, give or take a few decades, depending upon assumptions. Their general conclusion is that:

> If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next one hundred years. The most probable result will be a rather sudden and uncontrollable decline in both population and industrial capacity.[27]

The Limits to Growth study believes, however, that ecologically sound growth is sustainable far into the future provided that we change our ways. And, of course, the sooner we change, the "greater will be ... [the] chances of success."[28]

Ehrlich, in defending the Paddocks' advocacy of triage, makes reference to Pascal's Wager.[29] Simply stated, Pascal, a French philosopher and

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[26]Donella H. Meadows, Dennis L. Meadows, Jorgen Randers and William W. Behrens III, The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind (1972; rpt. New York: Universe Books, A Potomac Associates Book, 1974).

[27]Meadows et al., p. 24.

[28]Ehrlich, "The Coming Famine."

[29]Ehrlich, "The Coming Famine," p. 8, and Ehrlich, The Population Bomb, pp. 179-80.

mathematician, probability theorist and gambler, reasoned that belief in the Christian God entitled one to an afterlife of eternal bliss and that non-belief meant damnation. If there was no God, both the believer and the non-believer were dead. The non-believer gained no benefit for being right but suffered a loss for being wrong, while the believer benefited from being right but suffered no loss as a consequence of being wrong. Consequently, there was everything to gain and nothing to lose by believing in God. Pascal also looked at the odds of eternal life against the short period of one's terrestrial life, so even if a price had to be paid, it was small in comparison to the gains. Similarly, Ehrlich argues that if the Paddocks (and Ehrlich himself) are right, we can expect disaster, and if we accept their rightness, then through triage and other actions we can ameliorate the forthcoming catastrophe. Presumably, if they are wrong, there won't be a doomsday even if we practice triage.

There is a series of obvious fallacies in Ehrlich's reasoning. Practicing triage is not costless, particularly if the doomsday forecasts are wrong. If advocacy is successful in changing policy (and, after all, that is the object of advocacy), a very large number of people would suffer privation and possibly death who might otherwise be helped. And what about those who create the practice of triage? Keeping others out of the lifeboat isn't a pleasant thought and is fraught with moral and ethical implications even when the lifeboat is full to capacity. And, if it is far from capacity, keeping others out is downright immoral. Certainly, triage is not consistent with Ehrlich's statement elsewhere that we "must all learn to identify with the plight of our less fortunate fellows on Spaceship Earth if we are to help both them and ourselves

to survive."[30] The Pascal's Wager argument is equally applicable (or inapplicable) to any doomsday scenario and to the implied policies for its prevention.

Basically, Ehrlich favors foreign aid by countries like the U.S. with special emphasis on the "technology of birth control."[31] He has spoken against "the export of death control," which one author, John R. Maddox, termed "paternalistically offensive."[32] Yet Ehrlich does find that Hardin in his book, The Limits to Altruism, arguing for inequality and privilege, "makes his case straightforwardly and in some ways persuasively."[33] Hardin is basically an opponent of aid to poor countries and makes a strong appeal for privilege both within poor countries and within the world community.[34] Jay Forrester's work also has its political and ideological implications. Forrester developed the systems dynamics approach that was the basis for the famed Meadows report commissioned by the Club of Rome on the limits to growth. He admits that his work might "give the appearance of favoring upper income groups and industry at the expense of the underemployed."[35] Harvey Simmons finds Forrester to be

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[30]Ehrlich, The Population Bomb, p. 2.

[31]Ehrlich, "World Population: A Battle Lost?" p. 140.

[32]John R. Maddox, The Doomsday Syndrome (New York: McGraw-Hill, 1972), p. 60.

[33]Paul R. Ehrlich, review of Garrett Hardin's book, The Limits of Altruism, in Human Nature 1, No. 3 (Mar. 1978), 20.

[34]Garrett Hardin, "Ethical Implications of Carrying Capacity," and "Who Cares for Posterity?" in Hardin, The Limits of Altruism, pp. 46-69, 81-84.

[35]Quoted by Harvey Simmons, "System Dynamics and Technocracy," in H.S.D. Cole, Christopher, Freeman, Marie Jahoda and K.L.R. Pavitt, eds., Thinking About the Future: A Critique of the Limits to Growth (London: Chatto & Windus for Sussex University Press, 1974), p. 200. (Reprinted in the United States as Models of Doom: A Critique of the Limits to Growth, New York: Universe Books, 1973.)

impatient with democratic processes and in favor of policies that reduce health care and food supplies in order to save the World System from collapse.[36]

One of the ironies of the basic criticisms of doomsday forecasting is that the very politics criticized, the export of death control and food assistance, may be critical factors contributing to the solution or at least the amelioration of the population problem. It is generally recognized that falling infant mortality rates will eventually lead to falling birth rates. Since a fall in birth rates begins later and initially falls more slowly, the first impact of decreased infant mortality and extended longevity is to increase the net reproduction rate (birth rates minus death rates), i.e., increase population. In time the falling birth rate overtakes the death rate (or at least the rate of decline of birth rates is greater than the rate of decline of death rates), and what is called the demographic transition takes place as it has in the industrialized world. In the 1960s it may have been naive optimism to believe it would take place in the third world countries. But from the mid 1970s on, there is increasing evidence that precisely this transition has been taking place. Even the Ehrlichs now recognize that "equity" seems to be an "essential factor" in "reducing birthrates". "When people are given access to the basics of life -- adequate food, shelter, clothing, health care, education (particularly for women), and an opportunity to improve their well-being -- they seem to be more willing to limit the size of their families."[37]

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[36]Simmons, pp. 199, 201.

[37]Paul R. Ehrlich and Anne H. Ehrlich, "What Happened to the Population Bomb?" Human Nature, 2, No. 1 (Jan. 1979), p. 70. The Ehrlichs are more cautious and subdued in this piece. In all modesty, they consider that "awareness" generated by books like The Population Bomb contributed to the decline in the birthrate in the U.S. Possibly people were so frightened after reading the book that they

The general world population picture is spotty, giving considerable grounds for hope and also for serious concern. A number of formerly poor countries have emerged as middle income countries with life expectancies approaching those of industrial countries and with birth rates that have fallen dramatically in recent years. There is strong and increasing evidence of falling birth rates in most countries, even the poorest ones. Nevertheless, there is cause for concern because the evidence is weakest for the Indian subcontinent, where population control is needed badly, and for Africa, where in many areas there is no evidence of population slowdown. Recent World Fertility Surveys indicate that in most parts of the world women desire fewer children. Further, age at marriage is rising, reinforcing other trends for lowering birth rates. Family planning programs are succeeding.38 Still, even if our most optimistic interpretations of the population data are correct, there still will remain a population problem. As every demographer (doomsday prophet or other) recognizes, even when fertility falls to net reproduction, the young age structure of a previously growing population can mean population growth for decades before it levels off. And the current optimism about population growth is based upon declines in the rate of population increase.

The question is not whether we have problems of food supply and population

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were unable to have sex. As a matter of fact, the birth rate in the U.S. began to fall in the late 1950s, and the absolute number of births began falling in the early '60s.

38See, among the many sources on current population and population trends, Population Reports, Series M, No. 3, July 1979, "The World Fertility Survey: Current Status and Findings," and Population Reports, Series M, No. 4 (Nov. 1979), "Age at Marriage and Fertility." These surveys also indicate that only about half of the women in the world are aware of modern birth control techniques giving considerable room for expansion of family planning programs and for further reductions in the birth rate.

but what kind of problems and how bad they are. Many contend that the problem is not aggregate food production but rather income distribution. D. S. Miller, in a review of Nutrition and the World Food Crisis, states: "Food requirements are about 2,000 kilocalories per day per man, woman, and child, and global agriculture produces something in excess of 4,500 kilocalories per head per day of crops suitable for human consumption. Much of this food is used inefficiently for feeding livestock to provide animal products for the rich, but even so there is about 2,500 kilocalories per head per day available for human consumption. So, please let us not hear about the 'World Food Crisis'."[39] And the author further argues that "all the evidence suggests that farmers can cope with the supply problem providing it is made worth their while."[40]

There is in fact considerable evidence to support this last assertion. There was another study commissioned by the Club of Rome about the time of the Meadows report. This one was on the theoretical maximum food production possible in the world.[41] They find that "taking into account the possibilities of irrigation and the limitations of crop production caused by local soils and climatic conditions, the absolute maximum production ... is almost forty times the present cereal crop production."[42] Calculating on the basis of sixty-five

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[39]D.S. Miller, "What Food Crises?" A review of Mary Alice Caliendo, Nutrition and the World Food Crises, in Nature, 281 (Sept. 27, 1979), 323-324.

[40]Miller, 324.

[41]P. Buringh, H.D.J. van Heemst and G.J. Staring, Computation of the Absolute Maximum Food Production of the World (Wageningen, Netherlands: Department of Tropical Soil Science, Agricultural University, Wageningen, The Netherlands, 1975).

[42]Buringh, et al., p. 1.

percent of the total of available land (sixty-five percent being the percentage of the current land in production that is cereal crops), the potential output is thirty times the present production. The authors make a number of assumptions, such as use of the latest technologies, fertilizers, seeds and multiple cropping during all the growing days of the year. They recognize that in each specific area there are reasons why the absolute maximum cannot be reached. Even so, it does indicate a potential for agricultural development that is considerably beyond current production.[43] Further, they assume no change in technology. Some of the research efforts and possibilities recommended by the National Research Council of the U.S. National Academy of Sciences are simply astounding in their potentials. Among others are further possibilities for genetic manipulations of plants, development of nitrogen fixing bacteria for cereal crops, improvement in photosynthesis, and production from currently unusable acidic soils.[44] These are not pie-in-the-sky recommendations. Much of the research that the NRC called for has been under way for some time and shows signs of success.[45]

On mineral resources, the same story prevails. Robert Solow, in combating

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[43]In some cases, their assumptions turn out to be too conservative. They assume that eighty percent of the arable land in Asia is in use. Satellite data now indicate that in 1978 "only seventy-three percent of land was being used for production." Our Magnificent Earth: A Rand McNally Atlas of Earth Resources (Chicago: Rand McNally, 1979), p. 49.

[44]World Food and Nutrition: The Potential Contributions of Research, prepared by the Steering Committee, NRC Study on World Food and Nutrition of the Commission on International Relations, National Research Council (Washington: National Academy of Sciences, 1977), pp. 8-10.

