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APPLYING S&T TO GLOBALIZATION ISSUES:

REFLECTIONS ON GLOBALIZATION, COMPLEXITIES AND PROBLEM-SOLVING

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Premises

.... a theory of rational behaviour must be quite as much concerned with the characteristics of the rational actors - the means they use to cope with uncertainty and complexity - as with the characteristics of the objective environment in which they make their decisions. In such a world, we must give an account not only of *substantive rationality* - the extent to which appropriate courses of action are chosen - but also *procedural rationality* - the effectiveness, in light of human cognitive powers and limitation, of the *procedures* used to choose actions.

.....

It is customary in the theory of computational complexity to regard problems of a given size as "tractable" if computations do not grow faster than at some fixed power of problem size. Such classes of problems are known as "polynomial complex." Problems that grow exponentially in complexity with size are not polynomial complex, since the rate of growth of computation comes to exceed any fixed power of their size.

.....

Complexity is deep in the nature of things, and discovering tolerable approximation procedures and heuristics that permit huge spaces to be searched very selectively lies at the heart of intelligence, whether human or artificial.

.....

The theory of heuristic search, cultivated in artificial intelligence and information processing psychology, is concerned with devising or identifying search procedures that will permit systems of limited computational capacity to make complex decisions and solve difficult problerm.

.....

Many of the central issues of our time are questions of how we use limited information and limited computational capacity to deal with enormous problems whose shape we nearly grasps.

.....

When problems become interrelated, as energy and pollution problems have become, there is the constant danger that attention directed to a single facet of the web will spawn solutions that disregard vital consequences for the other facets.

.....

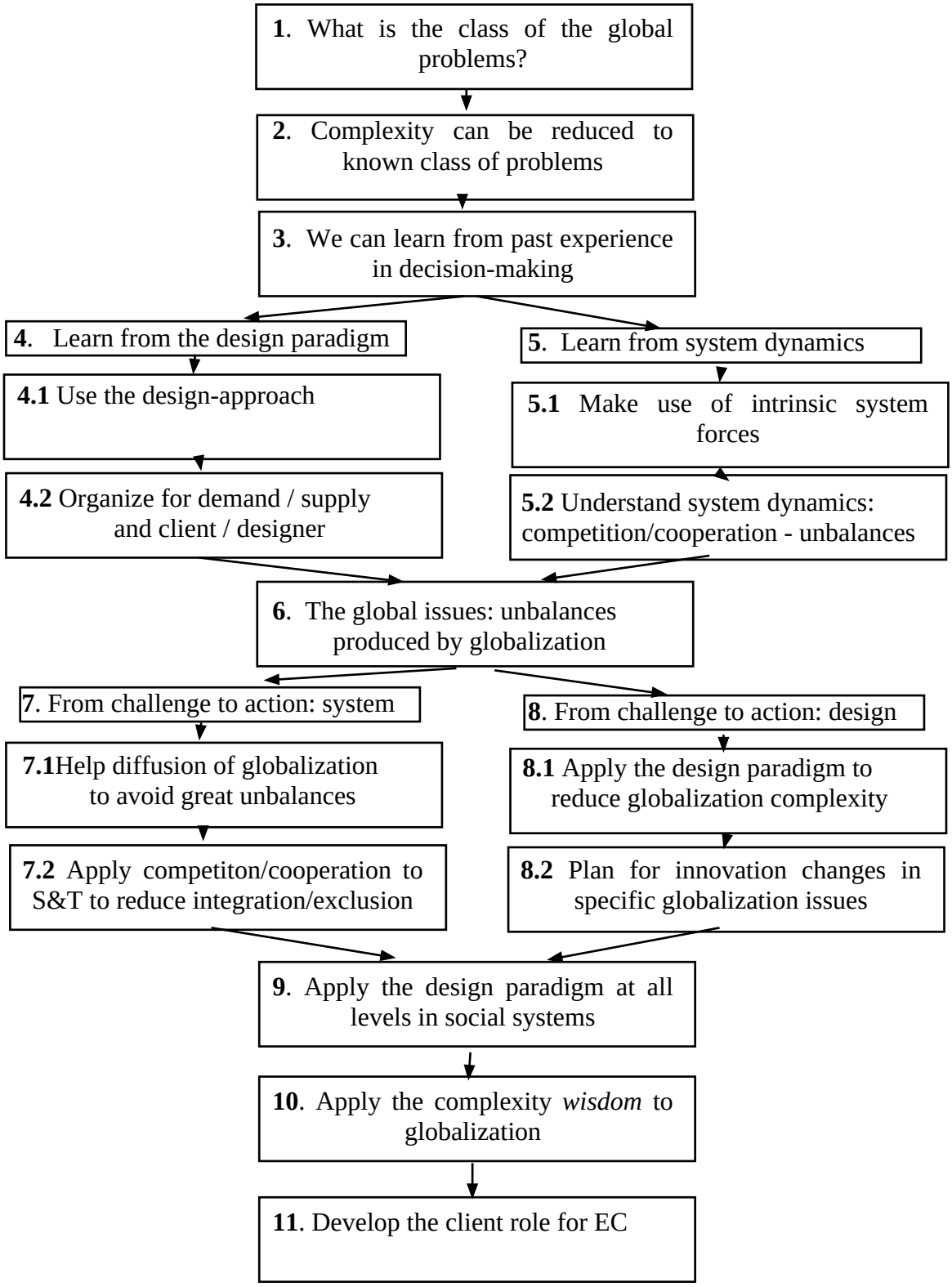
The study of procedural rationality in circumstances where attention is scarce, where problems are immensely complex, and where crucial information is absent presents a host of challenging and fundamental research problems to anyone who is interested in the rational allocations of scarce resources.

