PRIORITY AREAS AND OPPORTUNITIES FOR COOPERATION: INNOVATION FOR ENVIRONMENT, ENERGY, AND THE ECONOMY

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The American papers in this volume seem to support the view recently articulated by Robert Kuttner that "The twin issues of environmental and energy policy suggest the utter failure of laissez-faire approaches."[1] Taken together, U.S. culture (faith in the individual and in the marketplace), institutions (fragmented, decentralized) and politics (incremental, adversarial) add up to a history dominated by the notion that economic benefits, energy benefits, and environmental benefits are inherently incompatible. The existence of well-established special interests in each of these three domains has resisted integration and anything approaching policy coherence. A continuation of our piecemeal approach to policy-making seems inevitable. Yet a recent report by the Carnegie Commission on Science, Technology, and Government has challenged this conventional wisdom. It notes:

> The many faces of the environment-energy-economic challenge are, and will continue to be, of such priority that more effective organization and decision making must be put in

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[1] Robert Kuttner, The End of Laissez-Faire: National Purpose and the Global Economy After the Cold War, New York: Alfred A. Knopf, 1991, p. 278.

place in the U.S. government. Given the excellence of our environmental sciences, our capability in many fields of energy technology, and the leverage of our economy on world economic trends, the United States can be in a position to provide world leadership in harmonizing environment and development.[2]

What are the sources for this optimism? American strengths in **science and technology** are seen as the keys to resolving energy-environment-economy (E3) problems. Unfortunately, the Commission's report is long on description and short on prescription--very little new is contained in the recommendations section. But the idea that scientific and technological capabilities are at the heart of our future resolution of the E3 mess is right on target. Now this doesn't mean the traditional U.S. fascination with "technological fixes," which are partly responsible for the creation of our environmental and energy troubles. Instead, the optimism is justified because there is a new technological imperative at work in the world today--a "paradigm shift" in the way technological innovation takes place. And this shift has dramatic implications for the entire set of issues surrounding E3 interactions. The shift has special relevance for the organizations and institutions responsible for **governance** in the E3 arena. Governance refers to the joint

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[2] Carnegie Commission on Science, Technology, and Government, E3: Organizing for Environment, Energy, and the Economy in the Executive Branch of the U.S. Government, New York: Carnegie Commission, 1990, p. 2.

public-private responsibility for "steering" a modern society, and the label is chosen deliberately to move beyond the parochial idea that government alone can solve these kinds of problems.

The New Paradigm of Innovation

As with many important events these days, the first concise description and analysis of the new paradigm came from Japan. Fumio Kodama, in particular, has provided thoughtful and articulate assessments.[3] Kodama admits we still have only a rudimentary understanding of what the new paradigm involves, but it is possible to delineate a few of its basic characteristics. Like a number of observers, he sees ideas replacing other factors of production. He says that companies that succeed have to be very adaptable and capable of managing increasingly diversified technologies. These companies must also master the pace of innovation--very rapid waves of technological change follow each other. To miss a wave is to be out of the game. Monitoring global markets has become more important in order to identify the need or demand for a particular technology. Early articulation of that demand drives the innovation process. Similarly, monitoring enables companies to "fuse" existing technologies (as in the mechatronics revolution, combining mechanical and electronics devices) rather than investing in efforts to achieve radical breakthroughs. Across the board, institutional innovation is critical to maximize the potential of new

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[3] Fumio Kodama, Analyzing Japanese High Technologies: The Techno-Paradigm Shift, New York: Pinter Publishers, 1991.

technology. Moreover, cooperation among institutions (especially international cooperation) generally facilitates innovation by identifying multiple technological options. Taken together, Kodama calls this the "new industrial order," and he attributes much of Japan's success to the fact that the existing Japanese system happens to fit it.[4]

Very similar assessments have been made by a study funded by the U.S. Defense Department's Manufacturing Technology Program and the Iacocca Institute at Lehigh University. The study's authors argue that **"agile"** manufacturing systems, capable of combining technologies, management structures, and social values into powerful competitive enterprises are replacing traditional mass production systems across the globe. Agility refers to an extraordinary capability to meet the rapidly changing needs of a marketplace--to be able to shift quickly among product lines in real-time response to consumer demands. Agility requires flexible production technologies that are integrated with the skill base of a knowledgeable work force by adaptable management structures that stimulate cooperative initiatives within and between firms.[5]

Evidence for the paradigm shift can be found in the Japanese automobile production and assembly operations. According to the

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[4] Fumio Kodama "Changing Global Perspective: Japan, the USA and the New Industrial Order," Science and Public Policy, December 1991, pp. 385-392.

[5] Roger N. Nagel and Rick Dove, 21st Century Manufacturing Enterprise Strategy: An Industry-Led View, Bethlehem, PA: Iacoca Institute, Lehigh University, November 1991, Volume I.

most comprehensive study of the auto industry to date, something called **"lean production"** has replaced mass production in Japan. Manufacturing itself has been revolutionized. A lean production facility produces cars with less of everything: less capital, less work space, etc. Yet it produces cars with higher quality, more model varieties, with tighter links to consumer needs. Operating without an organizational "safety net" (fewer backup workers, or much less inventory, for example) does make lean production a vulnerable, fragile activity. Ironically, however, this turns out to be a strength. Vulnerability mandates recriprocal obligations and interdependence among all participants. And the participants increasingly involve individuals from diverse organizations (corporations, think tanks, government, etc.). What is required is combining the knowledge and skills of groups in ways that have not been done before to produce technologies that have never existed.[6]

Lean production is being transferred by the Japanese to the U.S. As of late 1991, seven Japanese auto companies have either begun assembly or announced their intention to begin production here. Moreover, some 270 Japanese or Japanese-U.S. joint venture transplant automotive suppliers have been established in this country. And the lean production process is working almost as well in America as it does in Japan. The successful transfer of

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[6] James P. Womack, Daniel T. Jones and Daniel Roos, The Machine That Changed the World, New York: Rawson Associates, Macmillan Publishing Company, 1990, pp. 13-53. See also Christopher T. Hill, "New Manufacturing Paradigms--New Manufacturing Policies?" The Bridge, Summer 1991, pp. 15-24.

Japanese work and production systems in these transplants suggests that Japanese production practices are organizational forms that can be uncoupled from Japanese culture and moved to other parts of the globe.[7] Lean production is not an oriental phenomenon, it is a rational approach to institutional economics.

Fundamental changes have taken place. Modern innovation is a **synthetic** process. Synthesis involves combining information, knowledge, experience, and materials in ways they have never previously been combined to create product or process technologies with capabilities and characteristics not previously available.[8] And synthesis is **incremental and continuous.** For the first time in history, the capacity exists continuously and routinely to make available new capabilities in computers, communications, etc., in perpetuity.