[45]For example, on the possibility of making plants much more efficient in their photosynthesis, see Robert C. Cowen, "Coming: A Leap in Food Supply?" Christian Science Monitor (Dec. 12, 1979), p. 16, and Peter J. Vejk, Doomsday Has Been Cancelled (Culver City, CA.: Peace Press, 1978), pp. 76-77.

some of the fears of imminent resource exhaustion, gives the following U.S. government estimates for years of availability and the crustal abundance of some of our minerals.46

	Known Reserves	Ultimately Recoverable Reserves*	Crustal Abundance
Coal	2736 yrs.	5119 yrs.	—
Copper	45	340	242×10^6 yrs.
Iron	117	2657	1815×10^6
Phosphorus	481	1601	870×10^6
Molybdenum	65	630	422×10^6
Lead	10	162	82×10^6
Zinc	21	618	409×10^6
Sulphur	30	6897	—
Uranium	50	8455	1855×0^6
Aluminum	23	68,066	38500×10^6

* with current technology

Solow defines "known reserves" as those recoverable using current technology. Technology is continually creating new resources. Resources do not exist apart from technology. The raw materials of the universe become useful to humans and therefore resources as a result of technology change. Further, science and technology are, through processes of alloying, creating new materials. This allows for resource substitution in case of scarcity. As many writers have noted, long before one runs out of a resource, there are myriad possibilities

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46Robert Solow, Lecture, University of Houston, Fall, 1976. General Data of Solow on crustal abundance is supported by Vajk, pp. 64-65, and Cole, p. 36. See also Nathan Rosenberg, "Innovative Response to Material Shortages," The American Economic Review, 63, No. 2 (May 1973), 111-118, and Scott Gordon, "Today's Apocalypses and Yesterday's," The American Economic Review, 63, No. 2 (May 1973), 106-110. A seminal work on the history of resource availability in the United States is H.J. Barnett and Chandler Morse, Scarcity and Growth (Baltimore: Johns Hopkins Univ. Press, 1963).

for recycling and reprocessing waste.

One wonders, if we are being overwhelmed by population and are at the same time running out of resources, as the doomsayers insist, what has been the aggregate impact upon the world's people? Despite all this travail, economic development has been unprecedented and has exceeded all forecasts.

> In average per capita income the developing countries grew more rapidly between 1950 and 1975 — 3.4 percent a year — than either they or the developed countries had done in any comparable period in the past. They thereby exceeded both official goals and private expectations. That this growth was real and not simply statistical artifact may be seen in the progress that occurred simultaneously in various indexes of basic needs. Increases in life expectancy that required a century of economic development in the industrialized countries have been achieved in the developing world in two or three decades. Progress has been made in the world in the eradication of communicable diseases. And the proportion of adults in developing countries who are literate has increased substantially.[47]

Preliminary data from World Bank and other sources indicate that, though development has been slowed, it has continued through the latter part of the 1970s.[48] In the United States economic growth slowed during the 1970s, but it was not vastly lower than that of the 1960s. Despite the carcinogens in our food and the pollutants in the air, we added 2.3 years to our life expectancy at birth bringing it to 73.2.[49] This brings to a total of over thirty years that

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[47]David Morawetz, Twenty-five Years of Economic Development 1950-1975 (Washington: The World Bank, 1977), p. 67. See also his article, same title, in Finance and Development, 14, No. 3 (Sept. 1977) 10-12.

[48]See World Development Report 1979 (Washington: The World Bank, Aug. 1979), and The Planetary Product: Progress Despite the Blues 1977-1978 (Washington: Bureau of Public Affairs, U.S. Dept. of State, Special Report No. 58).

[49]Health United States (Washington: Office of Health Research, Statistics and Technology, Public Health Service, U.S. Dept. of Health, Education, and Welfare

we have gained in life expectancy this century. With all the ways that we abuse modern technology, just think of the gains we can make (and have made) with its proper use.

Of all the resource questions, energy is the most complex and controversial. Energy shortages experienced in the United States in the 1970s were the result of political and pricing decisions and not of any resource shortage. Currently, research is going on toward improved ways of using fossil fuels, such as coal, toward nuclear fusion, and toward solar, wind, ocean current, and geothermal sources of power. In the last few years with increased prices for oil and periodic uncertainty of availability, the oil importing industrial countries have made significant improvements in energy conservation, particularly conservation in the form of increased efficiency in the use of energy. There is no lack of energy sources, merely a lack of the technologies to exploit them cheaply. The availability of cheap gas and oil has undoubtedly delayed work in all this area, but there is no reason not to believe that eventually we will succeed in this area as we have done in other areas in the past. The canard that there is insufficient uranium for nuclear power in the United States or in the world just will not stand up to scrutiny.50

Many of the doomsday deadlines noted earlier in this article have long passed, but this has not slowed the tempo of such prophecies. The Limits to

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1979), p. 115. See also Susan Previent Lee, "What's Needed is Affluence," New York Times, 4, Jan. 1980.

50See, for example, Kenneth S. Deffeyes and Ian D. MacGregor, "World Uranium Resources," Scientific American, 292, No. 1 (Jan. 1980), 66-76, or table above. On energy efficiency/conservation, see Robert Stobaugh and Daniel Yergin, eds., Energy Future: The Report of the Harvard Business School Energy Project (New York: Random House, 1979); James M. Griffin and Henry B. Steele, Energy Economics and Policy (New York: Academic Press, 1980), ch. 7, pp. 212-242.

Growth book has the twenty-ninth day riddle. A "lily plant doubles in size each day. If the lily were allowed to grow unchecked, it would completely cover the pond in 30 days, choking off other forms of life in the water." On what day will the lily cover half the pond? The twenty-ninth.[51] The twenty-ninth day riddle has become commonplace among those who are fearful of the future implications of current economic trends.[52] Past prophecies may not have been precisely right, but we are warned that the pond is half full.

People in the United States and elsewhere are living longer at higher material standards of living and with more education than any previous generations have ever known. The question arises as to why the gloom about the human predicament and why the prophecies of catastrophe in the name of science? Though I do not pretend to have a complete answer, I will offer some comments that might contribute to a partial understanding. That we have a long history of apocalyptic predictions means that in some way this vision is part of our culture, an assumption aptly demonstrated by other essays in this volume. Recently, this apocalyptic vision has tended to be clearer and stronger on the coming catastrophe than on the new world that will arise from it. Religious visionaries in our society have both condemned modern science and tried to use it to buttress their beliefs. It is understandable, then, that some segments of the public will respond to predictions of calamity by scientists. It is less understandable that scientists would make their sensational terms that are alien to the ethics and mores of modern science.

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[51]Meadows et al., p. 27.

[52]There is even a book with the title: Lester R. Brown, The Twenty-Ninth Day: Accommodating Human Needs and Numbers to the Earth's Resources (New York: W.W. Norton, 1978).

In the predominantly Protestant Christian culture of the United States and the Christian culture of the European industrial countries, the work ethic has played an important ideological role in explaining and justifying inequality of wealth within a country and among nations. It has become obvious that we have to work less to acquire our daily bread and that this may cause guilt pangs in terms of traditional beliefs. If we are drawing our usufruct too easily, something must be wrong. The party is over. The price we paid is insufficient and so we will have to pay the full price some day soon. To use Ehrlich's baseball metaphor, "Nature Bats Last."[53]

T.C. Sinclair argues that there has long been a strain of religious thought in Western culture that opposed economic progress, particularly industrialization. Quoting R.W. Tawney, he notes that advancing wealth was viewed as bringing with it avarice, cupidity, and a weakening of traditional relationships. "Much of the moral idealism which in earlier times found expression in various movements of social reform appears now, particularly in the USA, to seek an outlet in the environmentalist movement."[54] Pollution has become a symbol of our moral degradation. We have sold our soul for affluence and the judgment day will soon be upon us.

In this author's judgment, there is considerable confusion on the issues of development and resource limitation, owing to a lack of understanding of the nature of technology and technological change. What the critics of modern

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[53]Ehrlich, "Eco-Catastrophe," 32.

[54]T.C. Sinclair, "Environmentalism: A la recerche du temps perdu -- bien perdu?" in H.S.D. Cole et al., p. 175.

technology fail to realize is that the main difference between current and earlier technological change and diffusion is one of scale. Modern technology is truly global in its impact. Modern technology is a problem solving process, and problem solving generally creates other problems to be solved. Five centuries or more ago, before the development of flues, Europeans heated their homes (i.e., solved the problem of cold) and created massive amounts of pollution indoors. People throughout the world have (and many continue to do so) drawn their water from local sources that are used for animals and the repository for various waste materials. They are using and drinking polluted water. Those lucky enough to have access to modern technology heat or cool their homes efficiently and drink (relatively) clean water. Few would argue that these problems are not solved better than they were previously, but in the process of solving them, we, the creators and users of the technology, have succeeded in creating air and water pollution that transcends the home and village and encompasses regions, continents, and is of near global proportions. To argue that modern technology creates pollution while earlier ones didn't is to deny the facts of real life experiences of most of the world's population.[55] The difference is that our problems now transcend the home and village and must be solved at the global level and can only be solved with modern technology. Twentieth-century populations with their problems and aspirations will not find solutions in nineteenth-century technologies.

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[55]Any student of economic history knows that there were no golden ages in the past. There are a number of interesting popular and some scholarly works exploring the conditions of life in prior times, showing how unpleasant they were compared to the present. See, for example, the delightful book by Otto Bettimann, The Good Old Days — They Were Terrible (New York: Random House, 1974).

The scale of modern technology is also a factor in technology transfer and the change it engenders. The rapidity and magnitude of the potential cultural changes involved in using modern technology are enough to overwhelm many cultures. But it also offers unparalleled opportunities not only for material improvement but also for cultural advancement. In sum, industrial technology dwarfs our previous technologies in its power to do good or evil. Those who would have us reject it are, to say the least, confused. The real choice lies in the opportunity to understand the nature of technological change and to use it intelligently to serve human purposes.

The economics model (meaning the basic body of theory and method used by most economists) argues that we have little to worry about from resource exhaustion. As a mineral or some other resource becomes more scarce, the price system acts as a mechanism for transmitting this information. As the price of a resource rises, we find ways of conserving it and we work to develop technology to use it more efficiently. One author has noted that as we move to greater resource scarcity, pollution becomes less of a problem because there will be less waste of resources (pollution) when the resources are scarce and their expense relative to the price of labor and capital.[56] Rising prices of one resource cause substitution of less scarce resources. It appears that in the biologist, ecologist, and Club of Rome models, feedback mechanisms tend to worsen problems. From Malthus onward, forecasts of doom almost invariably are based on a form of exponential growth that brings the end upon us suddenly and

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[56]Rosenberg, 116.

without warning. However, those who accept such forecasts will not be surprised by the end, in the way that those who accepted the faith wouldn't be surprised at either the apocalypse or the golden age that followed. In the economist model of the price system, most (if not all) of the feedback mechanisms are positive in the sense that they provide the signals for correction and redemption.

In his delightful book, A Choice of Catastrophes, Isaac Asimov traces the etymology of the word "catastrophe" to the Greek word meaning to turn upside down.[57] There is irony here, since many of our contemporary catastrophists have turned reality upside down in their predictions of cataclysms that have yet to occur. Because of modern science and technology we live longer, healthier lives, yet somehow alternate-technology enthusiasts characterize these as death-dealing systems. This topsy-turvy thinking is characteristic of the movement.

Much of modern anti-technology writing is on nature and natural phenomena such as natural food or the natural functions of the land. Taken literally, such pronouncements are nonsense. Humans have always been tool users, and this in itself gives us a different role in the scheme of things. Malcolm Slesser writes: "The productivity of a natural eco-system is around 6 kg. per hectare per year of protein suitable for humans, and this is only obtainable from the better land on the earth's surface. Conceivably, such an unintensified system might support around two hundred million people, a figure surpassed by the

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[57]Isaac Asimov, A Choice of Catastrophes (New York, 1979), p. 13.

