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The Conference have indicated that the technological trajectory to reach the goal of global monitoring is well defined: remote sensing will be guided by global models, and the data so collected and analysed will be the input of an easy to use knowledge base.

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REPORT ON TECHNOLOGICAL OPPORTUNITIES

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ABSTRACT

The technological opportunities to predict and solve environmental issues as debated at the Conference together with the potentiality of related business development are presented here from a peculiar point of view: the Conference is considered to support the hypothesis that we are leaving in a period of transition of the "technical system". The increased difficulties, on one hand, to match the changes of the environment, and the development, on the other hand, of radical new technology such as that of remote sensing are both signs of such a transition.

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INTRODUCTORY REMARKS

Reporting the Conference debate on the issue of *technological opportunity* poses first of all a "what?" question.

The subtitle of the Conference - *predicting and solving environmental issues* - provides an answer. In other words: could technology provides solutions for both problems of predicting and solving the environmental issues?

But there is another angle to look at for the technological opportunity. It is the so called "fall-out" effect of technology development, in term of business opportunities. The Conference did not directly focus on such fall-out issue. I will try, nevertheless, to include also business opportunities in the theme of *technological opportunities*.

You should not expect that in my reporting on the Conference I will provide you with a summary or a synthesis of the papers

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and discusions. First of all because I am not an environment's specialist.

I have therefore to try a different approach.

My reading of the abstracts first, and then listening to the presentations were biased by a general frame of reference on today state of the *Technical System*. By Tecnical System, or TS, I intend the interrelated ensemble of man's products, their use, their manufacturing. By products we should intend any material or "immaterial" artifact in its more general definition.

Such frame of reference is that today the TS is undergoing a major transition to a new TS. Since this is nothing more than an hypothesis very much debatable - first of all on the meaning itself of the word "transition" - my biased approach to the Conference has been to try to consider it as an experiment to test such an hypothesis. In other words, to get evidence, if any, from the papers presented and from the debate that will support the *TS transition* hypothesis.

To perform this tasks, I am obliged first of all to draft the hypothesis.

THE TRANSITION HYPOTHESIS OF TS

The TS can be considered as a *complex open system*. There is a thesis that any complex open system developes along the time following a standard pattern of changes. The system goes through periods of stable expansions, interspersed by period of transition, following a *cyclical pattern* of dynamics whose phases are:

- a period of stability of the system's "structure" with predictable evolution of the system, exploiting the potentialities related to its structure,
- a period of transition were large fluctuations appear and are sustained,
- the passage through a catastrophy where the system changes its structure,
- a new period of stability with predictable evolution with a new system structure.

The hystory of techniques has shown that TS follows that type of pattern. There have beeen periods of hystory characterized by a given TS, followed by period of transition after which a new technical system emerged.

The period of transition might be quite long, and it might be very difficult to tell if it is in a transition period or not, by observing the system during the transition. In fact the TS in the so called stable period is not static. Technological innovation is a continous characteristics of the evolution of the TS in all periods. The basic difference being, that during a stability period the innovation should be compatible with the system structure: more radical innovations might therefore be blocked.

To answer the question wether today the TS is undergoing a transition or not is a matter of major relevance for the different policy options to help the system to progress. The better understanding of the dynamics of technological innovation together with the "paradigm" of a standard open system dynamics pattern, help in tackling the question of the transition of TS.

There are "signs" emerging from the TS which support the transition hypothesis:

- there are drastic changes in "horizontal" technologies (pervading all products and process): new materials (such as composites); new processing technologies (such as laser); new concept in production systems (such as flexible manufacturing); the revolution of information processing.
- there are business sectors (such as aerospace) where the new technologies have already made a deep penetration.
- the environmental challenges to products and processes have started a *de-maturity* process in mass producing industries (such as automotive).
- radical new technologies (such as genetic engineering) push for radical changes in important industrial sectors (such as biotechnology).

THE BASIC CYBERNETIC CYCLE OF MAN'S ACTIVITY

To be able to use the general hypothesis on the state of today TS for a closer analysis of the Conference debate, I have to expand a little on the specific features of the TS.