What continuous, incremental innovation can do to the product market over a short period of time is illustrated by the widely known Honda counterattack on Yamaha motercycles.

> Yamaha thought Honda was preoccupied with getting into automobiles in the United States and publicly announced that it intended to surpass Honda in motorcycles. They built a factory, they designed new product lines, and made the

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[7] Richard Florida and Martin Kenney, "Organization Vs. Culture: Japanese Automotive Transplants in the U.S.," Industrial Relations Journal, Autumn 1991, pp. 181-196; Martin Kenney and Richard Florida, "How Japanese Industry Is Rebuilding the Rust Belt," Technology Review, February-March 1991, pp. 24-33.

[8] Don E. Kash, Perpetual Innovation: The New World of Competition, New York: Basic Books, 1989, p. 38.

announcement to a shareholders' meeting in 1981. Honda's President Kawashima did not take to this kindly. He issued a rallying cry, "Yamaha wo tsubusu," which has no polite translation in any language, including Japanese. It is roughly what the Samurai yelled just before attacking. And that is what Honda did to Yamaha. They launched a product development attack, a time based product development attack, which allowed them to introduce into the marketplace 113 new products in 18 months in a product line that had only sixty. There were water cooled engines where there had been air cooled engines, V engines where there had been inline engines, four valve cross flow heads, electronic ignition, automatic transmissions, mono-shock rear suspensions, engines as a structural element in the motorcycle. Major changes if you happen to be a motorcycle rider.

This destroyed Yamaha in 18 months. Yamaha publicly surrendered in 1983. At the time they were technically bankrupt. They had lost 11 percent market share. Honda had gained 8 percent. Yamaha's debt/equity ratio went from three to one to seven to one because they had to borrow to finance one year's inventory of motorcycles unsold around the world, all of which had become technologically obsolete. It takes a long time to dig out of that kind of hole.[9]

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[9] Rudyard Istvan, "Discussions of How Some U.S. Firms and the Government Have Successfully Responded to the Challenge," pp. 87-97 in NCAR 44, The U.S. Dilemma: Moving R&D from the Lab to the Market, San Antonio, TX: Southwest Research Institute, 1991.

Continuous technological innovation relies on knowledge and skill, however, the critical knowledge and skill is not primarily derived from exceptional individuals (e.g., geniuses and entrepreneurs). Rather, continuous innovation comes from ordinary people with in-depth training who are organized into **groups** which have as their purpose producing higher quality and higher performance technologies, sometimes at lower costs.

Technology and Organization

Two parallel forces are at the root of the new innovation paradigm: process and product technology and the organizations that mobilize expertise innovate have both become much more complex.

Sometime, probably within the last two decades, we passed a technological threshold. Although it occurred incrementally, we moved from a world dominated by simple technologies to one dominated by complex technologies. Complexity refers to the number of components and subcomponents needed for a particular technological system (either a process or product), and the architecture (linkages or relationships among components and subcomponents) required. Most economically desirable products traded in the international market are complex and becoming more complex (e.g., aircraft, motor vehicles, office equipment). The same is true of the production processes that deliver them.[10]

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[10] Robert W. Rycroft and Don E. Kash, "Science, Technology and Community," a paper prepared for presentation at the Fourth Annual International Conference of the Society for the Advancement of Socio-Economics, Irvine, CA, March 27, 1992.

Complex innovation takes place differently than the current conventional analysis. We have tended to assume that innovation is linear in nature (a sequence of activities beginning with basic research and ending with products) and managed by internal market dynamics, as shown in Figure 1. Moreover, we have assumed that technology stands outside innovation, as a "black box," less significant than either inputs (labor, capital, materials, etc.) or markets. Figure 2 illustrates this perspective. Technology is seen as being produced in isolation from the other parts of the economy. About all that is said about the technological black box is that it is characterized by a fundamental dichotomy: only scientific knowledge is the province of government and everything else is lumped together under the label "applied R&D and is the responsibility of the private sector. And once technology somewhat magically appears, entrepreneurs are seen as taking over the transfer and diffusion processes necessary to link them to production and to markets.[11]

That the black box model oversimplifies reality has been widely understood for some time, but it serves very powerful interests, it conforms rather well with the innovation of many simple technologies (e.g., petrochemicals, pharmaceuticals), and it is compatible with American ideology.

Fundamental to U.S. ideology is the public-private sector distinction. The linear model allows a wall to be built between

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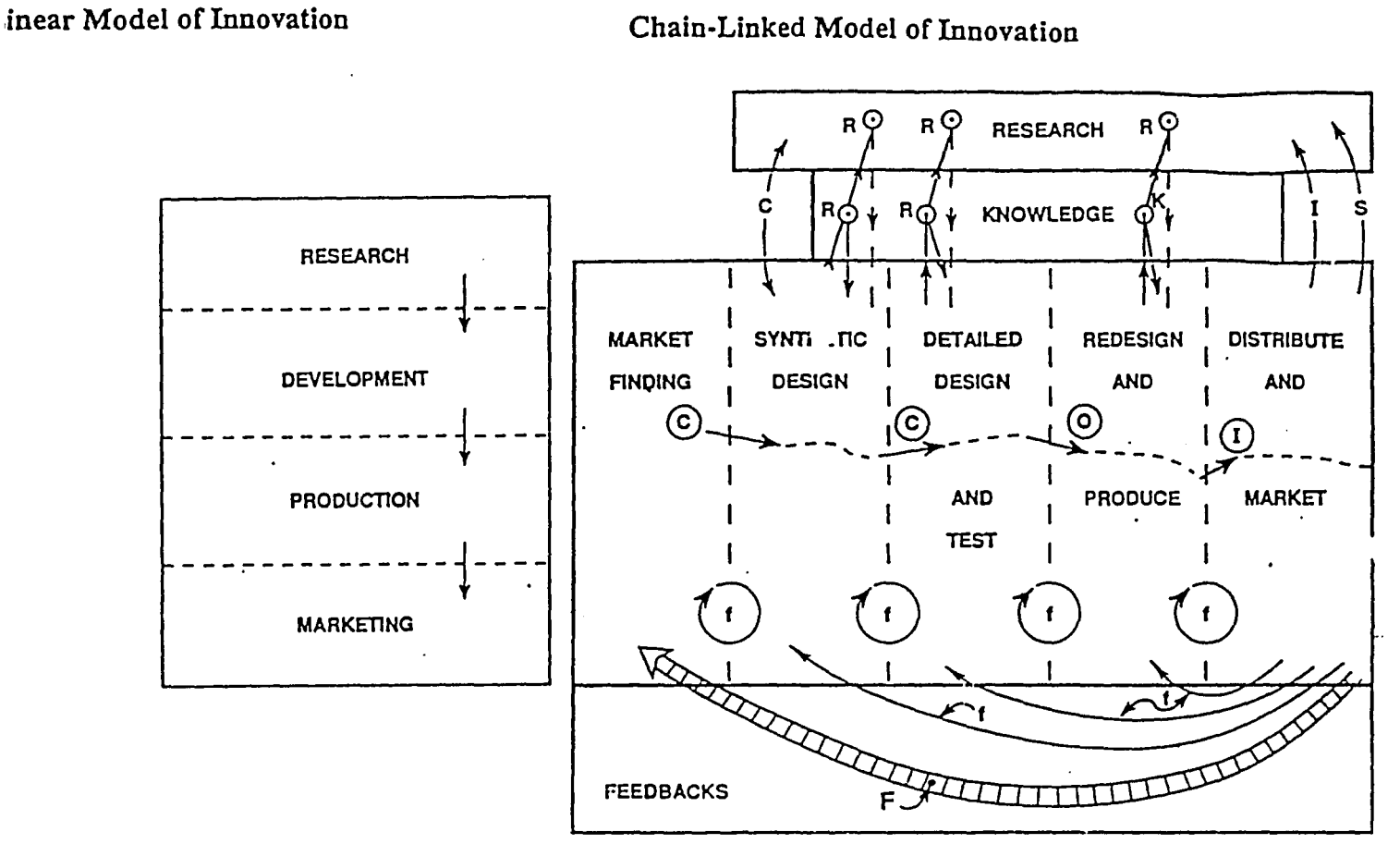
[11] Gregory Tassey, "The Functions of Technology Infrastructure in a Competitive Economy," Research Policy, August 1991, pp. 351-352.