Middle Ages."[58] Long before the Middle Ages, of course, humans were transforming the earth through agriculture and husbandry. As Rene Dubos has noted, "Human beings have probably never been in real 'balance' with their environment except under conditions where population density is extremely thin, as in polar regions or the Australian desert.[59] We don't live in a natural environment, and, with over 4 billion people on earth, we cannot recreate one.

Obviously, writers do not mean a literal "return to nature," though one wonders why they continue to use the phrase. All technologies — modern, alternate, or whatever — involve humans living in an artificial environment. It is not the naturalness that is important but the quality and sustainability of the life purposes that can be carried out.

Great emphasis has been placed on the "redundancy" of simpler technological systems and the security that this confers. The theoretical relationship between complexity and reliability is often illustrated with reference to such disruptions as power outages. Twice in over a decade the lights have gone out in New York City, and critics point to the vulnerability of modern technology. Presumably, they take for granted the reliability of electrical systems that work for years with only occasional disruptions. What would they have us compare our electrical systems to for reliability -- candles?

When it comes to the basic "life-support system," it is clear that modern

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[58]Malcolm Slesser, "Energy Requirements of Agriculture," in Food, Agriculture and the Environment, ed. John Lenihan and William W. Fletcher (New York, 1976, p. 1.

[59]Rene Dubos, The Wooing of Earth (New York, 1980), p. 57.

technology has created a redundancy never before achieved. Basic to life support is the provision of food. Modern technology has regularized and stabilized food production, and this has been a factor in the steadily declining death rates that have accompanied the rise and spread of modern technology. Despite stabilization of output, the major variable for agriculture remains the weather. An agricultural system that is essentially worldwide provides greater security against the vagaries of weather through greater redundancy. Our modern transportation and distribution systems provide the means to alleviate severe need, the result being that "only a tenth as many people died of famine in the third quarter of the 20th century as in the last quarter of the 19th century, despite the much larger population now."[60]

Redundancy is at the very heart of modern technology. Hospitals have backup systems. Planes can fly even with loss of an engine, or two. Bridges are built with overload factors. And on it goes. If backup systems fail in a hospital, the disruption can be severe and lives can be lost. But the severity of the disruption is a function of our temporary inability to derive the full benefit of a technology. If the technology were not inherently beneficial, its loss would be inconsequential. As we continually reiterate in our arguments with the small-is-beautiful enthusiasts, the aggregate evidence of mortality attests to the redundancy (i.e., safety) of modern technology. With the spread of modern technology, death rates are falling almost everywhere. The very success of technology in protecting and sustaining life leads to the need for

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[60]Julian L. Simon, "Resources, Population, Environment: An Oversupply of False Bad News," Science, 208 (June 27, 1980): 1433.

population control.

The human endeavor has always been subject to severe disruption by natural hazards such as earthquakes, floods, drought, and winds. But even here, technology provides protection. In a seminal study of natural disaster, Judith Dworkin found that, with the exception of Japan, low death rates from disaster prevailed among high-income countries.[61] Robert W. Kates argues that "death rates from natural hazards in the United States may be down to the reasonably preventable annual minimum.[62] Kates cites the standard figures on mortality from natural disasters: one in a million in the United States, one in a hundred thousand in the world, one in ten thousand in Bangladesh.[63]

It is true that most of the authors who write about risks of natural disasters also write of technological hazards. One such hazard stems from a willingness people have to live downstream from dams or in coastal areas subject to hurricanes. Our dams are so safe (not only in construction but also because of electronic sensing devices), and our hurricane-warning systems are so effective, that some of us have been lulled into a false sense of security. But a developing country could in fact choose modern technology while simultaneously planning its settlement patterns to avoid risks. In already developed countries, undertaking resettlement would be costly. Technological hazards can

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[61]Judith Dworkin, "Global Trends in Natural Disasters, 1947-1973," Natural Hazard Working Paper no. 26 (Boulder: University of Colorado, Institute of Behavioral Science, 1974), p. 5.

[62]Robert W. Kates, Risk Assessment of Environmental Hazard (New York, 1978), p. 11.

[63]Ibid., p. 49.

be minimized be exercising common sense; natural hazards can be reduced primarily with modern technology. When we look at death rates from all causes, it is undeniable that modern technology has yielded a longer life expectancy.

By having tamed nature in developed countries, modern technology has created the framework for the life-styles that win the plaudits of the back to nature enthusiasts. Natural or organically grown food is not a prestige item in poor countries where dysentery is rampant, yet critics speak about the pollution of food. Natural childbirth means higher infant mortality except where technology has reduced the general level of disease. To poor farmers throughout history, "nature" has meant floods or droughts, locusts or ill winds. Modern technology, in tempering these hazards, has given the devotees of antitechnology (or at least antimodern technology) the opportunity to pursue their own course. Rather than making each of us a mere "cog in a machine," modern technology (particularly when coupled with democratic political institutions and traditions) has allowed more diversity and freedom of life-style than ever before. But small-scale communities function insofar as people work together toward common goals. Choices are limited, so tastes must be similar.

Decentralization is another ideal of the small scale technology advocates. And it would be a worthy ideal — if valid. The irony is that our centralized, technologically sophisticated, democratic societies are functionally more decentralized than any others. Do-it-yourselfness is a function of the availability of modern technology in the home, and many of the do-it-yourselfers also benefit from the leisure afforded by modern technology.

We can seek to improve our technology and make it less hazardous; we can strengthen the democratic processes in the collective decisions that provide the

framework for our range of choices; we can work to give more people access to all the benefits of modern technology. These goals are consistent with trends already operative in modern technology. There are those of us who like modern technology. If we unashamedly continue to work to improve it, then achieving our objectives increases the possibilities for the back to nature folk to achieve theirs.

Possibly a position between these two models is appropriate, or at least that is mine. Clearly, technology has solved many problems, but in doing so has created others. Possibilities of serious general resource exhaustion are considered remote and virtually unlikely by most economists. However, there are other threats to human life that are not signalled to us through price. Groups convened by the U.S. National Academy of Sciences have concluded that the increasing CO_2 in the atmosphere is likely to lead to a warming of the climate and that chloroflurocarbons (from aerosol sprays) are adversely affecting the ozone in the stratosphere and are thereby likely to increase skin cancer.[64] Oddly, these are phenomena with a very large potential for damage, yet they receive far less publicity than other less founded prophecies. One presumably would be cheap to cure (there are alternate propellants for aerosols), while reducing pollution further (which we are doing) will be costly but necessary on a variety of grounds. Chlorofluorocarbons are outlawed in the United States but unfortunately they continue to be used elsewhere. One author, Professor Sylvan Wittwer, presenting a paper at the meetings of the American Association for the

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[64]Nicholas Wade, "CO_2 in Climate: Gloomsday Predictions Have No Fault," Science, 206, No. 4421 (Nov. 23, 1979), 912-913, and Thomas H. Maugh, II, "The Threat to Ozone is Real, Increasing," Science, 206, No. 4423 (Dec. 7, 1979), 1167-1168.

atomic power. After hearing of its enormous destructive powers, one of the senators asked if we couldn't destroy all bombs and the knowledge necessary to make them. The physicist answered, "Senator, the bomb is here to stay; the question is, Is Man?" Most of us would love to rid the world of destructive weapons and the knowledge to make them. We can't. But we can control them. We can't rid ourselves of modern science and technology because most people don't want to, and if we were to turn back our technology very far the globe would support far fewer of us. Nothing in this study is intended to deny the serious nature of the world's population and resource problems. I am in no way advocating complacency. However difficult our problems may be, there are no empirical grounds for apocalyptic visions of certain defeat. We could lose, but the bulk of the evidence indicates that we probably won't. There is a solid factual basis for cautious optimism. Success in solving these problems is a function of the extent to which human beings are willing to act with intelligence and not of inherent environmental limitations.

Of all the metaphors for our modern predicament, the one of Spaceship Earth seems most apt. It recognizes that we live together in a system and must work together cooperatively so that it functions for everyone's benefit. The Spaceship also symbolizes human beings' ability to use science and technology creatively to break barriers that were previously restraining. Mankind is capable of soaring toward the stars. John Dewey probably sums up my arguments better than I can:

> Man who lives in a world of hazards is compelled to seek for security. He has sought to attain it in two ways. One of them began with an attempt to propitiate the powers which environ him and determine his destiny .... The other course

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TECHNOLOGY AND THE USE AND CREATION OF RESOURCES

The various catastrophic visions that saw the world exhausting energy resources, minerals, land and breathables were directed mainly towards the activities of the industrial countries. Yet, if global limits to growth had been reached, economic policies for both the industrial countries and the less developed had to take this "fact" into account. Much of the impetus for the appropriate technology movement of the 1970's was out of a belief that renewable resources had to be used because we were fast running out of the other kind. That the specific catastrophic visions have not been borne out does not negate the possibility that the forecasts on minerals may have been more accurate. In this chapter, we address the question of the nature of mineral resources and the possibility of mineral availability for use in both developed and underdeveloped countries.

The earth consists of a hot molten core (of mainly iron and nickel and possibly sulfur), a solid but hot mantle (containing most of the elements) and a crust (of 15 to 30 miles thick on land, considerably thinner under the ocean). In this crust, the eight most common elements constitute about 98% of it by weight and even more by volume.

Of these eight, oxygen and silicon together comprise about 75% of the earth's crust by weight. Aluminum is a little over 8% and iron is 5%. The other four, calcium, sodium, potassium, and magnesium, range from about 2% to just over 3½%. These eight elements alone, with carbon and some trace elements (nitrogen, oxygen, and hydrogen from the air, as well as oxygen and hydrogen for

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Before exploring the details of minerals availability, it is necessary to develop further the functional theory of resources and the evidence for it. So much has been said about the limits to growth theory that many otherwise educated people seem unaware that there is a different theory.

1) Limits to Growth Theories. The basic belief is that most resources (particularly minerals and non-solar energy) are in some sense finite. The faster they are used, the sooner they will be exhausted. Exponential growth in resource use will result in sudden and catastrophic collapse. Increased efficiency in resource use, new technologies, recycling, and other forms of resource conservation will only postpone (generally a decade or less) but not prevent collapse. The only long-term solution to finite resources is population control, zero economic growth, and a shift to renewable resources in all areas of human life.[1]

2) Critical Resources in Short Supply. This position is consistent with (1) above or with (3) below. Certain key mineral or energy resources are in short supply and are likely to be exhausted within a few decades. For many of their uses there are reasonable substitutes, but for some there are no substitutes. In our complex economic and technological structure it is difficult to assess the extent of the adverse effect of these resource losses, but they are likely to be significant. As noted, one can hold to the concept of

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[1]These and similar strategies for preventing resource exhaustion were considered to be "fallacious" by the Paley Commission and were called "a hairshirt concept of conservation which makes it synonymous with hoarding". Resources for Freedom, Communication from the President of the United States, Transmitting the Report of the President's Materials Policy Commission, June 1952, Washington D.C.: U.S. Government Printing Office, 1952. Five volumes, Doc. 527, 82nd Congress, 2nd Session. Henceforth cited as The Paley Commission Report, op. cit., p. 21, Vol. 1.

