5.0 Environment and Life Cycle Considerations

5.1 Relationship of Environmental Issues to National Security

There is clearly a relationship between the environment and national security as seen within the following definition of national security. It is defined by the Office of the President as "the sovereign responsibility to remain a free and independent nation and protect our fundamental values, institutions and people."[3] Security is achieved through a combination of political, economic, military, and social strengths.[4] Within this definition, environmental considerations can affect national security in four fundamental ways:

- Pose a direct threat to the health or well-being of the American people
- Contribute to regional instability
- Enhance (or detract from) the economy
- Threaten our social stability

In her testimony to Congress in 1994, Sherri Wasserman Goodman, Deputy Undersecretary of Defense for Environmental Security, pointed out that "the values supported by a healthy environment—life, liberty, freedom from fear and want—are the same ones we stand ready to fight and die for."[5] Because the United States has abundant resources and a generally healthy environment, direct threats to our health and well-being are more likely to be those that impact the global commons, such as ozone depletion or global warming. There may or may not be irrefutable evidence that these are valid phenomena, but there is enough doubt to regard them as valid environmental threats and suggest that we respond as we would to a military threat: with vigilance, gathering of intelligence data, and preemptive action in proportion to the threat, such as eliminating our use of ozone depleting chemicals (ODC) and carrying that message abroad.

Environmental problems have the potential to create significant regional instability and ultimately, regional conflict. To the extent that a particular conflict threatens U.S. national interests, there is a direct connection between the state of the environment and national security. As the world's resources are depleted and polluted they become increasingly scarce and more valuable. As the premium on resources increases, the possibility for conflict over the use or pollution of the resources becomes more likely.

For example, upstream pollution of the Danube River is a source of great concern for the downstream nations. Air pollution from high-sulfur coal burned to generate electricity in the Czech Republic crosses the border and creates problems in neighboring countries. Depletion of fisheries worldwide threatens the primary protein supply of a large percentage of humanity. Just as diplomacy and the encouragement and support of international organizations are used to avoid regional instability, preemptive and peaceful resolution of environmental crises is a valid U.S. national security activity. However, this task requires a system of global monitoring and

3. U.S., Office of the President, *National Security Strategy of the United States*, 1993, (Washington, D.C.: GPO), p. 3.
4. U.S., Industrial College of the Armed Forces, *National Security Strategy Syllabus*, 1993, Washington, D.C.: ICAF), p. 4.
5. U.S., Department of Defense, "DoD's New Vision for Environmental Security," *Defense Issues*, Vol. 9 No. 24, (March 1994), p. 1.

analysis to collect and assess environmental data. Sophisticated sensors, such as those developed by the Air Force for other applications, will be vital for environmental surveillance.

Environmental considerations can act as a drag on the economy or serve to stimulate new markets and increase American competitive advantage. When compared with the environmental standards of other economic superpowers, such as Japan, ours are not unique. The relative advantage from lax environmental standards currently enjoyed by some emerging economies will be short lived. The differences in environmental standards will gradually vanish, based on emerging evidence that environmental improvement in industry enhances efficiency, reduces costs and ultimately increases competitiveness. Those economies that are embracing "sustainable development" are strategically positioning themselves for optimum future competitive advantage.

DoD and the Air Force have been at the forefront of developing remediation technologies and pollution prevention processes that could contribute significantly to U.S. competitiveness in a growing international market. One effort is the attempt to leverage the Strategic Environmental Research and Development Program (SERDP) to strengthen partnerships with industry, regulators, states, and the public for the field testing of new technologies. SERDP was established by Congress to support basic and applied research and development of environmental technologies. SERDP is actively supporting cutting-edge technologies, such as the electron beam scrubber that turns dirty high-sulfur coal emissions into a potential commercial product. Although development of new products for the market has not been a traditional DoD or Air Force mission, through environmental technologies and process development work, they can play a role in increasing U.S. international competitiveness while developing methods to control emissions, prevent pollution, and remediate past problems.

There is an additional issue, that of "environmental justice," that needs to be addressed. This emerging concept poses the question of social equity in the distribution of environmental burdens. Environmental justice considerations could have a fragmenting effect on society or an integrating influence, depending on how well we accommodate the concerns of that portion of the population that perceives itself as carrying a disproportionate environmental burden. Although this is not a traditional DoD or Air Force concern, there is a greater need to address the issue more energetically. Emphasis must be placed on efforts to select materials more carefully, with a bias toward those with greater environmental friendliness, conducting the research needed and then implementing pollution prevention methods and evaluating life-cycle costs for all materials and systems to place greater emphasis on final disposal.