FIGURE 1.

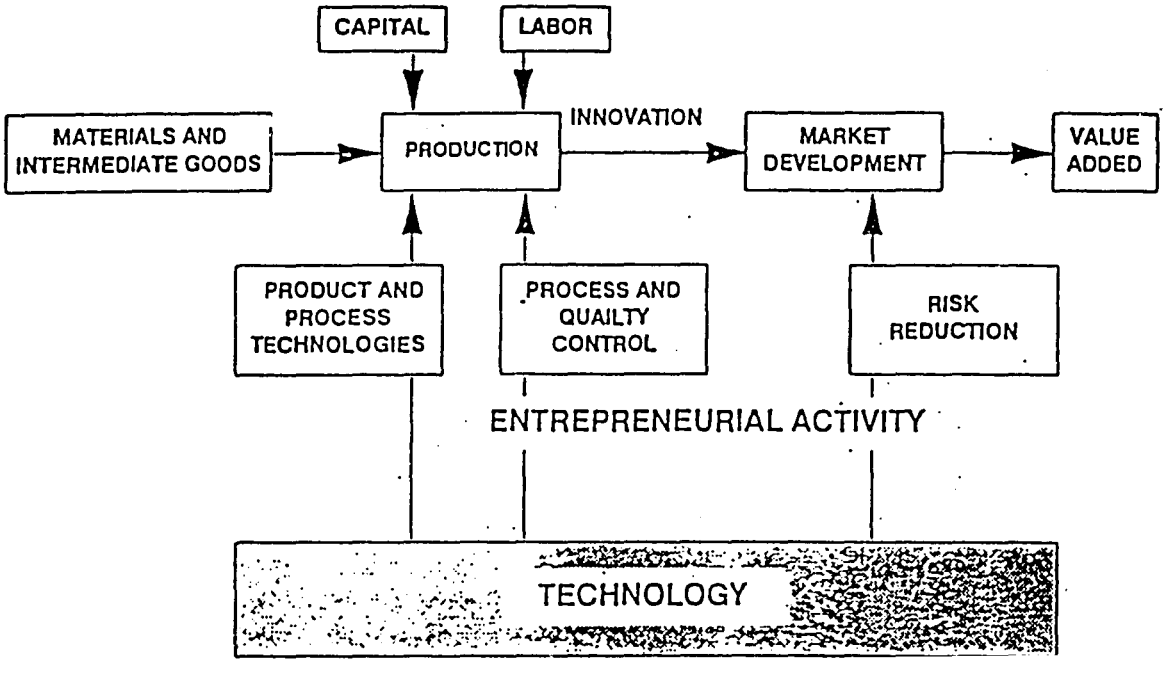
LINEAR AND COMPLEX MODELS OF INNOVATION



Source: Stephen J. Kline, "Innovation Styles in Japan and the United States: Cultural Bases; Implications for Competitiveness," Report INN-3, Thermosciences Division, Department of Mechanical Engineering, Stanford University, December, 1989, pp. 40-41.

FIGURE 2.

THE "BLACK BOX" MODEL OF TECHNOLOGY



Source: Gregory Tassey, "The Functions of Technology Infrastructure in a Competitive Economy," Research Policy, August 1991, p. 351.

the two sectors of society at the dividing point between R&D and everything further downstream, between pre-competitive and competitive stages. This is ideologically convenient because it defines where government intervention and support are legitimate and where they are not. The assumption is that the market's invisible hand will move ideas and methods produced by R&D into commercial products and processes. Any government policy for civilian technology, therefore, is to be avoided if possible, and public sector microeconomic interventions are downright sinful. The dreaded "industrial policy" would result, with bureaucrats "picking winners" and perverting markets.[12]

When the linear model is rejected, as it must when we look at complex technological innovation, the consequences for policy are revolutionary. What does the complex innovation model look like? Figure 1 graphically presents one conceptualization.

Complex innovation is usually incremental. The performance, and/or quality and/or cost of complex technologies are improved in small, continuous trial and error steps. Sources of ideas and methods are ever changing and they vary from one family of technologies to another. For example, in automobiles much of what is new comes from other sectors' (e.g., electronics or materials) products, not from R&D, while in biotechnology the new ideas are more likely to come from research. Sources of

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[12] Otis L. Graham, Jr., Losing Time: The Industrial Policy Debate, Cambridge, MA: Harvard University Press, 1992; Donald N. Frey, "Junk Your 'Linear' R&D," Research-Technology Management, May-June 1989, pp. 7-8.

innovation also will vary as technologies mature. For instance, research led to the solid state revolution in electronics but much present innovation comes from design.

In complex innovation it is often difficult to identify exactly where ideas originate. This is especially so when they come from production and marketing activities because they are likely to be conceived and implemented with little or no archival record. Moreover, ideas tend to be the product of groups, not individuals. In truth, the importance of communicating non-cognitive knowledge and skill and the need for group learning are essential for complex innovation.

As technologies increase in complexity, the opportunities for innovation increase. There are simply more components, subcomponents and architectures that can be modified in value-added ways. But the proliferation of innovation oppportunities can be very disruptive to the existing social and political fabric. Complex innovation, for example, makes patents less reliable as a way to guarantee the capture of economic benefits. With multiple innovation opportunities there are too many ways to innovate around a patent, and complexity makes it difficult to describe a particular technology in terms that are useful in the judicial system. Speed to market becomes the only sure guarantee that an innovator will be able to profit.[13]

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[13] Richard R. Nelson, "What Is Private and What Is Public About Technology?" Science, Technology and Human Values, Summer 1989, pp. 234-235.