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problems and still recognize severe resource problems in the short run. As noted above, it is possible that resources generally might not be exhausted but there are, using current technology, some specific resources in short supply, or else they are so costly to obtain as to be uneconomic. In this case, mankind has a problem of conserving existing supplies and creating the technologies for new supplies or new material substitutes. The issue is one of creating new technology for a transition that allows for economic continuity. This contrasts with the limits-to-growth theories which allow for no transitions because exhausted resources are truly exhausted and therefore require a fundamental redirection in economic and technological activity. There are no technological solutions. Attempting to solve resource problems with technology is illusory, a technical fix that won't work and in fact will make things worse. To the many limits-to-growth theorists, technology is the cause of the problem, not the solution.

It is also possible to argue that there are no serious global problems of resource exhaustion, even for specific reasons. However, some key minerals (including some of the most abundant) are distributed in high concentrations in some areas. Thus, there may be no global physical shortage of these economically exploitable resources; however, institutional factors, such as political conflict or simple economic blackmail may disrupt the flow of resources and cripple other economies. This is true whether it be an adverse impact upon fertilizer output and food production in poor countries owing to a rising price of oil, or a potential crippling of industrial economies due to a lack of energy or essential minerals. Where military prowess is a function of science, technology, and industry, industrial disruption can have more serious

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of new resources. "Resources are not, they become; they are not static but expand and contract in response to human wants and human actions."[3]

There is considerable historical and scientific evidence for the cornucopian position on resources. It is true that people at times have run out of specific sources or defense of one's own has been a causal factor for armies marching. Known sources of tin were exhausted in the Middle East several thousand years ago, threatening the Bronze Age civilizations of that time. Then, however, improved ways of working with iron were found.[4] And more recently, supplies of whale oil were becoming increasingly scarce just as we were learning to explore and drill for oil.

Prevailing Economists' View on Resource Exhaustion and Historical Evidence

One of the most comprehensive works on the economics of historical resource use in the U.S. is the 1963 study, Scarcity and Growth: The Economics of Natural Resource Availability, by Harold J. Barnett and Chandler Morse.[5] Barnett and Morse spell out the traditional view of resources. "The belief seems to be that natural resources are scarce; that the scarcity increases with the passage of time; and that resource scarcity and its aggravation impair levels of living and economic growth."[6] To economists, increased scarcity

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[3]Zimmerman, op. cit., p. 15.

[4]Asimov, Choice of Catastrophes, pp. 294-295.

[5]Baltimore: The Johns Hopkins Press for Resources for the Future.

[6]Ibid., p. 49.

1900. If, in the 1970s, the relative price of some minerals or other resources has increased, it is not necessarily the result of resource scarcities or difficulties of extraction.

Many of the projections of yearly supplies of resources are a function of the patterns of investment, exploration, and at times luck. In 1929 forecasts were made in the U.S. indicating only a ten-year supply of lead. In 1952 the Paley Commission was fearful about lead supplies keeping up with demands (even with high prices), though their primary concern was for domestic U.S. supplies.[11] In 1972 The Limits to Growth study (using 1970 data) found that there were from 21 years (with exponential growth in utilization) to 26 years (with a constant level of utilization).[12] Current estimates of world lead reserves are generally still in excess of 20 years. In fact, in the last few decades the ratio of reserves to yearly use has increased for virtually all minerals and other resources. The most egregious and important exception is petroleum and natural gas. From the late 1940s to the late 1960s, reserves of iron ore increased 1221%, manganese 27%, chromite 675%, copper 179%, and lead 115%.[13]

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[11] Op. cit., Paley Commission, Vol. II: The Outlook for Key Commodities, pp. 5, 148-149.

[12] Meadows, Donella H., et al, The Limits to Growth (A Report for the Club of Rome's Project on the Predicament of Mankind — a Potomac Associates Book), New York: Universe Books, 1972, pp. 56-57.

[13] John S. Carman, Obstacles to Mineral Development, New York: Pergamon Press, 1979, p. 78.

manganese as an alloy continues. However, new uses for manganese could reverse these trends, particularly if seabed sources lower its relative cost.[16] Also, with new technology, we learn to use resources more efficiently. For example, in 1900 it took seven pounds of coal to produce 1 kilowatt hour of electricity, but by the 1960s it took only .9 of a pound.[17]

Necessity can also force people to use resources more efficiently as the shift to higher mileage cars in the U.S. demonstrates. For example, in 1943 Germany was producing locomotives using 1/10th the amount of copper they were using in 1942. Though resource-short, Germany ended World War II with greater stocks of most raw materials than they had in 1939. This they achieved both by greater efficiency of use and by resource substitution.[18]

The evolution of the computer over the last three decades or so further illustrates the resource-saving character of many technological advances. ENIAC "contained 1,000 vacuum tubes, weighed 30 tons, took up 1,500 square feet of floor space, and used up as much energy as a locomotive." Now "a computer that consumes no more energy than a light bulb, that is small enough to be lifted

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[16]On the resource intensity of manganese, see Wilfred Malenbaum, World Demand for Raw Materials in 1985 and 2000, New York: McGraw-Hill, E/MJ Mining Information Services, 1978, pp. 39, 42, 44.

[17]Nathan Rosenberg, "Innovative Responses to Materials Shortage," American Economic Review, Vol. LXIII, No. 2, May 1973, p. 116. See also by the same author, "The Role of Science and Technology in the National Development of the United States," in William Baranek, Jr. and Gustav Ranis, Editors, Science, Technology and Economic Development, New York: Praeger Studies 1978, pp. 114-68. Also see The Paley Commission Report, op. cit., Vol. I, p. 116; and Ian Barbour, Harvey Brooks, Sanford LaKoff and John Opie, Energy and American Values, New York: Praeger, 1982, p. 34.

[18]Edward S. Mason, "Natural Resources and Environmental Restrictions to Growth," in Challenge, Jan/Feb 1978, reprinted in Robert C. Puth, Current Issues in the American Economy, Lexington, Mass.: DC Heath & Co., 1980, p. 305.

continental shelf are two of the Southern African strategic minerals, chrome and the platinum group, but their exploitation is in the far distant future.[21]

In some respects we will never "run out" of minerals. Except for those minuscule amounts that we may shoot into outer space, all materials used will exist in some form on earth. Some will be concentrated and available for reuse (i.e., recycling). Others will be sufficiently diffuse as to not make it economically worthwhile to concentrate them for reuse. The Limits to Growth estimated, for 1970, a 31-year supply of aluminum (assuming exponential growth).[22] Aluminum by most calculations is approximately 8% of the earth's crust.[23] It is obvious from this and other illustrations that exhausting or running out of mineral resources are at best imprecise metaphors. In actual fact, what they mean is the non-availability of a resource in a concentration or ore form that makes it economically usable with current technology. As we have noted, technological change alters resource availability. Most economists argue that price changes signal resource scarcity and allow people to make approximate adjustments.

Prices also alter resource availability. For example, the Paley Commission

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[21]On the continental shelf see Fincham and van Ransberg, op. cit., Chapter 12.

[22]Meadows et al, op. cit., pp. 56-7. Similarly, The Global 2000 Report to the President has a table with 1970 data showing an 8-year supply of industrial diamonds, which means that by now we have exhausted the reserves. However, world markets are currently glutted with all kinds of diamonds. See Ned W. Dearborn, "Nonfuel Minerals Projections," in Gerald O. Barney, The Global 2000 Report to the President, Vol. II: Entering the Twenty-First Century, Washington D.C.: U.S. Government Printing Office, 1980, p. 212.

[23]Donald Brobst, "Fundamental Concepts for the Analyses of Resource Availability," in V. Kerry Smith (ed.), Scarcity and Growth Reconsidered, Baltimore: The Johns Hopkins Press for the Resources for the Future, 1978, p. 120.

economically exploited goes down.... Therefore, it is simply not true, as is often remarked, that average rock will never be mined. As a matter of fact, in a few cases we are already mining commodities as by-products whose average grade in the ore deposit is lower than that in the crust (titanium mined in beach sand is an example)."[26] To utilize these ever-decreasing grades of ore down to common rock will require greater energy to extract the ore, to reclaim the land, since far greater volume will be processed for ore, and to counter the greater pollution from greater energy use itself.

In the future, not only will energy be one of the keys to mineral availability, but it will also provide an experience and model for understanding the minerals problem. Had this chapter been written in 1970 on energy sources, it would have been simple to point out the world dependency on petroleum from a few concentrated sources. One could have noted the long term declining price of energy and the historic function of science and technology in replacing exhausted energy sources with new more productive ones. One could have noted the multiplicity of new potentially inexhaustible sources, i.e., geothermal, tidal, solar, solar satellite, nuclear fission and fusion, etc. One could have noted the possibilities for greater efficiencies and substitutions, such as insulation for energy. One could have noted possibilities of greater recovery of oil, new finds, or obtaining oil from shale, tar, or heavy oil deposits. All of this was true then and remains true today. Further, policies are easier to frame in advance of a crisis than after it is upon us.

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[26]Brooks and Andrews, op. cit., pp. 41-42. For a table relating average rock currently mined and crustal abundance, see Brobst, op. cit., p. 123.

today in electronics, where it is such a prime and superior material that it is difficult to think of lasers, diodes, or semi-conductors without it.[31] In 1950, titanium was just emerging as a significant metal. It was "produced on a moderate industrial scale",[32] though it was already recognized that its use would expand greatly in the coming decades. Today, one rarely sees a list of strategic minerals that does not include titanium and refer to its use with aluminum for aircraft. In the Paley Commission Report, tantalum is mentioned rarely and only in conjunction with other metals. At the time the report was issued, the U.S. Government was already busily looking for worldwide sources for it and columbium. For the past thirty years, it has been a mineral in which there has been periodic shortage. Since 1975, the U.S. Government has been stockpiling it.[33] Vanadium is also treated lightly in the Paley Commission Report and referred to as "the least critical of all the alloying elements used for steel making."[34] It is interesting that a news item appearing as this is being written refers to U.S. high technology as being sold to China in exchange

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[31] Ibid., pp. 104-105. Namibia is the only known source of an ore, gallite ($CuGaS_2$) "that contains gallium as an essential constituent, but the quantity of gallite seems to be small: Mineral Facts and Problems, op. cit., p. 402. Currently, that is not of significance since we are recovering adequate supplies of gallium as a byproduct of aluminum and zinc ores. It should also be noted that the Paley Commission was concerned to find new uses for the "abundant supply of arsenic". Paley Report, op. cit., IV, p. 100.

[32] Ibid., p. 19.

[33] Mineral Facts and Problems, op. cit., pp. 1091-8. Tantalium's virtual omission in the Paley Report may be an instance of a mineral whose importance was not realized until we had a crisis such as the Korean War. It was used then and is now used as a capacitor in electrical systems.