5.2 Impacts of Environmental Laws and Regulations

Budget

With over 100 active and formerly used facilities on the Environmental Protection Agency (EPA) Superfund National Priorities List, the major portion of DoD's expenditures to date have gone to support cleanup efforts. This amounted to approximately $4.5B in FY 94 and FY 95. However, even total costs to date are relatively small compared to the ultimate liability, which is potentially huge. Using a DOE example for comparison, cleanup costs at the Hanford reservation are estimated at $100B to $200B over a 20 year period.

Readiness

As the Air Force devotes more resources to environmental compliance and remediation, it must evaluate the impact on future readiness. If the total DoD budget continues to decrease while environmental expenditures increase, the sacrifice would come from current operations, training and maintenance, because DoD currently funds environmental efforts from operations and maintenance (O&M) monies. While only a small fraction of the current DoD budget (about 0.2 percent of FY 94 budget) has been directed to environmental issues, this percentage is expected to grow even as total budget authority declines. These direct costs do not include indirect expenses, such as having to conduct training at a more distant training facility due to environmental restrictions.

Despite the diversion of resources to environmental issues, records show that readiness rates remain healthy across all Services. How long this will continue is speculative, and any degradation would manifest itself over time and be somewhat difficult to detect, except retrospectively. Because environmental costs come from previously allocated funds, there is an opportunity cost associated with each expenditure. Although it is not possible to know what opportunities have been foregone, there is certainly some marginal cost for environmental requirements. Because these are often added on as unplanned costs, the prospects are great for minimizing such costs through pollution prevention and life-cycle analysis focused on material selection and system disposal.

Going beyond funding, it is critical to view the impact of environmental requirements in a strategic sense. We have probably entered the first phase of a major shift in national security thinking, involving planning to operate in a green future. The insight of Sherri Wasserman Goodman, Undersecretary for Environmental Security, supports this contention as revealed in her testimony to Congress in 1994.

> "At first the notion of a green weapon system may seem absurd, but in reality it is not. These systems spend most of their lives in a peacetime role and often remain in the inventory for 30 years or more. During that time maintenance and refurbishment performed by contract and at our industrial depots use large quantities of hazardous materials and generate large quantities of waste." [6]

Mobilization Capabilities

Related to readiness is the ability to mobilize the elements of material power. Although it may seem obvious that increases in the environmental regulation of both private industry and the federal government would have a negative influence on our ability to mobilize, this is difficult to quantify.

The defense industry's efforts to cleanse itself have advanced to the point that there will be little impact of environmental compliance on its ability to mobilize. Industry processes have already incorporated these requirements, reflecting responses to current regulations. In addition, Executive Order 12856, of 3 August 1993, establishes a formal exemption mechanism for relief from environmental regulation in the interest of national security. In a crisis, regulatory

6. Prepared Remarks to the Defense Subcommittee, House Appropriations Committee, March 23, 1994.

impediments could be removed temporarily. The only area that will still be impacted is the production of ODCs. Since the nation is ceasing production of these materials, even if regulations are waived, the lack of production capability will result in significant delay.

On the other hand, expansion of U.S. environmental regulations to overseas activity could have substantial, negative impact. Adding more and more Federal agencies to the review process for overseas actions (e.g., deployments, exercises, relief efforts) certainly will cause delay and could jeopardize operations. There could be a particularly negative impact on foreign military sales (FMS). Skepticism about the desirability of U.S. systems products and training will have an adverse impact on the industries producing them. If we are going to rely on FMS to help maintain parts of the defense industrial base, then we must plan for alleviating these concerns.

A perspective on the effect of environmental concerns on mobilization is provided by Operation Restore Hope. Disposal of hazardous waste generated in Somalia, disposal of captured vehicles, and application of dust control agents were all issues driven by environmental concerns. In the case of the dust control agent, instead of using readily available waste-oil as is the practice in the region, over 4,000 barrels of a petroleum-free dust suppression agent were shipped from the United States to Somalia, 500 barrels by air. Although not a high impact issue itself, the potential impact of such issues on future operations and mobilization efforts is sobering.