Continuous complex innovation requires feedback loops everywhere, as indicated in Figure 1. Innovators must develop organizational scanning and forecasting capabilities. They must establish linkages with expertise wherever it resides--in firms, government, universities, and a host of other organizations. **Networks** have become critical to complex innovation.

In America, most innovation takes place in private companies. Yet conventional wisdom has tended to downplay organizational change at the level of the firm. In fact, neoclassical economic theory still regards the firm in much the same way it treats technology--as a "black box." Not that it is assumed that all companies are alike, it is posited that any differences are attributable to macroeconomic factors. Thus, firm differences result from the contexts within which they operate. Companies are forced to be different. Such an assumption, in turn, rests on the assertion that corporations have no discretionary choices in how they organize themselves. Firms face given and known sets of choices and have no difficulty in choosing the action within those options that is the best for them given their goals (usually as much profit as possible). There are, therefore, firm differences, but there is no essential autonomous quality to them.

An increasing number of anlaysts, however, reject this perspective. Firms do have discretionary choices available to them, especially with regard to innovation. What is missing from the conventional economic wisdom is that the process of

technological change itself involves fundamental uncertainty, risk, differences of perception about feasibility, etc. Technology is, therefore, a major force destroying the myth that corporate organizational choices are given and known. And, as noted above, technological innovation is intimately linked to organization. Any firm trying to innovate is ineviably faced with what Richard Nelson terms the "halting, trial and feedback, often reactive rather than thought-through process" that leads to new ways of organizing.[14]

American companies have been evolving since the first days of the Republic. Small, start-up, entrepreneurial firms have been significant factors in technological change for over 200 years. But they are no longer the dominant players. Larger, decentralized, diversified, horizontally integrated conglomerates with multinational capabilities became the key factor in U.S. technological prowess by the 1960s.[15] The conglomerates, for a time, seemed to have found the way to harness modern science and technology to business. Their large industrial R&D laboratories were the envy of the world. Filling the vacuum left by the destruction of Japanese and European competitors during World War II, the American multinational company dominated global commerce for the better part of two decades.

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[14] Richard R. Nelson, "Why Do Firms Differ, and How Does It Matter?" Strategic Management Journal, Winter 1991, p. 66.

[15] Louis Galambos and Joseph Pratt, The Rise of the Corporate Commonwealth: United States Business and Public Policy in the 20th Century, New York: Basic Books, 1988.

As this power manifested itself, however, U.S. managers began to believe they could efficiently supervise almost any kind of business. In a critical departure from the past, the chief executive officers of firms began to abandon the idea that corporate activities should be technologically related. When events in the 1970s (including the energy crisis and threats to the environment, as well as the recovery of Japan and Europe) began to reveal fundamental flaws in the dominant corporate strategy, structure and core capabilities, U.S. firms faced two difficult choices: (1) improve product and process quality and productivity by investment and innovation while looking to public policy for new partnerships over the long term; or (2) resort to financial measures to make American products cheaper in the short run. For the most part, the second path was chosen.

In what Bennett Harrison and Barry Bluestone call the "Great U-Turn," U.S. businesses tried to turn back the clock on labor relationships, engaged in increasingly speculative activities (mergers, hostile takeovers, etc.), relied more heavily on the defense connection, and scrambled around looking for ways to restructure themselves out of trouble.[16] By the early 1980s the warning signs were everywhere. Robert Reich termed the binge "paper entrepreneurialism," and Business Week warned of the

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[16] Bennett Harrison and Barry Bluestone, The Great U-Turn: Corporate Restructuring and the Polarizing of America, New York: Basic Books, 1988, pp. 3-20.

perils of the "casino society."[17] Things have not improved in the 1990s.

As the big businesses lost ground, Americans continued to hope that our small entrepreneurial firms would carry the day. Start-up companies would exploit their innovative capabilities on the technological frontier, in fields like biotechnology or semiconductors. The myth that "lone ranger" companies in places like Silicon Valley could take venture capital and succeed where the conglomerates were having trouble demonstrates how little attention was paid to the role of organization in innovation. Although entrepreneurial firms certainly were and are very good at breakthroughs in science and technology, they lacked the essential "complementary assets" necessary for complex, incremental innovation.

A core capability to innovate is not enough. Firms must possess or be able to acquire other assets, including manufacturing, marketing, after sales services, and possibly other technologies. These assets reinforce the core capabilities (such as teamwork, imaginative renumeration schemes, etc.). Innovation of all kinds (changing components, architectures, or the entire system) demands additional assets, even for modestly complex technologies. No company can keep pace in all areas by itself, but start-up firms obviously have the most trouble. Here

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[17] Robert B. Reich, The Next American Frontier, New York: Times Books, 1983, pp. 140-172; "Playing With Fire: Games the Casino Society Plays," Business Week, September 16, 1985, pp. 78-86.

is one of the keys to understanding innovation today: because of the importance of complementary assets, the larger firms can take better advantage of even meager innovation than the small ones can of quite remarkable innovation.[18]

As technologies have become more complex, the scramble for assets (either owned or acquired by contractural arrangements) has accelerated rapidly. This has been exacerbated by the increasingly difficult task of capturing the benefits of innovation. Weak appropriability (technology almost impossible to protect through patents or secrecy) is now commonplace in advanced technological sectors, and this means assets have to be developed or acquired very quickly. Contracting out is the obvious organizational response, because of speed and lower cost, but it carries with it substantial risks of loss of innovation to the contractors. All firms face this dilemma, and none of them have developed strategies to ensure that their complementary assets help capture the lion's share of benefits.

By the end of the 1980s, it was obvious that existing company organizational forces were inadequate for international competitiveness. Foreign companies were demonstrating that innovation depended not only on product development, but the range of process technologies related to manufacturing. They were also proving that good long-term relationships with other actors in the value-added chain (suppliers, assemblers/systems

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[18] David J. Teese, "Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy," Research Policy, 1986, pp. 285-305.

integrators, and customers) were essential. And they showed that inter-organizational partnerships with government, universities, and competitors could become very powerful competitive weapons. Above all else, foreign firms managed to integrate strategic decision-making with their scientific and technological expertise.[19] The time was ripe for the evolution of a new dominant organizational taype--the **network organization.**

When technological change is complex, proceeds at a rapid pace, and requires a diversity of expertise located in many different organizations, "interconnectedness" is a requisite for success. Networks provide the interconnects. By "network," it is meant the "lines of communication, the alternative express highways that people use to get things done."[20]

Networks are composed of both internal (e.g., within a single firm) and external (e.g., among organizations) linkages. Figure 3 illustrates both internal and external networks. Internal networks are the aggregate of core capabilities and complementary assets owned by a single firm. And the internal

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[19] National Academy of Sciences, National Interests in an Age of Global Technology, Washington: National Academy Press, 1991, pp. 34-35; U.S. Office of Technology Assessment, Making Things Better: Competing in Manufacturing, Washington: U.S. Government Printing Office, 1990, pp. 129-130; J. E. Goldman, "Fall From Excellence: Case Studies on the Decline of Industrial Innovation in the USA," International Journal of Technology Management, Special Publication on the Role of Technology in Corporate Policy, 1991, pp. 154-161.