[34] Paley Report, op. cit., IV, pp. 10 and 12.

materials performance has been pushed to the limit."[38] Chynoweth adds, "the more a society depends on complex and sophisticated equipment, the more vulnerable it is to scarcities of certain key materials, even those used in very model amounts".[39]

The science and technology which has through human history created materials substitutes has also created complex technologies with very specific, difficult-to-substitute-for-materials needs. This will continue to be true in the coming years. To some this vulnerability is an indicator of a larger necessity to return to simpler ways. For the vast majority this return to the past is seen as neither possible nor desirable. A minerals policy must be one that monitors and responds to technological changes and the material demands thereby generated. For the one thing that this chapter points toward is that the that the minerals problems are a matter of being able to make critical transitions to new materials and/or material sources. Hindsight may give clearer vision than foresight, but intelligent foresight gives a far greater scope for effective action.

In a real sense, on minerals, the sky is the limit. Long before we have exhausted mineral opportunities on earth, humans will be mining the moon and asteroids for high quality ores. Already the possibilities of manufacturing in space are becoming clear, as experiments can be conducted to create new alloys and materials under conditions of zero gravity. In time, manufacturing in space

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[38] Ibid., p. 124. Chynoweth notes, as we do above, that processing some of these minerals is energy intensive.

[39] Loc. cit.

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by any possibility can get enough of everything for both its economy and war purposes within its borders."[40]

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[40]See, for example, Alfred E. Eckes, Jr., The United States and the Global Struggle for Minerals, Austin: The University of Texas Press, 1980, p. 191.

Attachment D

ADDITIONAL DOCUMENTATION

The documents listed below were furnished by the subcontractor as appropriate reference materials and are available from the Africa Bureau's Evaluation Office, AFR/DP/PPEA, Room 3911, Main State, Washington, D.C., or from the Bureau of the Census, International Statistical Programs Center, Evaluative Studies Branch, Room 304, Scuderi Building, Suitland, Maryland.

1. Technology and Culture, The International Quarterly of the Society for the History of Technology, Volume 23, Number 2, The University of Chicago Press, April 1982.

2. Cultural Resistance to the Technological Change, reprinted from Technology and Culture, Volume V, Number 2, University of Chicago, Spring, 1964.

3. Technology, Traditionalism and Military Establishments; reprinted from Technology and Culture, Volume VII, Number 3, University of Chicago, Summer 1966.

4. Science and Technology for Development reprinted from Technology and Culture, Volume VI, Number 4, Society for the History of Technology, Fall 1965.

Appendix II

MEMORANDUM

TO: Mission Evaluation Officer

FROM: Bureau Evaluation Officer, Henry L. Miles

SUBJECT: Evaluation Guidelines

DATE: June 28, 1982

Attached you will find a set of the guidelines for obtaining the information needed to test AFR's policies and procedures and a sample executive summary illustrating the use of the guidelines. Please have these guidelines incorporated into PPs for new projects and PIO/Ts for evaluations.

The sample executive summary covers the adoption of a plow seeder in Mexico. We wanted to use an example from Africa but we could not find one. Do you know of any journal articles on successful transfer of knowledge, skills or practices in Africa? AFR decisionmakers need to examine some cases whether they cover AID projects or not.

AFR decisionmakers also need some examples of successful transfers that have occurred under AID projects. They need to know which technologies, i.e., skills, practices, knowledge, have transferred to African beneficiaries under AID projects. Information on successful transfers will provide the kind of specific information required to enable decisionmakers to select interventions with higher payoffs. Please prepare an executive summary like the example enclosed on each project that shows evidence of people adopting the skills or practices AID projects have promoted.

Please include the name of the person who prepares the summary. We really have a difficult time finding out who prepares documents. For example, most PPs contain only the signature of the Mission Director. Do you know why most documents do not include the names of the writers anymore? Send executive summaries to Mary Coleman, AFR/DP/PPEA, Room 6742.

AFRICA EVALUATION GUIDELINES

Introduction:

The Africa Bureau requires all evaluation reports to cover the questions listed below. Evaluators should answer these questions in an executive summary of less than five pages. Missions may include other requirements in scopes of work for evaluations but they must include these questions. AFR needs this information to test bureau policies and procedures and to increase the dissemination of evaluation findings. The attached sample Executive Summary provides additonal guidance regarding the precise data AFR seeks from evaluations.

I. What constraint did this project attempt to relieve?

Does the project attack a labor, policy or other constraint?

Example: This project attempts to relieve the labor constraint that causes farmers to plant cotton later than the optimum time thereby reducing average yields by 25 percent.

II. What technology did the project promote to relieve this constraint?

Does the project, for example, promote a new planting technique,animproved seed, vaccination of cattle or a research system that involves, subsistence farmers and, accordingly, will enhance prospects for developing technologies that meet their needs?

Example: This project introduces a package of herbicides, fertilizers and training in their use which will decrease the labor requirements for weeding food crops and release the labor farmers need to plant cotton at the optimum time.

III. What technology did the project attempt to replace?

Do intended beneficiaries plant with a digging stick, use unimproved seeds, vaccinate cattle and receive only unusable technologies from government-sponsored Research?

Example: The intended beneficiaries now use hand hoes to weed their subsistence crops. The project proposes to replace them with herbicides.

IV. Why did project planners believe that intended beneficiaries would adopt the proposed technology?

Does the new technology provide substantial economic incentives? Does the labor saved offset sufficiently the cost of the technological package? Does the potential for increased yield offset sufficiently the risk and cost of using the improved seeds? Have planners obtained the opinions and point of view of the intended beneficiaries? "What is lacking at the moment in many areas of rural Africa is the incentive to change, not the ability or desire" C. J. Doyle, a profile of the African cultivator.

Example: Implementing the technology costs about forty dollars per hectare; it, however, enables the farmer to increase income per hectare an average of one hundred and forty dollars.

V. What characteristics did the intended beneficiaries exhibit that had relevance to their adopting the proposed technology?

What average education level do they achieve? What activities aside from farming do they engage in? Have they used herbicides or fertilizers?

Example: Few intended beneficiaries have achieved the functional literacy level; however, many of them have use fertilizer and also spray insecticides using the same kind of tanks required to apply herbicides. Accordingly, the farmers already have most of the manual skills required to apply the new technology.

VI. What adoption rate has this project achieved in transferring the proposed technology?

Why have or why have not intended beneficiaries adopted this technology?

Example: Over a five year period a project in Zambia achieved an adoption rate of 80 percent for the proposed technology. During that period, however, the price of cotton rose to a level about 50 percent higher than the price expected to prevail during the life of this project. Farmers adopted the technology in Zambia because they had an economic incentive. Systematic interviews with farmers in the project area infer that prevailing farmgate prices provide sufficient incentive for farmers to adopt the new technological package for food crops so they can plant cotton at the optimum time. Since demonstration trials began only six months ago, the project will not generate information on the adoption rate for another eighteen months.

VII. Has the project set forces into motion that will induce further exploration of the constraint and improvements to the tecnical package proposed to overcome it?

What incentives does the national research service have to continue working on the constraint once the project has terminated? Does the research service have connections with other research organizations working on the same problem? Has self-interest caused groups to organize and pressure the government to continue funding?

VIII. Do private input suppliers have an incentive to examine the constraint addressed by the project and to come up with solutions?

If private input suppliers at present do not have an incentive to examine this or other constraints, discuss how the project might assist in providing incentives to get the private sector involved in such activities. Can local enterprises produce the physical portion of the new technologies: implements, improved seeds, farm chemicals? Does the promoted technology provide incentives for private industry to involve itself in the ongoing improvement and marketing of the technology?

IX. What delivery system did the project employ to transfer technology to intended beneficiaries?

Does the project provide training in the use of the new technology to extension agents who in turn will train groups of farmers? What entities will the agents use to organize groups: cooperative leaders clan leaders, community leaders? Does the project plan to diffuse the technology through private input suppliers?

X. What training techniques did the project use to develop the delivery system?

What kinds of skills did the delivery system need to make the technology transfer and how did it obtain them? What methods did the project use to develop these skills and how long did it take? What characteristics did the trainees possess prior to receiving the training: education, experience, sex?

XI. What effect did the transferred technology have upon those impacted by it.

The new method of sowing corn impacted on the Temascalcingo region in several ways. It reduced cultivation costs and allowed many to return to cultivate their lands. This has slowed the migration of landholders to Mexico City. The new seeder, however, has not had a positive impact on those without landrights. Many of them depended on planting corn for employment. The new seeder almost eliminated the need for day laborers during the planting season. This has increased the migration of the landless to Mexico City. Another factor also influenced these changes. Dredging the river removed the final threat to flooding in 1972. This factor without doubt influenced people in making their decision to farm or not to farm.

(The article entitled "Appropriate Technology in Rural Mexico", by Billie DeWalt, published in Technology and Culture, January, 1978, provided the basis for this ficticious A.I.D. project.)

25 May 1982 (AFR/DP:HLM)

SAMPLE SAMPLE SAMPLE

(AFR/DP/PPEA has prepared this sample summary to guide AFR evaluation officers and others in preparing the Executive Summaries now required for each evaluation report.)

EXECUTIVE SUMMARY

Prepared by: Henry L. Miles, AFR/DP/PPEA

Date: May 14, 1982

Project: Small Farmer Improvement

Country: Mexico

Cost: $50,000

I. What constraint did this project attempt to relieve?

This project attacked the cost constraint to raising corn, the only cash crop available to farmers of the Temascalcingo Valley. Farmer's average harvests of 1500 kilograms per hectare yielded them $110. Cultivation costs averaged $46.00 leaving farmers only $67.00 to pay harvesting and transportation costs and to pay cultivating costs of the next year's crop. In years of severe inundations farmers stood to lose all their cultivation costs. As a result farmers had begun to engage in other occupations.

II. What technology did the project promote to relieve this constraint?

The project promoted an animal drawn plow seeder to cut the cost of cultivating corn.

III. What technology did the project attempt to replace?

The project attempted to replace the traditional planting technology, the digging stick.

IV. Why did project planners believe that intended beneficiaries would adopt the proposed technology?

The project planners believed that cost savings would provid an adequate incentive to adopt the plow seeder. Planting one hectare of corn with a digging stick required twelve person days of labor and cost an average of $14.40. Preproject studies estimated the costs of planting with a plow seeder at under $5.00 per hectare. Planting one hectare of corn using the plow seeder actually required two person days of labor and cost $3.20.

V. What characteristics did the intended beneficiaries exhibit that had relevance to their adopting the proposed technology?

The farmers' land holdings averaged about two hectares. They ha experience in using draft animals and some had used a plow to plant corn. To plant with a plow farmers would fashion a tube of maguey leaves or of metal, attach it to the plow and drop seeds through it as they walked behind the plow. However, farmers experienced low germination rates using this technique. These seeders did not deposit the seeds deeply enough. Farmers asked a local blacksmith to build a plow seeder that would deposit seeds deeper.

VI. What adoption rate has this project achieved in transferring the proposed technology?

The community of Puerto de las Piedras, located a few miles from Temascalcingo, illustrates the adoption rate of this innovation. Prior to 1957 farmers had only one satisfactory planting technology, the digging stick. Between 1957 and 1967 about half of the farmers had begun to use the makeshift plow seeder. The project introduced two improved plow seeders in Temascalcingo in 1967. We do not know when the first one reached Puerto de las Piedras. By 1973, however, all but two of the 146 people with land rights had adopted the plow seeder These two, a father and son team, rented a tractor to plow and seed their land. About thirty percent of the farmers owned plow seeders; the other seventy percent rented them.