H.A. Simon, *Rationality as Process and as Product of Thought*,
in J. of American Economic Association, May 1978, vol.68, n. 2, pg. 1-16.

The above extensive excerpts from a seminal lecture by H.A. Simon anticipate the basic issues one is confronted with when approaching globalization looking for action inducing policies.

In the paper **CSS/fast-10**, ***System Analysis and S&T Policy Needs***, in attempting to identify policy recommendations for S&T intervention on globalizazion problems, we have been forced to support the analysis and the proposals by a description of an appropriate process for decision-making that take complexity and non-linearities intrinsically into account.

We will here, as an accompanying paper, try to streamline the basic reasoning of the approach and of the analysis described **CSS/fast-10**. To convey the essential steps of the discourse we will be somewhat apodictic. The figure below sinthetize the logical path of the reasoning, each box in the flow-chart corresponding to a section of the paper.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1 Globality issues: a new **class** *of problems?*

When dealing with issues that requires to look for solutions, decision makers should ask wheter or not the problems pertains to the same class they are instrumented to solve. While the concept of problem's class might be clear in mathematics, it is much more vague in other cases (such as for social issues). Nevertheless, in practical cases, a decision maker knows very well that he disposes of certain ability, tools and resources to approach problem-solving and that there are problems which are out of his reach.

When dealing with globality issues, it seems quite reasonable to suspect that they pertain to a class of issues/problems that the society, as it is now organized, is not able to approach. Can we, with a world divided into sovereign nations with different political and social organization (*state-centric* world model), approach problems which have reached a real global dimensions (think not only of some environmental issues, but also, e.g., of the international financial system) simply by agreements and cooperation among independent partners? It is not to be excluded that for some issues, particular solutions (considered good enough) could be find with present world organization. However, for the more general case we cannot but feel that a fundamental change is needed in the social system structure if we want to be able to even simply understand what the issues are and to specify the terms of references of the related problems in search for solutions. Even the emergence of a turbulent *multi-centric* world [1] does not assure a better dealing with the globalization issues.

A metaphor from mathematical problem-solving might help to better focus the general problematique. In the domain of natural numbers (positives and integers), we can define the operation of addition and we know that a solution will always be found. The operation of subtraction can as well be defined. However, to assure to find always a solution we have to make some basic change: to **shift** to a wider realm of numbers (include the negatives ones). Are we not, in the case of globalization, confronted with problem that - even if we are able to specify them - we might be intrinsically unable to solve, unless we make some basic shift in our *vision of the world*?

A more complex but more instructive metaphor, still in the domain of mathematics, is the following. Suppose that we ask to find the circle that pass trough three specified points in a plan. We know that the problem has a unique solutions.[2] However, the instruments and the approach that we will use are very important for the "quality" and the "efficiency" of the solution. We can adopt an empirical approach: try different circles, up to the moment when whe have found the good one. A better approach will be to remember of our elementary geometry: a triangle can always be circumscribed in a circle, whose center is the point of encounter of the bisectors. However, the graphical approach limits the precision with which we can define the lenght of the radius and the coordinates of the center (say that with a sharp pencil and a good ruler we could reach a precision of 1 mm). Can we find the solutions with a much higher precision (say a micron or a nanometer)? The geometrical approach will fail. However, by choosing a more powerful approach (the analytical one, the writing down of

[1] A variety of transnational state-free bodies crossing over national states. For a discussion of *state-centric* and *multi-centric* world models, see J.N. Rosenou, "Turbulence in World Politics. A theory of change and continuity", Harvester-Wheatsheaf, N.Y., 1990.