[20] Jessica Lipnak and Jeffrey Stamps, Networking: The First Report and Directory, New York: Doubleday, 1982, p. 1.

network manages the linkages to the external network--those assets that have to be acquired or utilized.

The strength of the network organization is its ability to think and act globally and to engage in **strategic** cooperation. It is now beginning to be understood in the U.S. that some industries, markets, or products, like the manufacturing of semiconductors, are strategic in character--they are not only highly profitable, but they have so many links to other industries, products or markets that control of them makes competitive entry or reentry by others very difficult and expensive. To lose them may be, quite literally, to lose your destiny.[21] Here the term "strategic" takes on a new meaning--it is no longer just the firm's definition of long-term profitability or market position, but a manifestation of **physical reality.** Certain technologies, by virtue of their linkages to other "things in the world," have value far beyond mere profits--they ensure at a minimum the survivability of the organization, and at a maximum its hegemony.

But strategic technologies are inherently very risky. The multiplicity of linkages accelerates product cycles and speed to market. Clear intellectual property rights are virtually nonexistant. This leads to an entirely different organizational

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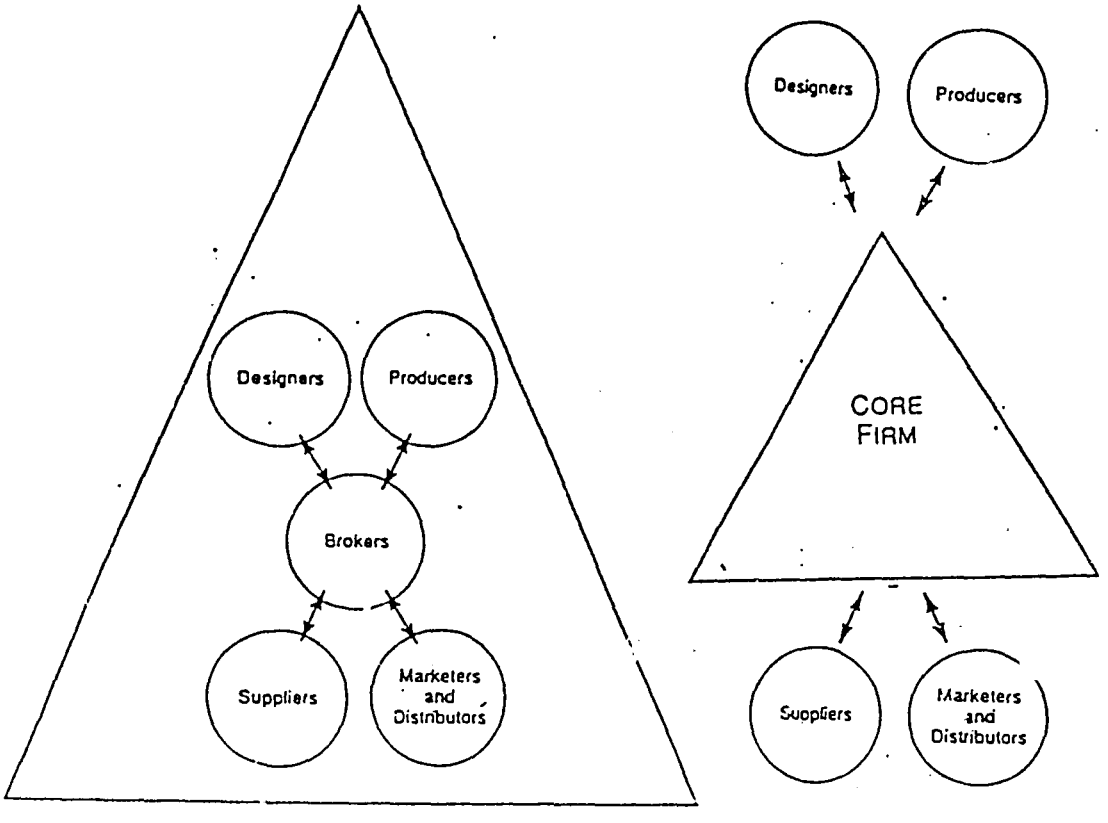
[21] Martin C. Libicki, What Makes Industries Strategic: A Perspective on Technology, Economic Development, and Defense, Washington: Institute for National Strategic Studies, 1989; Richard J. Elkus, Jr., "Lose Your Strategic Markets and You Lose Control of Your Destiny," Research-Technology Management, January-February 1991, pp. 7-8.

FIGURE 3.

INTERNAL AND EXTERNAL NETWORKS



INTERNAL NETWORK EXTERNAL NETWORK

Source: Charles C. Snow, Raymond E. Miles, and Henry J. Coleman, Jr., "Managing 21st Century Network Organizations," Organizational Dynamics, Winter 1992, p. 12.

structure, one based on "soft" forms of governance, involving informal reciprocity and the development of trust. People matter. Unlike the earlier corporate forms, the network organizations stress human resources development.[22]

The "flat" network structure reflects the priority placed on the workers skills. Responsibility is pushed as far down in the organization as possible. Rather than reducing the skill level of workers, problem-solving capability is sought and rewardedd in the network organization. Implicit in this structure is the premium put on communication. Information is widely diffused, and feedback from the workforce is valued and incorporated into the organizational structure.[23]

The significance of strategic cooperation and flat structure is that together they enable the network organization to innovate even better than the much-revered entrepreneurial firm. Networks can follow through on their breakthroughs.[24] Teamwork builds staying power, and successful teams themselves become reservoirs of complementary assets. The group approach achieves synergy.

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[22] Chris DeBresson and Fernand Amesse, "Networks of Innovators: A Review and Introduction to the Issue," Research Policy, 1991, pp. 365-366; Niles Hanson, "Competition, Trust, and Reciprocity in the Development of Innovative Regional Milieux," Papers in Regional Science, 1992, pp. 95-105; John T. Dunlop, "The Challenge of Human Resources Development," Industrial Relations, Winter 1992, pp. 50-55.

[23] John J. Bush, Jr., and Alan L. Frohman, "Communication in a 'Network' Organization," Organizational Dynamics, Autumn 1991, pp. 23-35.

[24] Richard Florida and Martin Kenney, The Breakthrough Illusion: Corporate America's Failure to Move From Innovation to Mass Production, New York, Basic Books, 1990.