5.3 Pollution Prevention

Prosperity without pollution has become the fundamental environmental theme of the 1990's. The new paradigm—pollution prevention—serves as the keystone of federal, state, and local environmental policy. Support for this approach is broad-based, and includes environmentalists, industrialists, law-makers, academicians, government regulators and policy-makers, and the general public. Pollution prevention is the environmental ethic of the 1990s. It replaces two decades of national and state environmental policies based on pollution control. It represents the latest step in the evolution of environmental policy in industrialized nations, especially the United States. That policy over the past twenty years has progressed from a narrowly focused preoccupation with regulatory command and control of "end of pipe" releases, to a more practical waste management technology, and ultimately to the more enlightened economics of waste minimization.

The advent of waste minimization was a watershed in the evolutionary process. It redirected the attention of industry, regulators, and environmentalists away from "end-of-the-pipe", and "fence-line" micro-environmental releases, back through the industrial facility or treatment process being controlled, right up to the plant or laboratory door and into the conference rooms where planning begins. The additional problems of non-point source pollution provided further impetus to revisit the basic processes and systems polluting the environment.

Pollution prevention emerged as the theme around which to establish a framework to protect the environment; in part, to confront the economic realities of the enormous costs associated with hazardous waste treatment and disposal. The good sense of the pollution prevention concept was clear, because past improvements in one medium invariably resulted in contamination of another. Transferring pollutants between environmental compartments no longer was a viable solution. The successful control approaches of the 1970s and 1980s in dealing with macro-environmental pollution of air and surface waters no longer were sufficient. A new, more flexible paradigm, that allowed creative solutions, jointly developed by industry, government, and environmentalists, would have to be put in place. The new framework, with a defined hierarchy of possible responses—source reduction, recycling, treatment and disposal—provides industry, government and the environmental groups an array of options from which to seek acceptable solutions.

For the Air Force and the industries it relies on, pollution prevention is an attractive environmental strategy for several reasons. If no pollution is generated, there are no pollutants to be controlled and managed. Future problems and risks are avoided. The old policies and methods resulted in billion dollar site remediations. Preventing pollution before it occurs has the added feature of preventing exposures to the community at large and to the workers charged with the management of pollution.

The Pollution Prevention Act of 1990 was designed to reduce the amount of industrial pollution in the United States by: 1) establishing a source reduction program at EPA; 2) calling for increased technical assistance to industry by EPA and states; and 3) requiring additional reporting on:

- Quantity of material (prior to recycling, treatment, or disposal) entering any waste stream or released to the environment.
- Quantities of material recycled and treated at the facility and elsewhere.
- Quantity of material released in one-time events not associated with production processes.
- Information on source reduction activities and methods used to identify those activities.
- Production ratio/activity index.
- Projections of future activities.

These reporting requirements, and the underlying challenge of pollution prevention and source reduction, are major concerns for the Air Force and its suppliers.

A significant potential benefit of industrial pollution prevention is economic. When wastes are reduced or eliminated, savings in materials result and more product is produced from the same starting materials. Re-examination of manufacturing processes as part of a pollution prevention approach can produce a variety of unanticipated benefits, such as conservation of energy and water and improved product quality. Given the escalating costs of waste handling, a program promoting source reduction can provide a major incentive to industrial firms. A dominant cost savings can be realized from significantly reduced future liability for future pollution.

On the environmental side, the advantages of pollution prevention include improving the effectiveness of managing reduced waste streams, minimizing the uncertainty associated with the environmental impact of released pollutants, avoiding cross-media transfers of released pollutants, and protecting natural resources. Finally, pollution prevention is consistent with the public's right to know and right to know more laws, and with increased public scrutiny of industrial practices.

Notwithstanding the fact that pollution prevention is the most effective way to reduce risks and avoid liabilities associated with producing the materials and products essential to Air Force operations, by 1999 the Air Force must reduce pollution by 50 percent (from FY94 levels). With 80 percent of hazardous material generation tied to weapon systems production, maintenance and disposal, the most effective way to reduce pollution is to design and engineer as much hazardous material and pollution generation out of a system as possible in the early stages of the acquisition process. However, to meet the 1999 goals, the opportunities to affect pollutant reduction through involvement in new system design will be few and the need for solutions to retrofit into existing systems will predominate.