[2] With the exception of the special case that the three points lay on a line.

the equation of the circle) we can in principle reach any precision we want. The problem have not changed of "class". Our ability to solve it however depend from our "skill". [3]

Suppose now that we change the problem: we want to join five points on a plan. Is it possible to do it by using circles? We know that the general answer is negative. Is it now the problem pertaining to another "class"? Before advancing an answer, we should make a deeper analysis of our instruments, and pose the problem of the class to which they pertain. Are circles a class of figure of its own? No. They are a special case of a more general class of figures: the conics (or quadratic curves). And we know that there is always a conic that pass through 5 points on a plan. So by a better knowledge of our instruments we can state that the two problems (the 3 points and the 5 points one) belong to the same class. Of course, with the 5 points problems we need to be much more knowledgeable in using mathematical tools. It will be difficult to find even a roughly approximate solution, unless we use the analytical approach (writing down the general equations for the family of quadratic curves): the empirical approach will now be practical impossible; the geometrical ones, quite difficult.
Suppose that now, encouraged by the success of the approach we choose a more difficult problems: selecting a curve that joins more than five points in a plan. We might now say that the problem class has changed, at least in the sense that there are in general no solutions belonging to the class of conics.

Applying the metaphor to the globalization issues, the basic question is whether or not we can (by using better knowledge; by generalizing the ways and approaches we are used to in problem-solving; by being ready to make "structural" changes in our organization) keep the related problems in the same "class" of problems that are within our reach.
We are confident that a positive answer can - have to - be given.

2 Globality is a higher level of complexity: complexity is not a novelty

What impresses us with globality issues are, first of all, their complexity, in the senses of "*everything interlinked with everything*". Can we reduce such feeling of untamed complexity?

First of all we should recognize that we are used to complexity: we face it at every level of our actions. Globality therefore might be seen as a generalization of something we know well: it might be seen simply as an higher level of complexity.

A complex system can be schematized as an hierarchy of interrelated components, integrated in sub-systems which contribute to the system objectives and, by their interactions, actually represents the system itself. Outside of the system is the environment. The system is structured into different levels of subsystems down to a level where we found only "elementary" components (unbreakable "atomic" bricks).

[3] With the naive empirical approach we need to dispose of a large amount of information (to store a set of different circles to try on the three points). With the geometric or with the analytic approach we have much reduced the information needed (a theorem, an equation, a problem solving routine). The original problem has been *algoritmically compressed.* We could perhaps generalize the situation saying that problem-solvers are succsessful if they can find a *compressed description* that can fit the problem in the class of problems they are able to solve.

This simple scheme can be used to build much more complex systems as a "*self-similar*"[4] object: using different "unit ruler" to observe the system, we will perceive always the same basic structure. By using a magnifying lens the "elementary components" become actually complex systems, that are made of lower scale "atomic bricks", having as environment the higher level components of which they are parts. [5] Looking at the earth from a satellite it can be seen as a system where what we on the earth perceive as our environment is actually part of the system.

What is new of globalization is that it has raised the scale of complexity, so that at least a part of what we were used to consider as our environment becomes actually part of the system itself.

3 Can we learn from past experience in decision-making / problem-solving?

If we are used to complexity, then - as active members of the system that we perceive as our own - we are used to act (react or pro-act) to respond to the system challenges.
If so, we should hope that to deal with globality challenges we can learn from our experience.

The trick we uses in dealing with complexity is to limit the range of the complexity of what we consider "our" system: we *expel* higher levels out of the system to make them part of exogenous environment (we cannot act to change the environment; we can only try to forecast its changes to take pro-active decisions), and we *accept* as "atomic" unbreakable parts some of the system components and inputs we use to (reactively or proactively) change "our" system.

The case of the automobile manufacturer can serve to illustrate the point: he knows that the automobile is part of a complex transport system, and that alternative solutions could be conceived (including those where there are no automobiles) to realize the transport system objectives. However, he considers the automobile as the system he should deal with. For him, the transportation system (which includes all the other transport modes) becomes part of the complex environment. Notwithstanding this simplification, the system remains a very complex one (with complex sub-systems and components) and the innovation challenges to respond to the transportation challenges are quite difficult to meet. He knows that the components that enter into the automobile product are complex systems on their own terms and can be the subject of innovation changes. However, he has to assume that they are - at least part of them - given and unchangeable. [6]

[4] The concept of self-similarity has found a large variety of illustrations with the development of fractal geometry and related computer based pictures of fractal sets. A naive example of a self-similar picture is that of a painter making a self-portrait of himself making a self-portrait in which it is visible the table with the self-portrait, and so own.

[5] As a matter of fact, it seems that nature - in building more and more complex systems - has extensively used that trick: from elementary particles to atoms, to molecules, to aminoacids, to basic organs. etc. We should add that at each level of complexity, "elementary components" are standardized (e.g., all biological diversity is built on 20 aminoacids.)

[6] The oil shock and the concern for the air quality have compelled automakers to consider the higher dimension of the transport system (even if up to now they have found possible to respond by adapting the automotive product without having to plan higher transport system level changes).