Indeed, networks allow the creation of assets that are not applied to any specific product, but to the general management of the production process itself, including logistics, quality control, etc. The group configuration facilitates process innovation in a way that has been difficult for traditional American corporations.

The ability to select organizational resources from different companies, the government, or universities and then synthesize them into a single business network has been termed a "virtual company." For as long as there is a market opportunity, the various resources can behave as if it were a single company dedicated to one family of products. The virtual company has the flexibility to adopt for each project the organizational vehicle that will yield the greatest competitive advantage. There can be no algorithm for the conduct of such an enterprise--what is needed is long-term commitment of physical and organizational resources in support of the creativity and initiative of people.

Implications for E3

As the quote from the Carnegie Commission noted, America has unquestioned strengths in energy and environmental science and technology. Yet like everything else in the U.S., the energy-environment technology development community is complex, pluralistic, decentralized and compartmentalized. It consists of many players, including a wide range of university laboratories and engineering facilities, R&D establishments in private firms and corporate consortia like the Electric Power Research

Institute and the Gas Research Institute, think tanks and not-for-profit foundations, and lobbyists and public interest groups. The federal government mission agencies, such as the Department of Energy and the Environmental Protection Agency are linked to this diverse set of private actors through contract and grant systems and to a large federal laboratory structure as well. And state governments are important participants as well, especially states like California and New York. In this multifacted arena it has always been difficult to coordinate, let alone integrate the activities of the diverse organizations into anything like a coherent policy strategy.[25]

In truth, the labels "energy policy" and "environmental policy" are misleading in the U.S. context. What really exists on the energy side are a set of "fuel policies," centered around oil, natural gas, coal, nuclear power and electricity. In the area of environmental protection, the emphasis is on the mitigation of particular pollutants such as sulfur dioxide, oxides of nitrogen, ozone, etc. Across this landscape there are no clear goals, resources are scattered over miscellaneous technologies, and funding tends to be guided by short-term and often parochial interests rather than a strategic view. It has been impossible to aggregate policies in the national interest.[26]

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[25] Oak Ridge National Laboratory, Energy Technology R&D: What Could Make a Difference? Oak Ridge, TN: Oak Ridge National Laboratory, May 1989, p. xxiii.

[26] Christopher Flavin, "Beyond the Gulf Crisis: An Energy Strategy for the 90s," Challenge, November-December 1990, p. 10.

Absent national strategy, policy has been crisis-oriented. A sense of urgency has been a requisite for resolute action. As the Gulf War demonstrated, when confronted with a tangible threat the U.S. can act in a comprehensive way to solve very difficult proglems. Unfortunately, many of the E3 threats today are less tangible than an invasion of Kuwait. Global climate change, for instance, is certainly a very great environmental risk, but it is fraught with scientific uncertainty, covers very long time horizons, mandates global cooperation, and involves immense costs. American policy-making organizations are simply not capable of deciding what to do with these kinds of problems. As Robert Fri says, the U.S. doesn't lack an appreciation of the importance of energy/environment issues, nor does it lack the technological capability to solve them, but it does have an institutional problem.[27]

The consequences of incoherence have been significant in the past, but are likely to be even more so in the future. Perhaps the best indicator of America's poor performance in the E3 area is found in energy efficiency numbers. Everyone believes improvements in the efficiency of energy production and consumption are one of the keys to resolving E3 issues, yet the United States has continued to lag behind other developed countries in this area. Between 1973 and 1987, U.S. energy consumption declined by about 23 percent, but American cars,

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[27] Robert W. Fri, "Energy and the Environment: Barriers to Action," Forum for Applied Research in Public Policy, Fall 1990, pp. 11-13.

homes, and appliances still use at least 20-30 percent more energy than other countries (and perhaps as much as 60 percent more). Moreover, the pace of increased efficiency in the U.S. has slowed down in recent years.[28]

A similar pattern can be found regarding pollution mitigation. America's "end-of-the-pipeline" approach, involving the use of "technology-forcing" regulations to remove particular pollutants has some success stories (urban concentrations of sulfur dioxide, lead concentrations, etc.), but the costs have been much higher than anyone expected. The U.S. Environmental Protection Agency estimates that in 1990, America spent about 2.1 percent of its gross national product (GNP) on environmental protection--some $115 billion. And newer problems like global change could cost a lot more to resolve. The U.S. Office of Technology Assessment has concluded that to reduce carbon dioxide emissions (only one of five "greenhouse gases") by about 25 percent by the year 2015 would cost about 1.8 percent of 2015 GNP. This would effectively double the current environmental protection bill.[29]

Of course, energy efficiency and pollution reduction are two sides of the same coin. And increasingly analysts are concluding that technological innovation is the most important factor in

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[28] Karen Zagor, "Gas-Guzzlers are Also Human," Financial Times, October 16, 1991, Section 3, p. 4.

[29] U.S. Congress, Office of Technology Assessment, Changing By Degrees: Steps to Reduce Greenhouse Gases, Washington: U.S. Government Printing Office, 1991.

controlling costs while achieving energy/environmental gains. Jae Edwards of Pacific Northwest Laboratory says: "It's a measure of how we substitute knowledge for energy, by, for instance, creating new materials that can replace energy-intensive old materials, like plastics for steel."[30]

Unfortunately, this kind of innovation has been difficult for the existing U.S. energy and environmental policy machinery to accomplish. In large part, this is because it still operates within the outmoded paradigm of technological change. The linear model is alive and well in the White House, the mission agencies, and much of the private sector. In energy and environmental affairs, this model has allowed laissez-faire proponents and their neoclassical supporters in the economics profession to do something as old as the U.S. itself: throw up walls of separation (public versus private) between the various stages of the innovation process. Glenn R. Schleede, Executive Associate Director of the Office of Management and Budget in the Reagan administration described the changes made in energy policy in the early 1980s:

> By far the most important change (in comparison with the Carter Administration) came from this Administration's redefinition of the federal role. In the R&D spectrum, stretching from the most esoteric basic research out through the actual commercialization of a technology, we have drawn

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[30] Pamela S. Zurer, "Economic Considerations Enter Fray Over Global Climate Change Policies," Chemical and Engineering News, April 1, 1991, p. 12.

> the line for federal intervention and support back much farther toward the basic research end. In the civilian or domestic sector, we do not think the government should be funding demonstration, product development, and commercialization efforts.[31]

It is asserted that research should be separated from more applied work, and that government should continue to fund the former, but not the latter. You cannot make these kinds of policy distinctions unless innovation is linear.