Man's interaction with the environment follows a *basic cybernetics cycle* (ref. 1):

- the environment acts on man who perceives it through his sens aided by sensors;
- the data so perceived are processed by the man's brain with the

aid of processors;

- on the basis of such analysis man decides to act on the environment using his language aided by expressors and his gests aided by actuators;
- the environment so modified acts on man, who perceives it by his sens aided by sensors.

The cycle continues on a progressive way, were new sensors by producing more data requires more powerful processors, which permit to conceive more ambitous actions of man on the environment which, to be developed, requires more powerful tool.

Artifacts have therefore developed during the course of man hystory with positive feedbacks. Innovation in any one of these classes of artifacts - sensors, processors, expressors, actuators - induce the need of changes on the other classes of artifacts along the cycle. *Radical innovation* in one class of artifact may be the determinant of change of the TS.

The present transition period of TS seems to be characterized by the emergence of radical innovation in sensors and processors.
This Conference is contributing the evidence coming from the environmental monitoring and control technology.

With the radical changes in sensors and processors new lines of business are developing grouped under the name of *Information Technology*.
The technological opportunity related to the new discoveries in microelectronics had the possibility to develope into innovations and business opportunities at a fast pace and large scale, thanks to non-market demand coming from defense project and "big science" project. The availability of the new sensors' and processors' technology has already had effect along the basic cybernetics cycle and more conventional market pull mechanism are now fuelling the further development of Information Technology. This market demand is coming from new expressors and from new components for "old" actuators.

One should now pose the question wether the new information technology will limit the impact for the actuator at the level of special components or wether radically new actuators will emerge. Technological scenarios can be described with radical changes in *actuators* such as, e.g., driverless automobiles.

The answer to the original question, wether the today *fluctuations and uncertainties* in the TS are signalling a transition to a new TS or not, might depend from the level to which information technology will diffuse in the field of actuators.

If we accept the hypothesis of the transition, then a major *policy issue* confront us. A transition period is an exciting but unefficient and "dangerous" period. The objective of mankind should therefore be that of *accelerating the passage through the transition* to the new more efficient TS. This objective is of particular evidence for the case of the environment issue, due to the unability of today TS to cope efficiently with the posted ecological problems. The paper by Mittenpergher entitled "Can we solve the resource and environmental problems together" has clearly indicated the paradoxical cases where the intervention to reduce one pollutants in one media - such as sulphur in air - simply transfer the pollution to another media (in the specific case, is the underground waters that are threatened by the leaching of the muds resulting from the treatment of the fuel in power plants).

The intrinsic mechanism operating within TS - such as the push of technological options and the pull of market demand - will eventually produce the change to the new TS. But the completion of the process might require a very long time.

Non-market mechanism are needed to anticipate the market pull in exploiting the technological opportunities. Large projects are needed with public funding. The environmental issue aiming at <u>high</u> <u>performance,</u> <u>cheap,</u> <u>clean</u> products and processes could provide the rational for large projects. The strategic relevance of the issue for our future should assure the needed determination to proceed.

THE CONFERENCE'S OPPORTUNITY TO TEST TS TRANSITION HYPOTHESIS

A complex open system when approaching a transition period shows a characteristic behaviour. The signals emerging from the systems can be so summarized:

- A) the system shows increased difficulties to match the changes of the environment;
- B) the system potentialities of growth are saturated. The interrelation between system components become extremely complexes and system actions very inefficient;

- C) Fluctuations from the "normal trajectory" of the system tend not to be quicly written off, and positive feedbacks appears which might lead to irreversible changes;
- D) the changes are visible also in the subsystems having a long time constant (a large inertia to change).

For the case of TS one could more specifically look for the:

- E) emerging of radical technology and their diffusion in some of the TS subsystems.

To which extent one could pretend that this Conference is supporting the case that such signals are emerging from TS?