4 Learn from the past: the design paradigm for decision-making / problem-solving

We are used (since Descartes) to consider a reductionist approach to problem solving: to break down complex issues into small pieces and from them to build - bottom-up - a complex solution.

However, this implies an intrinsic linear chain of cause-effect relationship between the elements of the system where the problem emerges. Since we know that there are non-linear feedbacks in complex system, the reductionist problem-solving approach implicitly assume that the feedbacks could be "frozen", taken for given, be part of the past of the system and not significantly modified by our intervention to change it. This approximation is in many practical cases a satisfactory one (very small actions on a highly inertial complex system).

If globalization brings to the fore interdependence among system members of such a magnitude to challenge the identity itself of each member (changing the system structure), than the *reductionist / separation (decoupling) of variables* problem-solving method is no more satisfactory.

We should therefore look at other procedures, which accept intrinsically the non-linearities. One such procedure is that of the design.

4.1 Apply the design approach

In the design approach - even in the very simple case of an architect that have to provide a solution for a customer wishing a new house - complexity (and feedbacks) enters in a not eliminable way.
Let us develop the case of building an house for a family. The process start with the customer having a vague idea of what he really want. Before the architect can accept the job, a better and clear definition (problem specifications) of the terms of reference of the problems have to be developed. In a linearized model, this will be the responsibility of the client. Instead, he needs to interact with the architect and together try to "design" the specifications. This is done by a complex process that take into considerations the existing portfolio of ideas on types of housing, preliminary sketching of alternatives, etc. The process ends when the client take the responsibility to say that his initial vague desires are now well spelled-out. We can call this initial phase (of better defining what the real problem to be solved is), a "*meta-design*" phase meaning that the interactive complexity of going through all the solving steps has already intervened even if only in a "simulated" design.
Now the problem passes to the architect's direct responsibility. However, very seldom we can say that the problem can right away be broken down into small pieces. The designer has accepted the terms of references on the basis of potentially conceived solutions.
However, before he could develop the real solution, a creative phase has to intervene. And this is a most non-linear process where all the variables are again put together, the specification is challenged items by items, somewhat rejected in the designer mind (the phase is called a "*divergent*" one), up to the point when the designer feels that the process can stop and a "final" solution emerges. The solution is still somewhat theoretical and global, lacking details. One or more designing steps follow to detail the solution. Again, "divergent" stages of thinking might be necessary before "*converging*" to satisfactory (good enough) solutions at subsystem or component level.
We have said that this designing phase is the sole responsibility of the architect. However,

the client will be called in, to get his agreement on details which can change the agreed specifications, the terms of reference. And the client intervention might require to modify envisaged solutions.
The process is an iterative one also when we pass to the implementation of the detailed design. Here the major responsibility passes to the constructor. However, no matter how detailed are the blue prints, there will be instances where the design specifications have to be changed (since they contradict or are in contrast with the reality of the available materials or because of the 3-dimensional effects of a building which was only simulated on 2-dimensional blue prints). Most of the interactions in the construction phase are between the constructor and the architect. However, in some instance, the client himself has to intervene to take final decisions.

In the design case we are faced with a "*micro*-world" complexity which however contains all the features of complexity and non-linearities of a "*macro*-world" complexity.

The proposal, here, is to *refer to the design problem-solving process as a paradigm for the highly non-linear case of globalization challenges.*

4.2 Organizational suggestions: separate demand / supply and specify client / designer roles

There are two extreme models of human behaviour in approaching complexity (two cultures): the one represented by the human and social scientist and the other by the physical scientist. We can refer to the first approach as "*holistic*" and the second as "*reductionist*". These two models have both contributed to the advancement of our cognitive approach to understand the world. However, neither of them are suited to specify actions able to change our world. The "design" approach is actually a compromise between the two: it is an interactive chain of "holistic" cognitive approach and "reductionist" building of solutions.

The *design paradigm* suggests that an important preliminary organizational rule is to be followed: *to define clearly the roles of different actors* in order to contrast the fuzziness caused by complexity and interdependence. Only with a clear definition of actors we can overcome the effects of feedbacks that blur actors and phases of problem-solving. *The process can therefore be considered as a chain of loops centred around each actor*. Each loop is covered a certain number of times involving the interactions of all the other actors up to a point when good enough convergence is met, so that it can be decided to pass the responsibility to the next actor down the problem solving chain (from the client, to the designer, to the producer.).

One of the major difficulties encountered in dealing with global issues is actually the lack of such clear role subdivision. There is a perceived challenge to be met, therefore there is a demand to do something. But, who materialize such demand in term of playing the role of the "*client*"? S&T can represent a potential supply of ideas and initiatives to develop solutions. But how do we organize the related response?

