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Industrial ecology, its origins, progress, and relation to IIASA

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Thanks to the organizers of this meeting for the opportunity to speak with you. I have three goals. First, I want to share with you my personal view about what made IIASA important in the past. Second, I want to share with you some of the main ideas of the field of industrial ecology, a field to which IIASA has contributed much. Finally, I will offer my view of what can make IIASA important in the future.

Why IIASA mattered

To explain what made IIASA important in the past, I will speak of my own experience. In June of 1979, I became a member of the 2nd class of the Young Scientists Summer Program. The class of about 25 young researchers included several Russians, a Bulgarian, a Czech, East and West Germans, and representatives of many of the other member countries, including the USA. For all of us, I think, it was a precious chance to go from being a uni-national to a multinational. It is important to emphasize the difference between being in a national setting that happens to have people from many countries, as most US universities do, and being in a genuinely multinational setting in which no national - or disciplinary - perspective dominates. Such a context is destabilizing for the individual and thus extremely stimulating.

The IIASA setting was especially stimulating because it brought into direct contact scientists from nations in conflict, in Cold War. Among the other members of the YSSP program, the person with whom I became most friendly was Czech. Even more important, my advisor was a Soviet from Novosibirsk, Oleg Vasiliev, leader of the Resources and Environment group within IIASA. Oleg, with whom I remain in contact, is an expert on the flow of the great Siberian rivers that flow into the Arctic. As a young American it was thrilling to work for a Soviet, especially one who was an excellent scientist.

Observers of the scientific enterprise broadly accept that science is international in scope and activity, and that international cooperation has always been intrinsic to it. Indeed, much experience suggests that the permanent framework of international intellectual communication that operates among scientists is essential for the advancement of science.

After the bombs of World War II, scientists became increasingly aware of their social responsibilities. Some scientists used their communication networks not only for cooperation in science, but also to reach across international lines of conflict, in attempts to mitigate such conflicts. Some of these activities are well known and documented -- for instance, the activities of the international Pugwash movement, which was recognized with a Nobel Peace Prize in 1995. Many other activities of similar nature but smaller in scope, or limited to regional conflict, are little known and less documented. Until recently, scholars had not examined these activities and their influence on international relations. Several of us with personal experience in these activities became aware of their increasing scope and concluded that they merited serious study.

Since 1995 Alexander Keynan, a biologist at Hebrew University in Jerusalem, and I have organized a series of studies on "Scientific Cooperation and Conflict Resolution." Because little documentation existed on the subject, the project began with a series of case studies on particular conflicts (such as US-USSR and Israel-Egypt), natural science disciplines (such as seismology), and institutions (such as Pugwash and IIASA). Most of the studies were conducted by scientists who themselves participated in attempts to use scientific cooperation for international conflict mitigation and drew on many interviews with other scientists involved in these activities. In 1998 the New York Academy of Sciences published a volume offering the case studies as well as a synthesis of the literature, "Scientific Cooperation, State Conflict – the Role of Scientists in Mitigating International Discord" (A. L. de Cerreno and A. Keynan, eds., *Annals of the New York Academy of Sciences* (866), 1998). Although the NYAS project included a case study of the Argentina-Brazil conflict, it emphasized U.S. experience during the Cold War and the Middle Eastern conflict. We have now completed a sequel volume, summarizing the wealth of experience of cooperation among European scientists after World War II within Europe. The volume is titled, "Scientists, War, and Diplomacy: European Perspectives," (J. H. Ausubel, A. Keynan, J.-J. Salomon, eds., *Technology in Society*, 23(3), 2001).

From our studies of science and conflict, I conclude strongly that both an intellectual and a practical opportunity reside in this field. Many relevant conflicts, institutions, and intellectual networks remain unexplored by scholars. And many diplomats and others concerned with international relations remain unaware of the potential within the scientific community for action for conflict mitigation. IIASA remains a prime framework in which scientists can mitigate international discord.

In June of 1979 I arrived in Vienna from the US National Academy in Sciences, where I was a resident fellow studying the causes and consequences of climate change. I went to IIASA expecting to stay for 3 months, but remained almost 2 1/2 years. My experiences at IIASA profoundly influenced my career in every way: the problems I work on, the ways I approach the problems in a technical sense, the shift from a uni-national to a multi-national perspective, the networks of people with whom I work, including Pekka Kauppi and Nebojsa Nakicenovic, speakers in today's program, and my belief in the contribution science can make to conflict resolution.