Reading the titles of the different sessions is already quite instructive to this respect:

- first of all the emphasys on the global issues is underlining the "increased difficulties" to match the environmental changes produced by the diffusion of man's activities (signal A). In the introduction to session 1.3 (Technological solutions to environmental problems) G. Bugliarello underlined the need to understand the general ways by which man interact with nature. In plenary sessions there where discussions on the role of economy and economists on the environmental issues, and wether the problem should not simply be related to our difficulties to deal with the human nature. It is a sign of increasing uncertainties that of starting asking "ontological" questions: the "why?".
- session 3.1 (pollution monitoring and treatment technologies) point to the "complexification" and the inefficiency of today production system (signal B) because of the need to perform very difficult monitoring of the pollution and to intervene with treatments sometime in a gigantic scale.
- sessions 2.3 (remote sensing: a planetary perspective) and 2.4 (automated information system: a key to global understanding) by stressing the need of global understanding, underline that the man artifacts are already producing positive feedback on a large scale (signal C) in their interaction with environment. The development of monitoring and management systems that will meet the "global" monitoring challenge (predicted on the basis of sucsessful undergoing R&D projects), in the same sessions 2.3 and 2.4 are *per se* pointing out the emergence of radical technology leading to new system organization (signal E);
- The information system on the "state of the earth" is itself a

subsystem of TS. Let us assume that it has a longer time constant than other subsystems of TS (its change will have then a determinant effects on shorter time constant subsystems). Sessions 3.3 (the use of remote sensing in biotic analysis) and 3.4 (remote sensing of terrestrial hazard) have dealt with the actual application of the new technologies of remote sensing. Even if still in an experimental phase, remote sensing represent therefore a "visible change in a subsystem with long term time constant" (signal D).

- the importance of the emerging new technology of environment monitoring and management is confirmed by the somewhat speculative session 1.2 (Environmental monitoring in emerging Nations). In this session the applicability of the new emerging technology of remote monitoring to problem like that of periodical floodings in Bangladesh was discussed and positive evidences from experimental programs were shown.

In general there was consensus that a new technical fix to tackle the environmental issue is emerging. The new fix is based on the availability of more and better information on the effects of man's activity on environment. During the discussion in session 1.3 (Technological solutions to environmental problems) it was underlined that the impact of information can be seen from at least three different viewpoints:

- information could improve the *global efficiency* of man's activity both by increasing the performance of production and by reducing the negative impact on the environment. This is the case of agricolture, as underlined in the paper by Morandi.
- information could help solving conflicting requirements between the use of natural resources - such as potable water - and its polluting by the release of wastes from industrial plants. The development of more powerful analytical tools will permit to understand what are - and for which substances - the safe level of pollutants allowable in the waste streams. Moreover, continuous monitoring will provide early signals on transient conditions that might reveal bad or improper functioning of the industrial plants.
- information could help in overcoming the irrational blocking of strategically important and acceptable technology - such as nuclear energy - when it has demonstrated on the basis of

cumulated hundreds of reactor x years of operations that it is clean and safe. The unability of society to have a simple look at nuclear energy - as illustrated in the paper by Mrs. Schwartz - might, on the other hand, be considered another indication of the general "complexification" of today TS.

FEATURES OF POST-TRANSITION TS SYSTEM

The Conference has dedicated sessions to the constraints that the ecology issues pose to economic activities (see session 2.6 "economic perspective on environmental policies" and session 3.5 "economic environmental management"). It did not however address the problem of which will be the features of the future TS to meet the global environment challenge.

In order to report on the technological opportunity extended to business opportunity, it is important to address such a question.

The paradigm of the dynamics of *complex open system* might help in showing the general features of system development especially so when looking at what characterizes the system emerging from a transition.

The paradigm postulates that any complex open system "progress" towards states of an increasing complexity that the system can manage by an increased "intelligence". The paradigm semantics is coming from the analysis of the evolution of living systems. Applying the paradigm to other system, such as TS, require to define such word as "intelligence": the system's ability to gather information and to process it (ref.2).

The "system intelligence" is part of the "system structure", itself a somewhat vague concept. During the transition period a "higher level of intelligence" developes together with the new system structure. The need of a higher level of intelligence is shown towards the end of a stability period: the system "complexification" and inefficiency is an indicator of the unability of the "system intelligence" to manage the "monitoring and processing" of intra-system and extra-system interreleshionships (which became progressively too complex during the system evolution in the "stability" phase).