The difficulty to clearly define actors and roles is however not new. Even in the case of producing goods to satisfy clear needs, not always the case is as simple as the one of building a house for an individual client. The "client" usually is represented by the market which is not a physical entity that can express the needs in terms of product specifications. The producer has to guess what the "market" (the future potential costumer) will appreciate. To do this in

practice, the producer has to simulate by himself the role of the client (see the firm's complex internal organization with well separated functions and roles such as Marketing, Design, Production). The organization procedure in a firm is simple enough for products that are already well diffused on the market and the problem-solving has to do with their slow adaptation to the market and S&T changes. The problem is much more difficult for the case of a radically new product. In such a case, changes in the firm organization are often needed (see the project and/or matrix organization). We know by experience how difficult are such cases, and how many firms fail in setting a proper organizational procedures to deal with the novelty. On the other hand the success cases show the importance of clear definition of roles to simulate *client/ designer/ producer* and the assumption of related responsibility by some one.

Globality issues are similar to the case of radically new products. The existing organization (at all levels, local, regional, world-wide) is not apt to deal with some of the more radical issues of globalization. The design paradigm suggests that a central role to be developed is that of the "client".

We might very well feel the globalization challenges, but unless we will clearly succeed in transforming them into problem specifications it will be difficult to allocate the needed re sources, to call the contribution of the S&T community. We know that there is no physical "client" to represent the society in general. However, like in the case of the market, someone has to materialize such a role.

Not all the globalization issues pertain to the same class. Some are really world-wide, some are emerging at local level through global interdependence. The "game" of decision-making and problem-solving has to be played at a scale which is proper to that of the single issues we are concerned with. But in all the cases the same design paradigm can be applied and actors have to be clearly defined to set to motion the demand-supplier mechanism of problem solving.

5 Learn from system dynamics patterns

Suppose that the design paradigm provides us with a satisfactory enough procedure to approach problem solving under complexity. We know, however, that there are designs which are good and other which are bad. The difference comes more from the holistic feature of design than from the reductionist one (which could in principle be subject to "optimization"). One feature that seems to distinguish good from bad design is its being somewhat in *synthony* with the system (that have to accomodate the "product" of the design) and with its environment.
Good designs seem to take advantage of some kind of synergy with the system. This is of particular relevance when the objective of the design is to modify very complex system. The designer should, in fact, in such a case worry whether the foreseen actions are big enough to change sensibly the system trajectory.

5.1 Put complexity intrinsic forces to work

In the case of globalization, are not any possible conceived actions too small to hope to produce results in a relative short time? Learning from the "good" design cases, however, we not necessary have to despair, provided our actions can count on "*leverage*" effects pro-

duced by the forces internal to the system. [7]

In general, the more we know about the system the higher the possibility to intervene on it successfully. It is therefore important that we understand some basic features of the dynamics of complex systems. However, how can we expect to understand the features of a system which is going through radical changes? We have, in fact, to presume that the globalization process is actually representing such a radical change in our "global" system.

A "conjecture" (not demonstrated but for which there are supporting evidences) is that in going through a radical change the system will continue to be "*self-similar*". It might have in creased the number of the levels in its hierarchical structure, but the same basic features will be reproduced at the new higher scale. [8]

5.2 Two basic complexity features: "competition vs cooperation" and "development through unbalances"

We point here to two major self-similar features of complex systems: "*cooperation vs competition*" and "*dynamic development through unbalances*".

This conjecture might apply only to the system which is of our specific concern (the human world system) or be common to a "class" of systems. In the first case, we can hope to learn what are the "self-similar" evidence of the system by looking only at it. In the second case we could have hints and knowledge supports by observing other systems of the same class, since some of these might be well studied.
In fact, we can say that a second "conjecture" is usually implicitly assumed in our cognitive approach to complex human systems: all the systems belonging to a certain class (open and self-organizing systems) share similar behaviour. We can therefore use the knowledge of other systems as a "*metaphor*" for the one of our own concern.

The most important metaphor that have been used extensively is that of the biological system. The biological metaphor underline two basic features - "*generation of changes*" and "*selections of the fittest*"- to explain the system dynamic. To these, one should add that the "members" that belong to the system do "compete" between themselves to pass the selection, but implicitly or explicitly they also "cooperate" (co-evolution) to be better off in passing the selection mechanism (some time also succeeding in modifying the environment). These features are self-similar: we found them at all the levels of the biological scale (from genes, to cells, to individual, to species).
Another important feature of the biological metaphor is that evolution (development) is not continuous, but it goes through periods of stability and periods of changes (punctuated evolution). In other words, the system cannot change radically (at the level of concern in the system hierarchy) unless it has cumulated a large enough unbalance.

[7] A well known physical examples is that of resonance: we can produce big effects with small perturbation, provided, however, that we "know" the "frequency" of resonance of the system.