VII. Has the project set forces into motion that will induce further exploration of the constraint and improvements to the technical package proposed to overcome it?

Yes, the project has mobilized the self-interest forces of the private sector to improve the technology and to reduce its cost (see answer to question VIII).

VIII. Do private input suppliers have an incentive to examine the constraint addressed by the project and to come up with solutions?

Yes. The seeder plow demonstrated to local blacksmiths that they could profit from making improved farm tools. The project assisted a blacksmith to design a plow seeder that would plant seeds at 20 centimeters, cover the seeds and retain firmly the seeding tube. The blacksmith produced the first two seeders in 1967. He sold them readily and produced others. By 1973 his sales had reached his produciton capacity of 200 seeders annually. He sold them for $20.00 each. Some buyers came from 50 miles away. The blacksmith could not afford a stamping machine which he needed to increase his production. Other blacksmiths in the area also began producing the seeder and selling it for about the same price. All of the blacksmiths sold as many seeders as they could or wanted to produce; however, they feared that one of the large plow manufacturers in Monterrey would begin producing the seeder in quantity and at a lower price.

IX. What delivery system did the project employ to transfer technology to intended beneficiaries?

The forces of the market transferred the plow seeder technology from the Temascalcingo Valley to other communities and regions.

X. What training techniques did the project use to develop the delivery system?

The project did not need to develop a system to deliver the improved technology. The project relied entirely upon the self-interest forces of the market to deliver it. Farmers became converted to the plow seeder by watching other farmers use it. The interaction among farmers and blacksmiths facilitated the transfer of the technology without the intervention of research entities or extension agents.

XI. What effect did the transferred technology have upon those impacted by it.

The new method of sowing corn impacted on the Temascalcingo region in several ways. It reduced cultivation costs and allowed many to return to cultivate their lands. This has slowed the migration of landholders to Mexico City. The new seeder, however, has not had a positive impact on those without landrights. Many of them depended on planting corn for employment. The new seeder almost eliminated the need for day laborers during the planting season. This has increased the migration of the landless to Mexico City. Another factor also influenced these changes. Dredging the river removed the final threat to flooding in 1972. This factor without doubt influenced people in making their decision to farm or not to farm.

(The article entitled "Appropriate Technology in Rural Mexico", by Billie DeWalt, published in Technology and Culture, January, 1978, provided the basis for this ficticious A.I.D. project.)

Appendix III SUGGESTIONS FOR CLARIFYING EVALUATION GUIDELINES

These suggestions for clarifying evaluation guidelines evolved directly from the subquestions developed at the working sessions and the suggestions made by participants in the seminars held on May 10-12, 1983, on technology transfer and the evaluation guidelines.

1. What constraints did this project attempt to relieve?

   a. Describe each constraint in sufficient detail to permit measurement of the influence of project technology on the constraint.

   b. Cite the method used to locate the constraint and the sources of information utilized in identifying it.

   c. Does the project address a binding constraint? If not, describe the binding constraint and the strategy for relieving it. For example, price policy may restrain production and make improved technologies ineffective and prevent their adoption. In such cases explain plans for bringing about a change in the price policy.

   d. Relate the constraint to the Country Development Strategy Statement (CDSS).

   e. Have the government and propective clients become aware of the constraint?

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f. What prevents the private sector from addressing the cited constraints?

2. What technologies did the project promote to relieve the constraints?

a. Provide a complete description of the technology the project promotes among end users.

b. Compare the complexity of the new technologies with technologies currently used.

c. Comment on the divisibility of the new technology and the feasibility of partial adoption e.g. plant only one row of a new crop.

d. Estimate the cost of the new technologies with those of currently used technologies.

e. Specify the skills needed and the changes in behavior required by clients to adopt the new technology.

3. What technologies did the project attempt to replace?

a. Describe in detail preproject technologies.

b. Estimate the cost of preproject technologies.

c. Discuss the divisibility of preproject technologies.

d. Specify the skills required by preproject technologies.

e. What have potential adopters done to address the constraint?

4. Why did project planners believe that intended beneficiaries would adopt the proposed technologies?

a. Compare the out-of-pocket costs of the new and the preproject technologies.

b. Comment on risk factors such as higher front end cost and the attitudes of potential adopters towards these risk factors.

c. Comment on the compatibility of traditional values with adoption and other factors influencing adoption such as complexity of the new technology, its communicability and its acceptability to opinion leaders.

d. Cite the sources of information used to answer this question.

e. Comment on the extent of diffusion of information about the new technology.

f. Comment on the impact of project technology on work schedules.

5. What characteristics did the intended beneficiaries exhibit that had relevance to their adopting the proposed technologies?

a. Provide information such as education background, amount of family labor available, family size, income or net worth, degree of social participation, access to the cash economy and attitudes toward traditional or modern values.

b. Indicate the clients' demand for labor throughout the year and discuss seasonal peak demands for labor.

c. Cite the sources of information utilized to answer this question.

6. What adoption rate has this project achieved in transferring the proposed technology?

a. Describe what constitutes adoption.

b. Cite the precise method of computing the adoption rate and identify the variables used in the computation. For example, adopters divided by potential adopters. (Define potential adopters)

c. Cite the sources of information used to answer this question, the values of the variables and a description of the methodology used.

d. Describe factors impeding adoption and constrainst not previously anticipated which affect adoption.

7. Has the project set forces in motion that will induce further exploration of the constraint and bring forth improvements to the technical package proposed to overcome it.

a. Describe the forces, if any, set in motion by the project to build a constituency that supports exploration of the constraint. Indicate how these forces will work to induce further exploration of the constraint and improvements to the technology.

b. Cite public sector linkages that will provide access to new knowledge related to the constraints attacked by the project.

c. Describe any actions which adopters have taken to sustain the technology after project funds disburse.

8. Do private enterprise suppliers or buyers have an incentive to examine the constraint addressed by the project and come up with solutions?

a. Discuss why the private sector has not audress the constraint.

b. Provide information on sources of inputs needed to sustain the technology and assess the demand for the prouuct affected by project technology.

c. Could one reasonably expect to develop a market for the promoted tecnnology?

d. Describe how the project seeks to create a market for tne technologies promoted.

e. Discuss market for the product impacted by tne project technology and whether it will handle the increased production.

f. Cite the sources of information used to answer tne questions.

9. What delivery system did the project employ to transfer tne technology to intended beneficiaries?

a. Describe the delivery system and each major component of it.

b. For each component of tne delivery system describe tne causal relationship that leads to extension and to tne adoption of project technologies.

c. Describe the indicators used to measure the effectiveness of the delivery system.

d. Do indigeneous delivery systems complement or compete with the system assisted by the project: for example, indigenous health healers versus health clinics.

e. Assess the sensitivity of adoption to adherence to the implemention schedule as well as essential actions to compensate for key events which may have not finished on schedule.

f. Specify the skills needed to operate the delivery system relative to those available.

10. What technology does the project intend to transfer to the delivery system and what techniques will the project use to make the transfer?

a. Describe the technology, if any, transferred to the delivery system.

b. Describe the training provided for change agents or other delivery system personnel.

c. Describe the methods used to communicate project technology to potential adopters.

11. What effect did the transferred technology have on those impacted by it?

a. Describe the effects of the technologies on adopters and other beneficiaries.

b. Describe the means used to measure the effects of the project.

c. Describe the causal relationship between adoption of project technologies and their impact.

d. Mention any complementary benefits of the technology transferred.

Appendix IV WORKSHOP AND SEMINAR NOTES

Contents of Appendix IV

IV-1 Summary of the Working Sessions Held During the Week of February 28, 1983

IV-2 Subquestions to Evaluation Guidelines Developed During the Working Sessions, February 28 - March 4, 1983

IV-3 Formal Comments on Seminar on Technology Transfer and the Evaluation Guidelines, May 10-12, 1983

IV-4 Technology Transfer Seminar Participant Response, May 10-12, 1983

IV-5 General Comments by Participants to the Seminars

Appendix IV-1 SUMMARY OF THE WORKING SESSIONS HELD DURING THE WEEK OF FEBRUARY 28, 1983

Cost Effective Alternatives

On the subject of cost effective alternatives for identifying and obtaining information required by the Africa Bureau's evaluation guidelines, the consensus was as follows:

The most cost effective method of applying the 11 evaluation questions to development projects in Africa includes preparation of an evaluation plan by evaluation experts early in the life of a project.

The evaluation plan would specify the information requirements for each project. Since it is obvious that information requirements may vary widely between projects and the scope of the evaluation would be based on criteria such as:

(a) size and complexity of project and the total amount of project funding

(b) complexity and uniqueness of the technology to be employed

(c) complexity and uniqueness of the issues to be addressed

(d) uniqueness and formidability of constraints to development

(e) complexity of the delivery system to be employed

(f) cultural and political considerations

The evaluation plan should also identify the project monitoring information which is needed in addition to the information normally collected. The plan should specify case studies, anthropological studies or ethnographies, baseline surveys, mid-term evaluation requirements and/or final surveys and evaluations.

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The evaluation experts would supervise the selection and training of the evaluation information system and data collection contractor and provide advice to the mission and the contractor at regular intervals and critical points during the project. Critical points may include the mid-term and final evaluations.

Constraints

On the subject of constraints to development, information developed is summarized below.

The technical constraints to development should always be defined in addition to political, economic, or cultural constraints.

Project planners and evaluators should determine if the constraint can be relieved within the project time frame and plan their evaluation accordingly.

Technology transfer may relieve an immediate constraint and create or unveil another post project constraint. Evaluations should deal with these post project constraints and the feasibility of adopting project technology to relieve them or recommend alternative technology to deal with them. Foreign exchange should always be considered as a possible post project constraint.

Cost-benefit analysis is an appropriate method of identifying constraints in many instances.

The establishment of an institutional structure should always be considered when searching for constraints as well as governments' willingness or past performance to establish institutions compatible with project goals and technology.

Monetary constraints such as run-away inflation or complete lack of confidence in the monetary system could constitute an ultimate constraint, meaning that this constraint must be overcome before attempting to relieve any other constraints or before the technology transfer can be sustained.

An ultimate political constraint may exist within AID on evaluation which is manifested by inadequate provision of money and resources for conducting evaluations.

Missions should be encouraged to forecast proximate outcomes at the beginning of a project.

"Out of pocket" or "front end" costs should be considered when attempting to identify constraints to development.

Technology

On the subject of technology transfer the propositions set forth below were promulgated.

The successful transfer of technology may solve the immediate problem but it usually will create a new, more solvable problem. Evaluators should expect to see a long term process set in motion that impacts the immediate problem. Successful transfer of technology includes the transfer of the ability to adopt the process to changing needs or situations.

Technology equates to problem solving. The nature of the problem must be understood before a strategy can be developed and technology selected to relieve the problem. Defining the problem is the first major hurdle and typically insufficient resources are provided for it. This results in incorrect identification of constraints.

Evaluators should ask if the technology package which includes the delivery system is a sustainable process.

Delivery Systems

The propositions presented include the following.