I also had Cold War adventures that added spice to the scientific work. In March 1981 I wrote the last speech delivered in the West by Soviet Arkady Belozerov, then IIASA's Deputy Director. A few days later Arkady was videotaped handing an envelope full of money to a Norwegian double agent for information about North Sea Oil in front of the Vienna Volksoper. The story made the front page of the International Herald Tribune as well as major weekly magazines in Germany and the UK.

I tell this story not for nostalgia nor to shock. Rather, the story makes the point that the stakes for international cooperation were high. The stakes were high because of the state of war that in fact existed between the US and USSR. And the stakes were high because knowledge was precious. Knowledge about energy systems and about food supply and others subjects of study at IIASA had high potential value. I said I would address why IIASA was important. IIASA mattered because it operated in a dangerous, high-stakes environment. The political context multiplied the value of its scientific contributions.

Industrial ecology

Now let me turn to industrial ecology. The Greek oikos, for house, fathered the siblings economics and ecology. Economics, literally, are the house rules. Ecology is the branch of biology which deals with the mutual relations between organisms and their environment. Ecology implies more the webs of natural forces and organisms, their competition and cooperation, and how they live off one another.

Industry, according to the Oxford English Dictionary, is "intelligent or clever working" as well as the particular branches of productive labor. During the late 1980s, reflecting on the first two hundred years of the industrial revolution, I and several other engineers and scientists began to wonder whether it might be time for a new fusion of the old siblings, economics and ecology. Industry, quantitatively, had essentially solved the problem of production. Factories could readily and cheaply make masses of shoes the world might want and stamp out masses of cars like tin ducks. But the massive production also generated massive by-production. And the by-products and the products themselves consumed material and piled and diffused into larger, more widespread threats. "Waste," a seemingly trivial offspring of early economies, now seemed prepared to impoverish or murder its parents.

Green nature appeared to have gone far in solving this problem. In nature, webs connect organisms living together and consuming each other and each other's waste. The webs have evolved so that communities of living organisms lose little or nothing that contains available energy or useful material. Organisms evolve that make a living from any waste product with available energy or useful material.

Industrial ecology asks whether Nature can teach industry ways to go much further both in minimizing harmful waste and in maximizing the economical use of waste and also of products at the ends of their lives as inputs to other processes and industries.

Ten years ago a group of us set off under the banner of "industrial ecology" to explore whether we could do away with all waste, or at least achieve massive reductions. Among the group were Stefan Anderberg, William Stigliani, and Robert Ayres, who accomplished much at IIASA in its industrial ecology projects.

Our view is that the *goal* of industrial ecology is to lighten the environmental impact of economic activity both per person and per dollar, and the *role* of industrial ecology is to find leverage, the opportunities for considerable improvement from practical effort. Industrial ecology can search for leverage wherever it may lie in the chain from extraction and primary production through "final" consumption, that is, "from cradle to rebirth."

A range of means exist to lessen impact. Let me briefly mention a few, including zero emission systems, lessening intensity of use of materials, and improved technical efficiency in providing a good or service:

--First, Zero emission systems. Our societies need to move from leaky to looped systems, both for energy and materials. In fact, in the 1980s at IIASA Wolf Haefele, Thomas Lee, and Cesare Marchetti pioneered the concept of "integrated energy systems" in which all wastes would be captured and sequestered or re-used. Fears about global warming make time for rapid advances in very large zero emission power plants. These ZEPPs can be paragons of industrial ecology.

--Second is lessening intensity of use. We can measure the intensity of use of a material in an economy against money. For example, we can measure the wood pulp that is used for each dollar in the US economy. Changes in taste or behavior can lessen materials intensity. So can materials substitution. For example, the use of concrete ties for railroad tracks in lieu of wooden ties reduced the intensity of use of wood in the USA economy.

--Third is increased efficiency in use of raw materials or other inputs. This leads to

--Dematerialization: trends in delivering equal or more services with less stuff.

--Decarbonization: evolution of the energy system for more service while burning less carbon, through more low-carbon fuel (natural gas) or no-carbon fuel (hydrogen) and through more efficient generation, distribution and use. The phenomenon of decarbonization was first identified at IIASA and named in 1989 by Nebojsa Nakicenovic and Arnulf Gruebler and their collaborators.