[8] We have already in Sct. 2 referred to a self-similar feature in approaching complexity: a system is made of sub-systems, made of subsystems while is itself a subsystem of a larger system. As decision-makers we simplify the degree of complexity by "freezing" complex sub-sub-system as "elementary components" and by tracing a boundary that separate what is inside the system from what is outside. If we go up or down the level of complexity, we will always see the system has having a lower level made of elementary components and an upper level outside which is the system environment.

The use of the biological metaphor as an heuristic tool to the cognitive approach to the human system, has pointed to similar features at different levels of observation (from individual, to groups, to larger social aggregates, in the social behaviour as well as in the technological realm).

We propose that the above self-similar features - together with thedesign paradigm - will contribute to developing a *wisdom of complexity* that should help us in with globalization.

6 The Global issues: unbalances produced by the globalization process

To start taking advantage of the *wisdom of complexity*, the self-similar conjecture of *development through unbalances* will help us to approach the first step of the design paradigm: *what are the problems for which we seek a solution*?

The elementary definition of a system is that of "a set of elements that interacts among themselves". In a spatially defined system, an important characteristics is the "range" of the interaction. Elements can directly interact with elements that are very close, or, in other cases, with very far ones. Elements, because of interaction, can aggregate in groups (subsystem) which can interact as a group with other groups or elements.

The evolution of the human system (thanks in particular to technological progress) has been characterized by a three-fold phenomenon: the *increase of the "spatial" span of interaction* among human beings (e.g. by new communication means); the *reduction of "time to interact"* (not only through telecommunication but also through physical interaction); the *increased "reactivity" of the "global" system to local actions* (see the cases of ecological concern).
Globalization can be defined has the undergoing step (the last one?) in this evolution of increasing the "range" (space, time, reactivity) of human interaction to the dimension of the earth itself.

Paradoxally, the ultimate consequences of this change should be that no one is small enough to consider the effects of his action negligible at the global system scale. We know that there are indeed physical systems where this is the case (deterministic chaos). However we should hope to be far from the chaotic end, and that the human system will find ways to restructure itself so that small actions produce again small effects (and local problems could be met with local actions).

The increased range of interactions between system elements is not only a fact that we have to accept but it can represent a potentiality for positive system development. However, this potentiality is not evenly distributed. There are elements (or groups of elements) that can use the increased interaction range to their advantages or which are in a context that amplify their action effects. There is a "*reinforcing mechanism*" so that the diffusion of the basic changes of globalization follows privileged paths. We could use the word "*percolation*" to synthesize such a non uniform diffusion process (percolation is the phenomenon by which a fluid diffuse in an apparently homoge neous filter by preferred paths which the fluids cuts itself through the filter).

"Percolation" produces a separation among the elements of the systems, between the "*integrated*" and the "*excluded*". This will produce unbalances to which the system will later re-

act. The system reaction will be proportionate to the degree of unbalances reached (with the possibility of overshooting).

The risk is that the globalization process is producing too big unbalances, too widening gaps, between the "integrated" and the "excluded". Is already that the case?

In fact, what we call the "*globalization issues*" are actually the result of too great unbalances which have already developed. Unbalances in the uses of natural and artificial resources (such as the S&T endowment), have resulted in "global" negative externalities produced by the "integrated", that interest both them and the "excluded".
This, however, is not the only paradoxical situation of an unbalanced globalization process.
Another paradox is that the ones that are excluded from the increased ranges of the potentially positive factors, cannot consider themselves as "small" with respect to the global system. Their actions have also negative global externalities (see the de forestation effects in the LDCs regions) to which the "integrated" react.

7 From challenge to action: take advantage of the intrinsic response of the global system

When passing from the globalization challenges to actions, we have to distinguish between the process of globalization and the global issues already apparent. First preoccupation is to help the globalization process to develop in a uniform way (an application of the *wisdom* of complexity!), avoiding producing other great unbalances.

7.1 Help the globalization process to diffuse at all system's levels through competition/cooperation to avoid too great unbalances

As already noted, globalization is a process that not only we are forced to accept, but that should not intrinsically be considered harmful.

By observing the unbalances in human systems we note that they increase when competition (or self-interest) is pushed to the extreme without at the same time developing some kind of cooperation.

One possible reaction to reduce unbalance or to stop its growth, is to develop "barriers" against competition. This response will, however, have only transient effects, and, at the end, increase the unbalances which will be followed by great oscillations to readjust to a more reasonable level. In fact, to set up barriers is in contrast to the intrinsic system trend to increase interdependence and interaction. "*General wisdom*" suggests that *the ones that contrast "global" system trends are condemned to be "losers"* ("great men have always 'understood' and been 'interpreters' of their time").