Energy projects like the Carter administration's synthetic fuels program were the main target of this change, but environmental protection was also attacked. For instance the 1982 R&D budget submitted by the White House for the Department of Energy would have reduced its funding about 44 percent from roughly $4.5 billion the previous year to $2.5 billion the next. At the same time, the budget for energy-related R&D in the Environmental Protection Agency called for a decrease from about $100 million to $35 million. Almost all of this change involved cuts in applied R&D.[32]

The only exception to this trend was continued support for the range of civilian nuclear energy technologies Everything else on the technological agenda suffered dramatic funding

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[31] Claude E. Barfield, Science Policy from Ford to Reagan: Change and Continuity, Washington: American Enterprise Institute for Public Policy Research, 1982, p. 41.

[32] Don E. Kash and Robert W. Rycroft, "Energy Policy: How Failure Was Snatched from the Jaws of Success," Policy Studies Review, February 1985, pp. 433-444.

reductions. Much the same pattern continued in the Bush administration. Figure 4 compares the federal government's non-nuclear energy R&D budgets in 1980 and 1990, and it shows that over the ten year period, even in current dollars there has been a reduction of about 34 percent. The Bush National Energy Strategy explains why: only a modest buildup of renewable energy R&D and an expansion of domestic oil production are to be allowed. There are no pollution-reduction plans (except existing environmental laws) and no technological innnovation other than continuation of the Clean Coal Technology Program.

There is support for a good deal of fundamental environmental science, as has been the case for about a decade. The Global Change Research Program (more than $1.5 billion this year) follows close on the heels of the National Acid Precipitation Assessment Program (half a billion dollars over 10 years). Again, this is consistent with the Reagan interpretation of the linear model and with the values of the U.S. scientific community, which stresses the primacy of basic research. Between 1970 and 1990, funding for basic atmospheric, geological, oceanographic, and interdisciplinary environmental sciences more than tripled. Much of this had to do with the Reagan administration's call for "good science" in environmental affairs, and can only be regarded as a way to buy time and avoid taking action on environmental problems.[33]

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[33] Robert W. Rycroft, "Environmentalism and Science: Politics in the Pursuit of Knowledge," Knowledge: Creation, Diffusion, Utilization, December 1991, pp. 152-153.

FIGURE 4.

NON-NUCLEAR ENERGY R&D, 1980 AND 1990

(In $Million, Current)

Category	Carter, 1980	Bush, 1990
Solar	$509.5	$85.1
Fossil	747.6	344.7
Conservation	238.9	174.9
Geothermal	140.9	17.3
Biomass	57.8	-
Hydropower	18.5	-
Electric Systems	93.9	35.6
Clean Coal Technologies	-	531.5
Total	$1807.1	$1189.1

Sources: American Association for the Advancement of Science, AAAS Report IV: Federal Budget, FY 1980, Washington: American Association for the Advancement of Science, 1979; American Association for the Advancement of Science, AAAS Report XIV: Research and Development, FY 1990, Washington: American Association for the Advancement of Science, 1989.

The acid rain research program was, by most accounts, a failure. Designed to inform policy in a timely way, the project's interim report was two years late and the program lost political credibility when its first director was forced to resign amidst charges he manipulated findings to conform to the administration's positions. When its final report was released in late 1990, it was widely ignored.[34]

There are fears the same thing could happen to the global change research enterprise. The emphasis on basic science has created controversy, especially among environmentalists who are pressing for a more action-oriented posture. Even supporters of the program acknowledge that there needs to be better integration of fundamental knowledge and more applied research in areas such as the evaluation of mitigation technologies.[35]

Both of these programs represent the old paradigm's tendency to allow technological developments to take place, then to monitor and evaluate their environmental, health and safety impacts in the early stages in order to add to the "pool" of knowledge, from which, it is hoped, some technological fix may ultimately be derived. The linear model provides for the coupling or bridging of science and technology largely on faith.

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[34] Leslie Roberts, "Learning from an Acid Rain Program," Science, March 15, 1991, pp. 1302-1305.

[35] Edward S. Rubin, Lester B. Lave and M. Granger Morgan, "Keeping Climate Research Relevant," Issues in Science and Technology, Winter 1991-92, pp. 47-55.

On balance, the American approach to E3 innovation has left a lot to be desired. Ideology, culture, short-term political bias, the resistance of traditional energy industries, and lack of trust and reciprocity among all participants, including environmentalists, have limited the development of a comprehensive technological innovation strategy.[36] This pattern can't continue. The future will demand better technologies. As Alvin Alm puts it:

> Technological innovation has never been more important, particularly as pollution prevention becomes a government strategy and business reality. In some cases, national goals cannot be achieved without deployment of new technology. For example, achievement of the 1990 Clean Air Act goals in many cities will require use of some combination of new fuels, electric vehicles, smart highways, and other technologies.[37]

Add to this the very pressing problems of Third World countries as they try to respond to a range of local, regional, and global ecological threats. Much of the controversy and rhetoric at the recent United Nations Conference on Environment and Development (UNCED) had to do with technology transfer in the E3 area. Robert White, president of the U.S. National Academy of

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[36] Robert W. Rycroft and Don E. Kash, "Technology Policy Requires Picking Winners," Economic Development Quarterly, August 1992, pp. 227-240.

[37] Alvin L. Alm, "Environmental and Technological Innovation," Environmental Science and Technology, July 1992, p. 1300.

Engineering has said speeding the development and diffusion of environmentally advantageous technology is perhaps the greatest challenge facing the world engineering community.[38]

Fortunately, there is growing appreciation among international economic development scholars and practitioners that something dramatic has changed in technological innovation and transfer. Amitav Rath, for instance, agrees that complexity unermines the linear model of innovation. He concludes that the new conceptualization, while not complete, demonstrates that the effects of scientific and technological changes are even more powerful and pervasive than first thought, and that it is the process of assimilating, adapting and developing technology and institutions that is critical.[39] Similarly, Fransisco Sagasti says that the increasing pace and complexity of scientific and technological advances makes knowledge generation, dissemination and utilization more important--a phenomenon likely to accelerate in the future. For him too, there is an imperative to innovate institutions, and this implies the overthrow of "heavy ideological baggage."[40]

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[38] Robert M. White, "Technological Challenge at the Earth Summit," The Bridge, Winter 1991, pp. 5-11.

[39] Amitav Rath, "Science, Technology, and Policy in the Periphery: A Perspective from the Centre," World Development, November 1990, pp. 1429-1443.

[40] Francisco R. Sagasti, "International Cooperation in a Fractured Global Order," Impact of Science on Society, 1989, pp. 213-220.