Outside the short term challenge of meeting the mandated 1999 goals, the longer term opportunities to develop new materials and processing techniques and then the manufacturing methods themselves, which are vital to new weapons systems, must be addressed by considering pollution prevention at every phase of development. As U.S. businesses continue to place more emphasis on up-front costs, as well as on pollution prevention, there could be a short-term loss in their competitive advantage vis-à-vis their international competitors. U.S. industries apparently have made the decision that these short-term costs will be offset by the long-term benefits of owning more technologically advanced, efficient, and "environmentally friendly" plants. However, their selection of which materials, processes, and manufacturing methods they should invest in will be extremely cautious, tending to favor those with highest potential to profit from commercial application. The downselecting process by U.S. industry then could result in unfulfilled Air Force needs. Additionally, some new methods will need to be developed to treat wastes that survive pollution prevention planning efforts, because the commercial sector cannot economically and competitively take on the development risk.

The above are supporting reasons why the Air Force must build its environmental applied research capabilities to world class status. Inevitably Air Force/industry partnering will result, where the Air Force will need to shoulder a substantial amount of the pollution prevention process development risk. This will produce added long term benefits for the Air Force, because it will possess as well the treatment process know-how to apply to weapons systems operations, maintenance, and refurbishment. As U.S. policy has moved toward a process-oriented approach that focuses on pollution prevention, the U.S. environmental industry itself has changed. The thousands of small businesses formerly devoted to serving the command and control environmental industry has shrunk, and now about 25 major corporations dominate the U.S. environmental industry market. The Air Force cannot afford to rely on this reduced talent resource.

The realization that pollution prevention will ultimately cost less than remediation has given impetus to technological innovation. The development of new environmentally sound technologies and processes is of interest to developed and developing countries alike.

The importance of technology and process innovation as a contributor to economic competitiveness, as well as to environmental protection, makes technology development a significant element of the U.S. environmental agenda. The need to incentivize such development and innovation is leading the U.S. to undertake long-needed regulatory reform on one hand and, on the other, to give mandates to the national laboratories, the DoD laboratories, the National Institute of Standards and Technology (NIST), and ARPA to pursue environmental technology development. The 1995 budget provided more that $2B for environmentally-related research and development.

The promotion of innovative environmental technology promises to increase environmental protection in a more economically efficient way. It is also expected to stimulate the development of new commercial products and markets for the U.S., such as clean cars and new techniques and uses for recycling and resource reclamation.

5.4 Life-Cycle Assessment (LCA)

An apt definition of LCA that captures the intent of the assessment process, identifies it as an attitude that displays an acceptance by manufacturers of their share of responsibility for the environmental burden caused by their products from design to disposal. Thus the LCA is a quantitative tool, which ensures that real rather than superficial environmental improvements are identified. Pollution prevention through LCA is a substantial change from evaluating waste management options that look mainly at single issues, such as recyclability or reduced toxicity. Figure 5.1 offers a notional look at pollution from a weapon system viewpoint.

An LCA is a snapshot in time of input and output. It can be used as an objective technical tool to identify environmental impacts associated with a specific product, process, or activity, and to evaluate opportunities to reduce the impacts. The LCA is a holistic approach that analyzes the entire system around a particular product, process, or activity. It encompasses extracting and processing raw materials; manufacturing; transportation and distribution; use, reuse, and