With specific reference to TS the trend towards an increased complexity - either in the products or in the manufacturing

processes or both, and in the scientific knowledge - is apparent along the hystory. Since the average intelligence of man did not change in the meantime, one could ask how it is that today man could deal easely with a much more complex TS than in the past. The answer is that the complexity is "packaged" into easy to use "products" (both material products or "immaterial" ones such as the scientific disciplines' corpus of knowledge).
How could we deal practically with the "global environment monitoring and management information system" unless the related mass of information and knowledge could be packaged with simple recipes for use? As a matter of fact several papers in session 2.3 and 2.4 stressed the need to develope methodologies and procedures to manage the immense collection of data that the remote monitoring system is starting to produce.

If we are in a transition period we could not yet take advantage of the new "system intelligence", but we could sense it emerging. And this Conference is supporting the idea that a new "intelligence" is indeed emerging at least with respect to the problem of environmental monitoring. Not having yet available the new instruments to approach the ecological problem we have all the difficulties of dealing with a very complex situation using old techniques. The possibilty of solutions are limited and cumbersome. Often a "patch work" is the only practical possibility.

LOOKING AT THE TECHNOLOGICAL OPPORTUNITIES

If we are living in a transition period of TS, the problem of the technological opportunities related to the ecology issues can be seen from two perspectives:

- from the necessity to adapt the past, but still prevailing, TS to the environment protection needs;
- to anticipate the changes to a future TS which should provides more simple and apt solutions to the problem.

The environment problem is seen from today TS mainly as a constraint for the manufacturing processes and for the products. The technological opportunity to solve the problem tend to induce an increase in complexity and cost while reducing performance's efficiency.
This nothwistanding, specific business opportunities have emerged

and developed. They have the characteristics of *market niches* related to the development of new components for products (such as catalists for automobile exaust gas) and new plant to treat the wastes ("add on" business opportunity).
The increased complexities of constraints to the production activity requires specialized knowledge which might not yet be "packaged" in easy to use recipies. This give an opportunity to provide specialized services, e.g. in engineering (such as the preparation of the environment impact report).

The environmental issues, on the other hand, represent a challenge to intrinsically reduce pollution, by *rejuvenating* existing products and by developing new manufacturing processes. And the need to process more information that goes together whith the environmental protection issue, represent *per se* an opportunity of business development for new hard and soft products and for new services.
This perspective from the *future TS* point of view, materialises in specific actions and opportunities of today, because of the technology to be developed. The business opportunities might be related less to market mechanisms (than in the case of the today TS perspective) and more to non-market demand such as that coming from public pilot projects.

OPPORTUNITY ISSUES UNDERLINED AT THE CONFERENCE

The Conference emphasis was on global issues. This approach have characterized all the sessions, those related to the assesement of the state of the environment or to more general social problematiques as well as those dealing with the technological opportunity to solve the ecology problems.

From the grand angle of the Conference perspective it is difficult to expect that special attention could be given to the opportunity of the environment industry of today. Session 3.1 was dedicated to the problem of pollution monitoring and treatment techniques. In these area an "add on" environment industry has developed which - according to a recent study performed for the European Community- is employing in Europe some 1.5 million people. One has reasons therefore to think that the market niches to produce components and treatment plants for today artifacts, should be already well exploited and the technologies well esta-

blished.
The papers in session 3.1 instead pointed out that the problem itself of determining the *polluting inputs* to the different media - which is upstream of the technology to abate by proper treatment the various pollutants - is far from solved. This state of uncertainty should make uncertain also the regulatory legislation which is the major determinant of the demand of "environment industry"'s goods.
To our hypothesis of a transition TS this remark comes has a confirmation of the state of inefficiency and complexity of the present TS.