These people are calling into question the dominant development theories (neoclassical, structuralist), and they cite as evidence for their attack the fact that those countries which have achieved the greatest economic success in recent decades (the so-called Newly Industrialized Countries--South Korea, Taiwan, Singapore, Hong Kong, etc.) have been precisely those that have recognized the evolutionary complexity, non-linear, institutional characteristics of technology. And they have used state power to develop support structures (for diffusion, standard-setting, capital formation, etc.). The NICs, it is posited, have succeeded because they rejected the oversimplification of the traditional models (dualistic concepts of state power vs. free market, export promotion vs. import substitution, and the like), and have begun to take for granted shorter time frames for production, distribution, and consumption, the need for flexibility and foresight, and the strategic advantage of cooperation.[41]

Compare the gulf between this set of assumptions and the dominant U.S. position and one can begin to understand the isolation of American politicians, technical experts, and diplomats at the 1992 Earth Summit. Representatives of almost every other nation recognized, at least implicitly, that any strategy to promote more sustainable patterns of development must draw upon technology. They recognized as well that environmental

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[41] Norman Clark, "Development Policy, Technology Assessment, and the New Technologies," Futures, November 1990, pp. 913-931.

protection can and must be built into the new technologies themselves. Finally, they have begun to realize that the innovation of these technologies is likely to come not from single institutions but rather from networks of institutions. For development purposes, this puts a premium on not only the traditional concerns about infrastructure building, but also the provision of effective linkages between, for example, research institutions and technology users.[42]

Fortunately, this is precisely what the new paradigm is all about. Today it is possible to blend incremental technical improvements from several separate fields of technology to create products that revolutionize markets. If intelligently used, this new production system can generate technologies that synthesize all three dimensions of E3. The criterion is straightforward: technologies should not be developed unless they hold the potential to generate all three categories of benefits. Just as reduced size or weight have become standard parameters of synthetic innovation, so will energy efficiency and environmental compatibility (ease of recycling, use of benign materials, and the like). There is no technical reason this cannot be accomplished. As Kodama says, it all depends on institutional capabilities such as translating market data into a well-defined product and process, monitoring the globe to decide what new

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[42] Amitav Rath and Brent Herbert-Copley, Technology and the International Agenda: Lessons for UNCED and Beyond, Ottawa, Canada: International Development Research Center, February 1992, p. 57.

ideas and innnovations out there might be of utility, and participating in partnerships that have reciprocity. In his words, the future is "nonlinear, complementary, and cooperative."[43]

Areas for Cooperation

The U.S. and Japan Energy and Environment Teams could make a major contribution to both the academic and practitioner communities in both countries if they could begin to explicate the degree to which a new technological paradigm in fact exists, and if so, what **organizational** forms it takes. The possible research questions fall into three groupings.

General Questions. We need to know a great deal more about the **network organization,** both internal to the firm and as an external mechanism by which firms link to other, non-corporate entities (government, universities, etc.). Substantial empirical literature exists regarding inter-firm collaboration in technology,[44] but there is relatively little research on the external networks that incorporate non-profit institutions. Daniel Okimoto has a good description of the variety of linkages involving the Japanese Ministry of International Trade and

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[43] Fumio Kodama "Technology Fusion and the New R&D," Harvard Business Review, July-August 1992, pp. 70-78.

[44] John Hagedoorn and Jos Schakenraad, "Inter-firm Partnerships for Generic Technologies--the Case of New Materials," Technovation, 1991, pp. 429-444; John Hagedoorn, "Global Strategies in Innovation: Networks in Research and Production," International Journal of Technology Mangement, Special Publication on the Role of Technology in Corporate Policy, 1991, pp. 81-94; John Ziman, " A Neural Net Model of Innovation," Science and Public Policy, February 1991, pp. 65-75.

Industry (MITI), and his discussion of the role of "intermediate" institutional structures is insightful.[45] But there is little tangible information regarding these connects in Japan and even less in the U.S. experience.

A related issue is the difference between formal and informal linkages. Formal networks may be specified by short-term,highly legalistic mandates and arrangements concerning proprietary information, etc., as is typically the case in America. Or they may involve informal, personal, obligatory, long-term interactions, as appears to be the case in many Japanese networks.[46] What are the track records of these very different types of organizations, in terms of contributing to innovation? Are most networks "hybrids," involving both informal and formal linkages? How does the mix of relationships change over time?

In all of this we would want to know about the decision-making process. What kinds of consensus-building and maintenance rules and procedures are put in place to enable simultaneous cooperation and competition? How do innovation networks survive in capitalist societies?

Energy/Environment/Economy Questions. The second grouping focuses the more general questions on the E3 substantive arena.

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[45] Daniel I. Okimoto, Between MITI and the Market: Japanese Industrial Policy for High Technology, Palo Alto, CA: Stanford University Press, 1989, pp. 155-156.

[46] S. K. Subramanian and Yeswanth Subramanian, "Managing Technology Fusion Through Synergy Circles in Japan," Journal of Engineering and Technology Management, 1991, pp. 313-337.

How, if at all, are E3 networks of various types functioning in the Japanese-American context? Networks clearly are at work in fields such as biotechnology or materials science and technology, but it is not known whether this kind of innovation exists in the energy or environmental area.

What special circumstances (an environmental definition of national security, because of instability created by ecological deterioriation, etc.) might make E3 networks of innovation attractive in the future? Is threat a major component of the creation of coalition/network investments in E3 technologies? Would it be prudent for the Western democracies to invest the billions of dollars spent on the Gulf War in more productive and proactive E3 initiatives?

Is the natural resource dimension of E3 a barrier to the new paradigm of innovation? Are older industries, like oil production and refining, key obstacles to the transformation to synthetic production? Are resource-poor countries, like Japan or Singapore, at something of an advantage in putting together new kinds of coalitions precisely because they don't have the abundance of natural resources which is so central to American culture and ideology?

Third World Development Questions. The final grouping asks whether and in what way the more general and E3 questions apply to the issue of development in the Third World. Do (or can?) the network organizations transfer technology successfully to less developed countries? How does the development context alter the

ability of the industrialized countries to apply the new paradigm to the Third World context?

In the end, this is the crucial issue. It stretches the imagination to believe that the West can continue to concentrate its human and physical resources in activities that contribute to global deterioration. When someone like William Ruckelshaus, twice administrator of the U.S. Environmental Protection Agency, (both times in Republican administrations) makes the following statement, then the world has changed:

> [W]e shall have to redefine our concepts of political and economic feasibility. These concepts are, after all, simply human constructs; they were different in the past, and they will surely change in the future. But the earth is real, and we are obliged by the fact or our utter dependence on it to listen more closely than we have to its messages.[47]

The efforts of the Japanese and American teams should focus on the "messages from the earth." Physical reality imposes limitations on what can be accomplished. However, these boundary conditions are not carved in stone. Every day of the year we invent new rules of the game; we find new ways to put together the parts of the puzzle in innovative ways. If the U.S.-Japanese Energy-Environment Teams can get beyond this conventional wisdom, they will have broken new ground.

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[47] William D. Ruckelshaus, "Toward a Sustainable World," Scientific American, September 1989, p. 175.

ATTACHMENT C
INTRODUCTORY ADDRESS TO SEATTLE WORKSHOP BY RICHARD BISSELL