Methods for discovering and measuring progress include:

--Materials flow and balance analyses.

--Comprehensive accounting for industrial ecosystems at several levels (firm, sector, region) by elements (such as chlorine or cadmium) and by sectors (such as wood products or automotive). Recall that the first industry to introduce comprehensive materials accounting was the nuclear industry, studied at IIASA in the 1970s by Rudolf Avenhaus, the first member of IIASA's scientific staff. The nuclear industry carefully accounts for every gram of uranium and plutonium. It is an important model for all of industrial ecology.

--Life cycle analyses of products: Only a handful, such as Styrofoam cups and diapers, have been analyzed. We need quick, reasonably accurate ways to sketch many products as well as skills to detail the most important or subtle.

--Indicators: Intensity-of-use, waste-to-product ratios and a suite of other metrics or compasses need to be developed and tested to guide the economy to get more out of material and leak less.

Important levers to achieve the goals of industrial ecology relate to choosing materials, designing products, and recovering materials. Other levers relate to institutional barriers and incentives. For example, what are the prospects for waste markets and waste exchanges? Can accounting that tracks materials better favorably improve both the environmental performance and profitability of firms? What leverage can be gained by changes in regulation of the recovery and transport of industrial wastes or by manufacturers taking back products?

Strikingly, key features of the new, information-rich economy, in product development, manufacturing, and logistics, as well as new service organizations, may favor the movement toward low-waste. The new economy may help make the simple, powerful idea that society must balance its accounts of materials and energy an idea that we can act upon effectively. The internet makes possible re-use of products through auction sites. It makes possible waste exchanges, and generally creates markets where none could afford to exist before. It makes detailed labeling of parts and products cheap and reliable, so they can be tracked, recognized, and sorted.

The gratifying fact is that industrial ecology now exists as a field. We have a flourishing *Journal of Industrial Ecology*, which receives many high quality submissions. An International Society for Industrial Ecology has been formed and will have its first major meeting in November 2001 in Leiden. IIASA can take pride in having contributed to the intellectual and institutional formation of industrial ecology, which is after all precisely a form of applied systems analysis.

How IIASA can matter

Let me conclude by sharing my ideas about what will make IIASA important in the future. IIASA must work on dangerous problems, dangerous as much because of politics and fashion as because of the seriousness of the problem.

With regard to politics, the Cold War is over and Germany is no longer divided, so one must look elsewhere for political danger. Sadly, danger is easy to find: in the conflict between the rich nations of the North and the poorer ones of the South; in the conflicts associated with the rise of China to the position of 2nd most powerful nation; on Korean peninsula; between India and Pakistan; between Europe and the Maghreb; and in the Middle East. IIASA should seek to bridge such conflicts through their scientific communities.

IIASA can succeed in this role only if it is genuinely international. It cannot succeed as an Austrian institute with a spritz of foreign visitors.

If the political context is tense enough, cooperation in almost any domain can help. Americans and Chinese began with the famous ping-pong diplomacy. But in many situations, we can choose more urgent subjects than ping-pong. Climate change was an intellectually dangerous problem a generation ago. In 1975 at IIASA American economist William Nordhaus invented the idea of carbon taxes and Italian physicist Cesare Marchetti offered the first menu of carbon sequestration and invented the term "geoengineering." In 1981 at IIASA a Swedish expert on operational gaming, Ingolf Stahl, and I published the first paper on carbon emissions trading. Now I think these climate problems are intellectually safe.

But dangerous problems abound. Globalization offers some, for example, the evolving geography of employment. The next wave of nuclear energy development around the world may be an appropriately sensitive and risky topic. In contrast to production, consumption remains a dangerous subject, because it touches issues of individual freedom. Issues relating technology to personal privacy and confidentiality might qualify. The interactions of the new economy and industrial ecology might also offer some danger. What do we understand about a world in which chips could go into 1,000 objects per capita, or 10 trillion objects? No group has yet offered in detail the technical vision of a large prosperous economy that emits little or nothing.

I give these as examples. IIASA is a small institute. It can address only a few problems. But let me conclude by stating again that whatever IIASA does, it must be politically and intellectually dangerous.