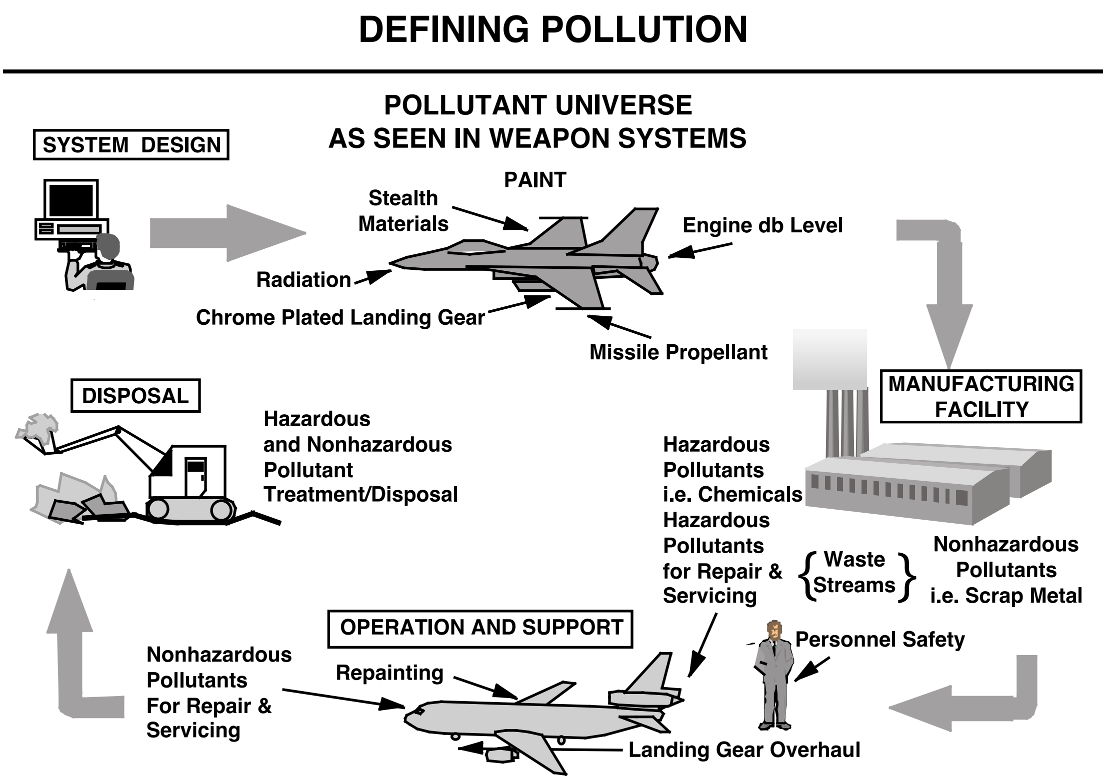

Figure 5.1 Weapon System Pollution

maintenance; and recycling and waste management.[7] It also factors in the downstream and upstream effects of product use.[8] The Society of Environmental Toxicology and Chemistry (SETAC) defines LCA as looking holistically at the environmental consequences associated with the cradle-to-grave life-cycle of a process or product.

Another approach involves looking at how waste can be reduced or eliminated, starting with the point of generation in the manufacturing operation, to its processing, treatment, or ultimate disposal as a residual hazardous waste.[9] Pollution prevention can take place at any stage in a product life-cycle, and changes at any stage can have positive or negative effects on waste generation at other stages.

LCAs can assist in evaluating proposed changes to product process designs, so that trade-offs can be identified. For example, an apparent improvement to a product that decreases air pollutants, but which results in increased water-borne pollutants, could be identified by an LCA. Any potentially offsetting effects of the water-borne pollutants could be accounted for in an overall environmental assessment of the product, process, or activity.

5.5 Product Stages and LCAs

The process of evaluating the environmental impacts and releases of a specific product as it goes through various stages of development is depicted in Figure 5.2.

For the raw material acquisition stage, an LCA considers activities that involve removing materials from the Earth, such as crude oil. The second stage is material manufacture, which includes processing raw materials, for example, turning crude oil into polymeric resin. In the product fabrication stage, the processed raw materials are made into products. For example, polymeric resin is melted and formed into a number of products, such as plastic bottles.

Many activities take place during the next stage: filling, packaging, and distribution. Transportation, however, occurs throughout all the life-cycle stages and is not accounted for as a single activity during distribution. The next stage—use, reuse, and maintenance—incorporates how the product is used after the point of sale. The last stage, recycling and waste management, assesses how the product is ultimately disposed of, including recycling. Figure 5.1 depicts the stages of production life-cycle assessment.[10]

Generally, LCAs are thought to be costly and time-consuming, because they are inherently complex and data intensive, subject to technological change, and depend on data that often are proprietary. This can be particularly true of LCAs for public use, those which rely on published and public data sources, and which are intended to compare one consumer product to another. However, in 1990, SETAC concluded an LCA workshop recommending that complete LCAs should be composed of three separate but interrelated components:

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7. Fava, J. A. et al, "A Technical Framework for Life-Cycle Assessments" Society of Environmental Toxicology and Chemistry Workshop held in Smuggler's Notch, VT, August 18-23, 1990.
8. "Background Document on Clean Products Research and Implementation," prepared by Franklin Associates Ltd., Inc., for U.S. Environmental Protection Agency, Cincinnati, 1990, EPA/800/2-90/048.
9. Hunter, J.S., and Benforado, D.M. "Life-Cycle Approach to Effective Waste Minimization," 3M Company, paper presented at the 80th Annual Meeting of APCA, New York, NY, June 21-26, 1987.
10. Curran, M.A., "Broad-Based Environmental Life-Cycle Assessment", *Environmental Science and Technology*, 1993, Vol. 27, pp. 430-436.