A better solution is, instead, that to favour the system trends by taking advantage of the system "leverage" effects. Our suggestion is that cooperation is the other side of competition and it is intrinsically tied to it. We cannot consider the one without the other, at all levels of human actions (individual, local, regional, global).

Cooperation should not to be confused with "solidarity", with altruistic behaviour. Cooperation instead has to be seen as of direct interest of all the cooperating partners.

The competition/cooperation loop, to be effective, has to close at all levels of actions. Instead, there is a tendency to separate the levels where actors have only to compete, from the ones where actors have only to cooperate.
An example of how this behaviour have increased unbalances come from the development of urban social environment. In the past, in many European towns (take Naples as an example), different "classes" of peoples inhabited the same buildings where there were a clear distinction of the different social position of the tenants (even in the height of the different floors). However, the vicinity of poor and rich tenants made possible, on the other hand, a kind of cooperation-solidarity to develop (the poorer tenants suppling services to the richer ones). Unbalances were evident and undesirable. However, the result of shifting the responsibility to close the competitive/cooperation circle to an higher level (through social state solidarity) have produced urban ghettos (around social housings) shifting the unbalances to a much higher scale and making the situation even more undesirable and unmanageable.

7.2 Use competiton/cooperation at the S&T sub-system level

Limiting ourselves to the S&T sector, we note how important is the competition/ cooperation behaviour at different level of actors scale:
i) scientists compete among themselves to assure individual recognition, while they eagerly present and discuss their results or intuitions with peers;
ii) entrepreneurs will search for *appropriable "localized" innovation change* while in the meantime developing indirect and direct (e.g. joint ventures) methods to get access to others' know-how, so contributing, indirectly, to the increase of the endowment of *"generic"* technological know how;
iii) cooperation to develop common technological standards is an important features of S&T progress, provided that standardization does not extend to the limit of freezing all the freedom to develop new ideas and to adapt products to the variety of users and needs;
iv) S&T planning can be conceived only as a combination of top-down (a sort of "cooperative" effort to individuate goals, allocate resources, etc.) and bottom-up (competitive) actions.

Also in the case of S&T we note a tendency *not to close the loops of cooperation/competition at all levels*. One instance of separation of the competition and cooperation role is evident in the case of the EC R&D policy: in principle only 'pre-competitive' R&D can be the object of EC initiatives. On one hand this might limit too much the effectiveness of the EC use of R&D as a tool for its objectives. On the other hand, in case it be important to have an R&D public policy to develop "products", to leave such possibility only to the national governments might lead (as it actually happens) to develop national 'flag' enterprises.

A general recipe to respond to the globalization challenges - which has to be applied also to S&T - is not only to push for more cooperation but *to be assured that competition/ cooperation develops at all system levels.* The problem is particular difficult when proper actors/institutions are not yet developed at the new "global" sub-system.

S&T is a powerful determinant of change: can we aim at S&T based innovation changes to help the globalization process to diffuse reducing the integrated-excluded divide?
S&T is itself part and determinant of the globalization process. Therefore, S&T should be looked at to avoid too great unbalances to develop. As a matter of fact, one can notice a "*percolation*" phenomenon in the diffusion both of Science and of Technology which con-

tribute to the globalization unbalances. [9]

One should recognize the importance of investments on 'intangibles' with priority on education and scientific research. The more such investments will reach the excluded part of the world, the more there is a chance that also the research agenda will become broader and cover areas of future interest (in term of opening potential application concerned with the dealing of globality issues). Along with the availability of resources for such intangible investments, organization intervention will necessary be aimed at increasing the efficiency of the investment, but also at helping the process of change of scientific exploration. Ideas such as developing a 'commonwealth of Science', twinning of research institutions, networks of research between North and South countries *have to be encouraged*.

For the Technology side of S&T the 'percolation' phenomenon is even more evident. Application of science for practical purposes tends to be pushed by 'innovators' to get entrepreneurial advantages (localized technological changes). Competition is the basic motivation. Other aspects of the globalization process, such as the opening of the world markets, the increased scale of productions and of size of firms tend to keep the technological knowledge internal to the innovating enterprise.

It is therefore important that one develop policies to push the cooperation side also for technological development. Fortunately, the increasing resources needed to develop important innovation changes and the necessity to follow many alternatives research routes to assure final success, push entrepreneurs towards some kind of cooperation (pre-competitive research, joint ventures, etc.).
There is therefore matter for intervention to increase *cooperation in technological development, including networking of companies from advanced and developing countries.*

8 From challenge to action: the design approach to global issues

Globalization has already produced too large unbalances that can be interpreted in term of "global issues". While on one hand one should develop policies and actions to avoid the further growing of such unbalances (counting on the leverage effects of the globalization process to reduce the scale of the global issues), on the other hand we cannot wait for the intrinsic ('natural') reactions of the global system to reduce the unbalances (not only it will take too long a time, but the ways might be too harmful).