It is reasonable to expect that a viable delivery system will be in place at the end of the project?

At the end of the project, what capability will remain?

In Africa an ethnography should be considered for every project.

What should the ratio of cost of evaluation to project cost be? It may not be unreasonable for evaluation costs to exceed project costs on small projects. The information and data collection may otherwise be inadequate for identifying constraints.

Specify the technique and range of techniques currently in use.

Look at all of the inputs necessary for the new technology to function.

Are there complimentary social and economic inputs needed to support the new technology?

At this point in the working session an extended discussion was held on the problems of communicating the meaning of the 11 questions to AID officials, mission and contractor personnel untrained in evaluation and technology. It was concluded that the most cost effective alternative for accomplishing this would be a subordinate set of questions to each question that would direct users to the proper answer to each question. In addition to general

subquestions it was decided that specific questions for each sector would be needed eventually to clear up issues peculiar to the sector.

Moreover, an evaluation plan would be needed for each project that would set forth specific information and data collection requirements for the project.

The remainder of the working session was used in developing the subordinate questions to each question. This effort is documented in enclosure 1.

Appendix IV-2 SUBQUESTIONS TO EVALUATION GUIDELINES DEVELOPED DURING WORKING SESSION, FEBRUARY 28 THROUGH MARCH 4, 1983

Subquestions

I. What constraints did this project attempt to relieve?

a. What is this project attempting to do and what keeps this from happening without project implementation?

b. What constraints did this project attempt to relieve and in what way do these constraints resist achievement of project goals and purposes?

c. What is preventing the private sector from addressing these constraints?

d. What AID policies are implemented if these constraints are relieved?

e. Are there alternative, more cost-effective ways of relieving these constraints other than the technology transfer proposed by the project?

What alternative to the project technology were considered?

f. Does the project attack a labor, policy, technical or other constraint to development?

g. How were these constraints identified or determined?

II. What technology did the project promote to relieve this constraint?*

Note: Dr. T. DeGregori will prepare a one or two page explanation of what technology is.

a. How will the technology proposed by the project relieve the constraint?

b. Will the technology proposed by the project increase production and what evidence is there that it will?

c. Will the proposed technology create a relative advantage, an economic advantage or a marginal cost which is lower than competing technologies?

d. How does the cost of using the new technology, especially the front end costs, compare with the existing technology?

e. What hardware or physical resources are involved in the transfer of the proposed technology?

*Refers to technology directed at end user only. Use question 10 for technology directed at the delivery system.

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f. What behavioral changes are brought about by the proposed technology?

g. What ideas, skills, knowledge, processes, techniques, practices or software are being transferred by the proposed technology?

h. How would you describe the process and what it does in layman's terms?

III. What technology did the project attempt to replace?

a. What are the potential adopters doing now and how are they addressing this problem now?

b. What knowledge, practices, skills, etc, are needed in implementing the existing or preproject technology?

c. What are the environmental conditions now?

d. What technology gap, knowledge gap, skills gap and hardware gap exists between the preproject technology and the proposed project technology?

IV. Why did project planners believe that intended beneficiaries would adopt the proposed technology?

a. Is there an economic incentive or a relative advantage to adopting that can be readily perceived by the potential adopters?

b. Are there risk factors or out-of-pocket costs and does it relate to the relative advantage?

c. Are there traditional values, cultural or behavioral factors that may affect adoption?

d. Is labor cost per unit of output reduced by the project compared to existing or alternative technologies?

e. Does a labor or seasonal labor, or land constraint now (preproject) exist and how will the proposed technology affect this?

Does the new technology permit more efficient or extensive or intensive use of land, labor or other factors of production?

f. What are the preproject needs of the country(s) and area(s) targeted by the project?

g. How is the energy being used under preproject technology and what affect will the project have on this use?

h. What basic needs such as food, shelter, health, and clothing will be affected by the project and in what way will these be effected?

i. What other incentives or disincentives exist that may influence adoption of project technology?

j. Are there any environmental factors that will offset the good done by the project?

k. What effect will the project have on nutrition, water, endemic disease, and education?

l. What sources of information were used in answering these questions?

Has a feasibility study been conducted?

Have any case studies or baseline surveys been conducted?

m. What is the role of private enterprise and how will it be affected by the project?

n. What skills will be acquired by target beneficiaries and what markets exist for these skills?

o. What impact will the acquisition of skills or education provided by the project have on the composition of the labor force or urban drift?

Will the labor classification and labor market of project beneficiaries be changed by skills or education provided by the projects?

V. What characteristics did the intended beneficiaries exhibit that had relevance to their adopting the proposed technology?

a. What are the potential adopters doing now that would indicate a willingness to adopt project technology?

Have they shown an interest in similar projects?

Can you cite evidence of this interest?

b. Has a household survey or has farming system research been conducted which can provide authoritative information on characteristics of adopters and potential adopters?

c. What research or information requirements were specified in the PID, and in the evaluation plan for the project?

d. How much funding (PD & S) was made available for research?

e. Do any social organizations exist that will impede or faciliate use of the project technology?

f. Describe the educational level of potential adopters?

g. How will the availability of labor be affected by the project?

Is there a time constraint or potential adopters that will affect their availability or limit their participation in the project or in adopting the project's technology?

VI. What adoption rate has this project achieved in transferring the proposed technology?*

a. How will you measure adoption rate?

b. In measuring adoption, does adoption of part of the technology constitute adoption or does partial adoption constitute adoption? For example, a farmer could elect to use the seeds and fertilizer but not to irrigate or follow the planting schedule or the farmer could adopt the whole package in 3 acres out of 8 acres.

c. What measurement of interest and awareness will be used in the early years of the projects to indicate later year results?

d. How do you distinguish between successful and unsuccessful adoption?

VII. Has the project set forces in motion that will induce further exploration of the constraint and improvements to the technical package proposed to overcome it?

a. Describe the forces that the project could set in motion.

Were any of these set in motion by the project?

b. Will these forces sustain themselves in addition to addressing the constraint?

c. Is the project technology compatible with further development of technology in the project area or related areas?

Is the technology complimentary to alternative technologies?

In what way will it facilitate further technology transfer?

d. What indigenous institutions or forces will be created that will sustain the project?

e. Have we created an institutional structure as a part of the project that will serve as a delivery system?

f. Does the institution have the capability of sustaining itself and promoting the technology politically and economically?

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*Refers to technology directed at the end user only.

g. Do you foresee the creation of linkages that give the beneficiaries access to new knowledge as the project develops?

h. What actions will the intended beneficiaries have to take to sustain the new technology after project funds are exhausted and what actions do you foresee them taking?

i. Do you foresee that this project will create public sector linkages that facilitate the transmission of knowledge about new and improved technology?

VIII. Do private sector suppliers or buyers have an incentive to examine the constraint addressed by the project and come up with solutions?

a. What are the reasons why the private sector can not now address and solve the problem addressed by the project?

b. Is there a reasonable expectation that a market can be developed locally, nationally, or internationally?

c. What market constraints, technical or informational, including lack of skills, can be anticipated that will discourage the private sector from addressing this problem?

d. Does this project seek to create or enhance any market mechanism that will be capable of sustaining the project in later years?

e. In what way do you anticipate that the market mechanisms will sustain the project technology after project completion and facilitate diffusion or transfer of technology?

In what way is this complementary to VII d?

f. Does the project assist in creating or reinforcing private sector enterprise capable of delivering to the market the inputs needed to sustain the technology after project funds stop?

IX. What delivery system did the project employ to transfer technology to intended beneficiaries?

a. How will each step in the implementation of the delivery system lead to actual adoption and extension of technology? (ambiguous)

b. In each step of the delivery system, what are the achievements that will be measured and mentioned? (ambiguous)

c. Is there an indigenous delivery system and how does it relate to or complement or compete with the system proposed by the project?

d. Is the indigenous system capable of supporting project implementation requirements? If no, are there modifications that could be made to the indigenous system that would enable to fulfill the project requirements?

e. If the delivery system is not in the private sector, what are the arguements for and against having it in the private sector on this project?

f. What institutions will the project utilize or interface with or create in implementing the project delivery system?

g. In establishing the delivery system, can you anticipate any tension or friction that will occur?

h. Has a baseline been defined or described from which the delivery system starts and if so, how would you describe the gasoline? What are the skill levels and educational levels of the change agents?

i. What skill levels and manpower are needed to implement the project delivery system and how much training is anticipated? (Move to Q 10)

On what basis was the decision made to have a training program of this type? (Move to Q 10)

j. What are the causal relationships between adoption and delivery systems?

k. How many will be trained and how many will stay on the job and practice in the field during the project and subsequent to its completion? (Move to Q 10)

l. What are the competing demands for these skills and has a policy or practice been adopted by this project that will enhance the retention of key employees during the life of the project and subsequent to it? (Move to Q 10)

m. How would you describe the step-by-step logical relationship or causal relationship between the delivery system and the transfer of project technology?

n. How will training be accomplished? (Move to Q 10)

o. What training techniques or methods will be used at each step of the delivery system? (Move to Q 10)

p. What training techniques or methods were used to train change agents, administrative personnel, delivery agents and adopters? (Move to Q 10)

How many received training? (Move to Q 10)

q. How does the delivery system create an awareness of the project technology?

r. How does the delivery system develop an interest in project technology?

s. How does the delivery system enhance evaluation and testing of project?

t. How does the delivery system enhance adoption and sustain it?

u. What kind of management information and monitoring system has been established to evaluate project implementation? In addition to the obligation of funds, what events or major milestones will be monitored and reported?

v. How sensitive in adoption to adherence to the project implementation schedule and what adjustments are needed, if any, if key events are not completed on schedule?

w. What information is collected by the project monitoring system that is relevant to carrying out AID policy?

X. What technology does project intend to transfer to the delivery system and what techniques does project intend to use to make the transfer?

Note: This question was revised subsequent to the working session.

XI. What effect did the transferred technology have upon those impacted by it?

a. For evaluation purposes, what complementary or unexpected benefits have resulted or are expected to result from the project?

b. Can any undesireable outcomes or results from adoption of project technology be anticipated?

c. To what extent can project benefits or outcomes be expected to enhance development or retard it?

May 16, 1983

MEMORANDUM TO: AFR/DR, Henry Miles

FROM : PPC/EA, Alan Rufus Waters

SUBJECT : Evaluation Strategies

The visit of Tom DeGregori seems to have been outstandingly successful and you are to be warmly congratulated on the quiet and reasonable way in which you have tackled this extremely sensitive topic. I enjoyed Tom's seminar and felt that his general and scientific approach to the subject was valuable and caused minimal disturbance.

There are a couple of general and positive ideas that you might consider in continuing to evolve your questions. First, this is strictly a supply side approach in economic terms. In other words, you are asking questions which elicit information about cost. This is very good, but there is another side to any transaction.

You do turn to the consumer or the demand side in Question 4, I sense that this a section which might be expanded or at least edited to be more specific.

The basic premise of Question 4 is very good. However, we might ask whose viewpoint should really rule. By this I mean that I would ask whether it is the project planners who should be induced to believe that the intended beneficiaries would adopt the proposed technologies, or whether direct access to the intended beneficiaries would not be more appropriate.