Life-Cycle Stages

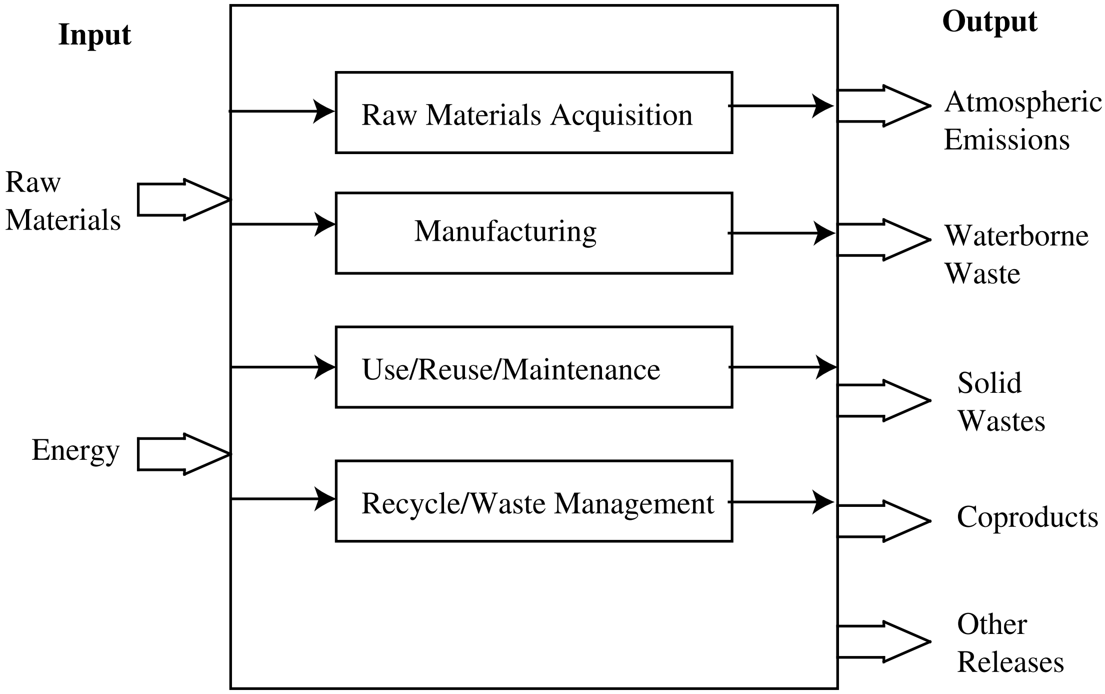

Figure 5.2 Defining System Boundaries

- Life-cycle inventory
- Life-cycle impact analysis
- Life-cycle improvement analysis

In addition, others have pointed out that it is far more feasible to formulate approaches that influence the choice of materials from which products are made.[11] For example, energy concerns in the 1970s motivated the U.S. Bureau of Mines to sponsor studies on the energy demands of major U.S. industries. Rather than examine the energy needs for the plethora of products made from aluminum, for example, this study instead inventoried the energy required to make aluminum itself.

This type of focus on materials can help guide product design, and it can offer opportunities for manufacturers who want to avoid unanticipated future regulatory and cost burdens as they evaluate alternative process modifications and material substitution options. Even if it turns out that cross-pollutant and cross-impact comparisons can never be satisfactorily resolved, the inventory phase of LCAs remains a valuable method for directing attention to pollution reduction opportunities regardless of their relative harm. It is not necessary for all LCAs to

11. White, A.L., and Shapino, K., "Life-Cycle Assessment. A Second Opinion," *Environmental Sciences and Technology*, 1993, Vol. 27, pp. 1016-1017.

include impact analyses. Their inclusion depends on the objectives of the study and the intended use of the information.