Returning to the grand perspective of the Conference debate, the technology issue was dominated by the need to develope sensors and processors. Several sessions were dedicated, from different points of view to these problematiques. Some papers have been somewhat overlappings in the sens that all referred to the same general objective - the need to monitor at a global scale - and to the few large pilot projects underway (such as GEMS = Global Environment Monitoring System) or planned (such as EOS = Earth Observing System).
This clearly shows that the art of *global environment monitoring* is in a state of flux.
But it appeared another aspect from the papers and the discussion that well support the hypothesis of a transition to a new TS. The *technological trajectory* to reach the goal of global monitoring is well defined with no major alternatives:
- remote sensing is the solution and to be effective it should be guided by complex global models. The data so collected and analized should be the input to an easy to use *knowledge base*.

This *technological trajectory* is quite "distant" from any actual operating environment monitoring system. We are therefore faced - in the basic cybernatics cycle - with a radical change in the ability of man to collect and process information from the environment.
If the scenario on sensors and processors is clear enough, one could ask what technological scenario could be derived for the other components of TS. The Conference did not speculate much on the impact that the ability to control the state of the environment will have on the future TS. Hints were given, though, on

the implications for the developing countries (session 1.2), controlling desertification (session 1.4), urban planning (session 2.2).

The Conference did not directly address the problem of business opportunity with the exception of the case of the new services to provide the information coming from remote sensing. In fact the exibit at the Conference's premises has shown that commercial activities are starting in that direction. In USA the Landsat data exploitation has been recently passed to a commercial organization, EOSAT. In Europe the availability of information services from future orbiting platforms, such as foreseen by the SPOT program, is already advertized (in Italy by Telespazio). It is too early to extrapolate what will be the actual development of this business in the coming 10-20 years.
Specific application services have already been pointed out, and debated at the Conference, such as:

- the historical reconstruction of the territory, as illustrated in the paper by Posocco and Pasqualini;
- the development of "Biomaps", as solicited in the paper by Baer;
- the application to early monitoring of incoming natural disaster, such as flooding, and the evaluation of subsequent damages.

One has however the impression that many more services should be developed to exploit the full potential of remote sensing. Custom tayloring of the information services should be developed to serve the costumer's specific needs (in an easy to use *packaged* way). One case of interest is that of agricolture. The potentiality for these applications is here, if one consider that, in parallel, new information's processing technologies are being developed, under the name of *knowledge engineering* (e.g. expert and learning systems).

I like to underline one message that emerged clearly from the Conference which is of relevance for the future of the business related to the remote sensing technologies.
To meet the global environment monitoring and managing target the described *technological trajectory* has to be followed. To this effect, large projects are needed to which large amount of public resources will have to be devoted. These projects will represent a non-market demand for instrumentations, processors, services

industries. The scale of the needed resources are such that this non-market demand might play a role similar to that played by defense or big science projects.

The prospected new International Center on Global Environmental Research in Venice - *for the foundation of which this Conference* can be seen as the first stone - can be considered as one of the action programs to be developed.

THE CHALLENGE FROM ECOLOGY TO DESIGNER

To conclude this report I will again refer to the subtitle of the Conference: predicting and solving global environmental issues.

That of predicting is a challenge for scientists. That of solving instead is a challenge for designers.

The Conference did not specifically address the design problem. Enphasis was on *global understanding*. But if the scenario of global understanding will become a reality, than disposing of the knowledge on the mechanisms of man-environment interactions and of the relative effects, will challenge the designer to a radical shift of approach.

The designers have always assumed that the artifacts that they design to be built - no matter how gigantics they might be - they are small with respect to the global environment. As a consequence, their impact on the environment could be solved by interposing interfaces between the artifacts and the environment. The *global understanding* begin to indicate that this might not be true anymore.

The "smallness" hypothesis on the other hand did not require to understand the global behaviour of the system. If this hypothesis no longer hold, than designers should know what are the global patterns of behaviour of our planet and how they interact with human modification of nature. But if the system is complex enough - and this is certanly the case here - then *global observations* are needed, since a "reductionist approach" leave few hopes to "reconstruct" the *wholeness* of the system in term of the *reduced* knowledge of the interaction among its components. And this Conference have given us confidence that *global understanding* is feasible.

We have learnt to design <u>components</u> of the global system. We have now to learn to design complex multilayered hierarchical system. It is not just the so called "system approach" (taking into consideration all the system interactions in designing components). It is the actual designing of the *global system*.

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