We have a whole profession which has emerged as a generic entity in the last two decades and now stands with full respectability on its own two feet: marketing. Marketing studies the demand side of the equation and it has as yet had little impact on the activities of this Agency.

In order to accept or reject any proposal it is desirable to know the earliest point at which rejection becomes inevitable. Therefore, the approach should be to discover first if there exists an identifiable demand for the final services or the commodities which the proposal is intended to generate.

Also, there is the question of cash flows which are necessary for the proposed activity to continue functioning. You discuss

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this in your Question 4a, however, this matter of working capital and cash flows is the subject of a separate section of the American Finance Association and is a recognized area of study within that profession and that organization. Whether an activity is in the hands of government officials or private individuals it still has to generate sufficient recurrent expenditure. Also, it has to have funds available to meet outflows, not only in accounting form but in actual cash at the appropriate times. This area should be tackled.

In Question 4b you mention the question of risk. This is important, but once again it is the subject of professional study by a major segment of the accounting profession and perhaps a good CPA whose interests lie in the measurement of risk could address this issue in more specific terms.

In Question 4d you might recognize that prices are the most effective source of information to people in a widespread market and to potential and actual producers of services and commodities. Therefore, some recognition or discussion of the role of prices as information indicators, as well as their rationing function, might well be included.

Finally, the impact of project technology on work schedules in Question 4f is an excellent idea and relates immediately to the cost of labor. There is the underlying anthropological issue of what it takes to induce people to work an unusual schedule, but from the standpoint of a project the issue is one of the outlay necessary to induce a particular schedule. I think an economic approach to this would be in terms of labor costs.

To repeat, I think you are doing an outstanding job and I want to support you in every way. I will be happy to generate some further comments if you feel they are fruitful.

cc:
AA/AFR, F. S. Ruddy

Appendix IV-3.2 FORMAL COMMENTS

May 12, 1983

TO : AFR/DP/PPEA/E, Henry Miles

FROM : PPC/E/PES, Michael Zak

SUBJECT: Suggestions for Clarifying Evaluation Guidelines

As you requested on May 11, I offer the following comments on your May 4 draft on the subject.

1. Beneficiaries: This appears in several of the questions. There may be more than one set or group. PIDs and PPs often don't capture the different groups. An example is the Lesotho PP for Basic and Non-Formal Education Systems currently under review. Our comments on the PP were sent to you yesterday and therefore not repeated. In the Lesotho instance teachers will benefit initially through upgraded skills. The training is but a means to broader ends - a more efficient and better education for students as measured by improved school performance and increased rural income and employment. Impact on students as beneficiaries is not to be found in the PP.

2. Comments keyed to Questions:

(a) Questions 1-5: are descriptive and not evaluative. By changing tense (from past to present) you should be able to track data from the project design stage.

(b) Questions 6-8: are legitimate evaluation questions.

(c) Questions 9-10: are descriptive and not analytical. For example, it would be useful to know if the "technology" didn't work why it didn't work, what alternatives were chosen or rejected or available, etc. Where training is involved it would help to know whether the training was relevant useful etc.

(d) Question 11: definition of beneficiaries is required. See my earlier comment.

3. Bottom line: Your guidance is now up to eight pages. Is it realistic to expect people to have or devote the time to complete the guidelines for each project? Pruning is suggested.

INFO: PPC/E, R. Blue
M. Hageboeck
J. Murphy
PES RF

Appendix IV-3.3 FORMAL COMMENTS

MEMORANDUM

TO: Bureau Evaluation Officer, Henry L. Miles AFR/DP

FROM: Andrew B. Sisson AFR/PD/SWAP

SUBJECT: Evaluation Guidelines

Date: May 13, 1983

Another question that you might consider adding to yuor current list of eleven in "Suggestions for Clarifying Evaluation Guidelines" is:

What were the unintended impacts of the technology?

Possible clarification points are:

a. Define the unintended beneficiairies and describe their benefits.

b. Define the unintended losers and describe their losses.

c. Determine if there were unintended consequences of the technology which prevented or discouraged its adoption.

A brief example of a possible response: the introduction of irrigated rice in the SEMRY Rice Project in North Cameroon (financed by the World Bank, French Caisse Centrale, and Cameroon Government).

Unintended impacts include: increased incidence of schistosomiasis, worsened social relations among many farmers, improved fishing inside the project area, worsened fishing and cattle grazing outside the project area.

a. Wealthy town merchants who gained revenues by selling rice on the parallel market.

b. Fishermen and cattle herders west of the project area who suffered from diminished river flows and poorer pasture stemming from the irrigation works.

c. Farmers claiming that irrigated rice has increased illness, causing them to participate less in the project.

If you have questions, please call at 632-8242.

Appendix IV-3.4 FORMAL COMMENTS

May 12, 1983

Hank,

In general, I agreed with Mike Zak and others who stated that the first five questions should come right from the PP. The problem is they often don't. Our design process and documentation is so convoluted. I view the design process in a more simple way. I try to answer the following questions:

-- What is the problem? Why are current technologies inadequate?

-- Do we have a technology which can be used to solve the problem?

-- If so, what will be done, by whom, where, for how long, and how much will it cost? (i.e., what is the delivery system?)

Just thoughts, but maybe you want to suggest the Hariadene that these key questions be answered in the executive summary for a project paper.

Regards,

Rose Marie

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Appendix IV-4 SUMMARY OF PARTICIPANT RESPONSES

The questionnaire used for obtaining responses from participants is included in this section following this summary. Of the approximately 150 people attending the seminars, 24 returned the questionnaire. The sample should be regarded as a nonprobability sample of the convenience or man-on-the-street type. Essentially, it indicates the responses of those with sufficient interest and time to respond. Many of the respondents were senior officers at AID.

1. First heard of the Africa Evaluation Guidelines

At seminar	7
Other 1983	3
In 1982	8
Prior to 1982	4
Nonresponse	2
Total	24

2. Number of Project Evaluation Summaries read during the

	0	1-2	3-6	7 or more	Nonresponse
Last 3 months	7	12	3	1	1
Last year	4	5	9	5	1

3. Uses made of information obtained from evaluation summaries

Used for:	Yes	No	Nonresponse
Different project	8	12	4
Action	14	6	4

4. Number of respondents who have ever read an executive summary.

Have read	11
Have not read	10
Nonresponse	3

5. Number of participants who want their name placed on distribution list for executive summaries

Yes	17
No	4
Nonresponse	3

6. Number of participants who believe that the evaluation guidelines will provide the project evaluation type information to support their decisions.

Provides information needed	15
Does not provide information	5
Nonresponse	4

7. Number of participants who do not believe the evaluation guidelines are sufficient for their information needs who specified additional information needs.

Specified additional information needs	1
Did not specify additional information needs	4

8. Question that participants considered to be most important:

	Count
First in importance	
Question 1	10
Questions 7, 9, 11	2 each
Questions 4, 5, 6, 10	1 each
Nonresponse	4
Second in importance	
Question 2	7
Question 4	3
Questions 1, 7, 9, 11	2 each
Questions 3, 5	1 each

9. Participants who used evaluation findings in their work

Used	13
Not used	6
Nonresponse	5

10. Order of importance of information obtained by participant from seminar.

On guidelines	12
On technology transfer	3
On other things	2
Nonresponse	7

11. Participants expressing an interested in attending a seminar on technology transfer.

Yes	19
No	3
Nonresponse	2

12. Duties of Respondents

Desk	6
Project	6
Backstop	2
Other	8
Nonresponse	2

Appendix IV-4.1 SUMMARY OF PARTICIPANT RESPONSES

TECHNOLOGY TRANSFER SEMINAR
PARTICIPANT RESPONSE
MAY 10-12, 1983
(427G)

1. When did you first hear of the Africa Evaluation Guidelines?

   At time of seminar Yes 7 No ___
   Other 17 Year: 1983 3 1982 8 Prior to 1982 4 NR 2

2. How many Project Evaluation Summaries have you read in the past three months? _____ during the past year? _____

3. Did you read the summaries to obtain information for a different project? _____ or in connection with an action on the project covered by the evaluation? _____

4. Have you read an Executive Summary prepared in response to the AFR Evaluation Guidelines? Yes ____ No ____

5. Do you want your name placed on the distribution for such Executive Summaries? Yes _____ No _____

6. In your opinion do the questions cover the project evaluation type information to support your decisions? Yes _____ No _____

7. If no, please indicate in the document entitled "Suggestions for Clarifying Evaluation Guidelines" the additions or modifications needed to get the information that you need.

8. Please indicate in rank order the five questions in the guidelines that you consider most important.
   1st _____ 2nd _____ 3rd _____ 4th _____ 5th _____

9. What specific evaluation findings have you used in your work during the past year?

10. What information that you obtained in the seminar do you consider the most useful?

11. Would you like to attend a seminar dealing with measuring the transfer of technology?

12. Please describe briefly your current duties.

NR = nonresponse

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Appendix IV-5 GENERAL COMMENTS BY PARTICIPANTS TO THE SEMINARS
Held on May 10-12, 1983

IV-5.1 Comments on the 11 Questions

Question 1

1. Insert the word to development after constraint.
2. Why not substitute the word "problem" for the word "constraint."

Question 2

1. Substitute "address" for "relieve" and "problems" for "constraints."
2. Substitute "inputs/interventions/methods/practices" for "technologies."

Question 3

1. Insert the words "or improve" after "replace."
2. Delete "technologies" and insert "methods/practices."

Question 4

1. Delete "technologies" and insert "method/processes/procedures."

Question 5

1. Delete "technologies" and insert "methods."

Question 6

1. Delete "technologies"

Question 7

1. Delete "constraint" and insert "problem" and delete "bring forth" and insert "cause" further."
2. Reword to emphasize that this question refers to public sector.

Question 8

1. Delete "come up with" and insert "cause."

Question 9

1. Delete "employ" and insert "use."

Question 10

No comments

Question 11

No comments

General Comments

1. The 11 questions should be addressed at the project design stage. Baseline information should be collected as needed to facilitate project planning and redesign. The real constraints to development should be identified.

2. More attention should be given to cost data - out of pocket costs and total costs.

3. Ask if the project planners have talked to potential adopters or intended beneficiaries.

4. Were field surveys conducted? How were they conducted?

5. More information is needed on the amount of labor and work scheduled.

6. People doing evaluations are not qualified. Evaluation gets only minimum support. This stems from rotation of mission directors who are concerned with their own immediate problems. Short term attitude in missions works against evaluation.

7. CDSS should specify evaluation. Then mission would do it. Some of the 11 questions should be answered at the PID stage.

   Note: This comment was made at almost all sessions.

8. Project designers are usually not good implementors. They usually do not distinguish between techniques and technologies. from frequently forces approvals without answers to questions.

9. Project design should be a rolling design. Solve problems as we go.

10. Baseline data lacking in many cases. Questions cannot be answered properly without it.

    Note: This comment came up at all sessions. Question 4 should include population density.

11. Questions cannot be answered without adequate baseline data.

12. A sector assessment should be a prerequisite to project design.

13. Private enterprise is hard to encourage in Africa.

14. The executive summary is great for high level presentations but does not contain enough detail for the working level.