It is important that the LCA identify and measure both direct and indirect environmental, energy, and resource impacts associated with a product, process, or activity. Direct impacts might include emissions and energy consumption of a manufacturing plant. Indirect impacts include energy costs (by the functions of the product), impacts caused by extraction of raw materials used to make the product, and by product distribution, use and disposal. It is becoming increasingly apparent that indirect impacts, particularly post-manufacturing ones, often dwarf direct impacts. Improving the environmental performance of products of processes requires that they be designed to reduce post-manufacturing impacts.

It was noted at the 1993 conference at the Massachusetts Institute of Technology, "Life-Cycle Assessment: From Inventory to Action", that when indirect impacts are taken into account, conventional wisdom about the environment—the reduce, reuse, recycle hierarchy—may no longer apply. Recycling may consume more resources than it saves if, for example, recyclables must be transported long distances for processing or sale. Reducing toxicity may result in environmental costs if, for example, switching from chlorinated to water-based solvents requires increased energy use that generates additional solid waste.

Graedal, Allenby and Conrie have reported this year on using matrix approaches to carry out abridged LCAs.[12] The central feature of the abridged assessment system is a 5 x 5 assessment matrix, the Environmental Responsible Product Assessment Matrix, one dimension of which is the life-cycle stage and the other is environmental concern (Table 5.1). In use, the Design for Environment (DFE) assessor studies the design, manufacture, packaging, in-use environment, and likely disposal scenario, and assigns to each element of the matrix an integer rating from 0 (highest impact, a very negative evaluation) to 4 (lowest impact, an exemplary evaluation). In essence, the assessor is providing a figure of merit to represent the estimated result of the more formal LCA inventory analysis and impact analysis stages. The process is purposely qualitative and utilitarian, but provides a numerical end point against which to measure improvement. Once an evaluation has been made for each matrix element, the overall Environmentally Responsible Product Rating (R_{erp}), is computed as the sum of the matrix element values:

$$R_{erp} = \Sigma\Sigma M_{ji}$$

Because there are 25 matrix elements, a maximum product rating is 100.

The matrix scoring system provides a straight forward way to compare options for improving a complex manufactured product or an industrial manufacturing process. In using the method for assessing generic automobiles, at least two aspects of modern (1990) automobile design and construction were identified as retrogressive versus that (1950s) from the standpoint of their environmental implications. Both are apropos to Air Force weapon system manufacture.

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12. Graedel, T.E., Allenby, B.R., and Conrie, P.R., "Matrix Approaches to Abridged Life-Cycle Assessment," *Environmental Science and Technology*, 1995, Vol. 29, No. 3, pp. 134A-139A

Table 5.1 Environmentally Responsible Product Assessment Matrix

Environment					
Life-Cycle Stage	**Materials Choice**	**Energy Use**	**Solid Residues**	**Liquid Residues**	**Gaseous Residues**
Premanufacture	**(1,1)**	**(1,2)**	**(1,3)**	**(1,4)**	**(1,5)**
Product Manufacture	**(2,1)**	**(2,2)**	**(2,3)**	**(2,4)**	**(2,5)**
Product Packaging and Transport	**(3,1)**	**(3,2)**	**(3,3)**	**(3,4)**	**(3,5)**
Product Use	**(4,1)**	**(4,2)**	**(4,3)**	**(4,4)**	**(4,5)**
Refurbishment-Recycling-Disposal	**(5,1)**	**(5,2)**	**(5,3)**	**(5,4)**	**(5,5)**

One is the increased diversity of materials used, mainly the increased use of plastics. The second aspect is the increased use of welding in the manufacturing process. In the vehicles of the 1950s, a body-on-frame construction was used. This approach was later switched to a unibody construction technique, in which the body panels are integrated with the chassis. Unibody construction requires about four times as much welding as does body-on-frame construction, plus substantially increased use of adhesives. The result is a vehicle that is stronger, safer, and uses less structural material, but, one that is much harder to disassemble, recycle, or throw away.

The Air Force should concentrate on conducting life-cycle inventories for the materials and processes that go into the systems it uses. These limited LCAs will reveal substantial numbers of opportunities to investigate material and process substitution possibilities with the potential to reduce or prevent pollution. In addition there should be established on an expedited basis a group within the Air Force Laboratory system charged with developing the database and, particularly, the methodologies for performing LCAs for all current and future materials and systems.