8.1 Apply design paradigm to reduce globalization complexity level

To respond to specific challenges the recipe we suggest is that of the '*design paradigm*'. The complexity of the global issues has to be accepted as an intrinsic feature. However the design paradigm tell us that we have to 'simplify' the complexity by deciding what is the '*internal*' complexity and what can be considered '*exogenous*' to the decision-making scope

[9] While Science in principle is a "*generic*" endowment of human kind, the ability to do scientific research depends from the level of local education, from the availability of financial resources and of infrastructures. Moreover, even if one has the possibility to perform research activity, the choice of the research agenda is conditioned by the existing directions of the research activity, by the 'internal rules' that characterize the ways by which the scientific community behave. All this will tend to reinforce the role and choices of the countries that lead the scientific development.

of action. In other words, we have to enter into a process of issue classification and of problem definition, defining the roles of the '*client*' and of the '*designer*'.

'Global' issues can in fact be classified as issues whose 'complexity' can be reduced to local dimension, or to regional, or to really global one. According to the different classes, different actors will have to take the responsibility to play the role of client and designer. [10]

The requirement that *the role of the client and of the designer be realized at a system level coherent with the problem 'dimension'* is therefore another aspects of the general rules of avoiding too great unbalances (in this case unbalances between the ones that represent the demand and those that represent the ability to respond).

The problem - to find a satisfactory cooperation/competition regime among all the actors interested in the *design response* - is particularly difficult with global issues because any approach to respond with solutions will produce negative externalities as well as benefits. The difficulty comes from the fact that often the one that suffers for the externalities are not the same that benefit from the solution (see the case of transport infrastructure). The definition of what the problem really is and of its 'dimension' depends from the possibility to close the balance between the losers and gainers from the solution.

There is an important, even if very difficult, plan of action to be undertaken directed on one side to *increase the participation of the 'excluded' to the scientific research activity, and on the other side to shift directions of research*.

For the first part of the plan of action, as indicated in the previous section, one should try to put system foreces to work by pushing cooperation as well as competition extending to the "excluded" the possibility to "compete" in S&T.

Concerning the second part of the plan - to shift directions of research - the *design paradigm* suggest the importance to concentrate on the organization aspects and specifically to who should paly the role of the *client.* The EC has an important role to play as client for S&T an globalization. We will make some specific suggestion in the last section of the report.

8.2 S&T and global issues: how to plan for innovation changes in complex systems

To deal with the global issues by applying S&T potentialities means to 'plan' innovation changes. The 'design' paradigm help in avoiding the trap of considering planning as a 'rational, linear' approach in problem solving, and in accepting complexity as an intrinsic feature. However the 'scale' of the global issues and their 'higher hierarchical' level of complexity make the problem difficult even if we are determined to use the design paradigm (including creating new institutions, if needed, to play the client role).

First of all we have to accept that an innovation plan rarely could be a one shot operation. Actions might be aimed at developing the 'building blocks' of future solutions. When this step is performed, the imagined solution might not be possible, because the resulting 'building blocks' are different than originally conceived, or because the new developed informa-

[10] *The design paradigm can be seen as a process of cooperation / competition between the client and the designer* where the emphasis is on the one or the other of the two according to the phase of the problem solving process. This is a confirmation that cooperation/compeition is a self-similar feature of human systems.

tion might show that more radical changes might be necessary.

In planning innovation changes for complex systems, a hierarchy of innovation objectives has to be posed according to the system hierarchy: innovation objectives could consider only components innovation (**tactical** innovation policy), or consider subsystem innovation (**strategical** policy), or even the entire system change (**structural** policy).

The case of transport issue will clarify the idea. The challenges include energy conservation, environment protection, avoiding saturation of transport infrastructure and improving quality of life in urban environment. Contribution to the challenges can be obtained aiming at innovating the today public or private vehicles (the 'components' of the transport system). There are however limits in the result that can be obtained with such constraints in innovation objectives. One can think to innovate at 'subsystem level', e.g. developing new and more efficient public transport that will produce a shift in demand from private to public transport. 'Components' (building blocks) for such innovation plan might not, however, be there. So, efforts should be dedicated to prove that new solutions can be developed for public transport (e.g. public modes of transport that can have a flexible, demand responsive, routing). Finally, the results might not be satisfactory, unless one innovate the entire system, which might require to include, in our planning, the change of the 'environment' of the transport system (e.g. urban planning to reduce saturation effects of congested transport demand).

The more we plan for innovation changes that includes higher levels of the system hierarchy, the longer will be the time for solution, the higher the uncertainties. It will be difficult to have the needed society consensus on innovation actions if we can point only to long term uncertain successes. So, *an acceptable plan should include a high proportion of short term tangible results, to make acceptable the devoting of resources to more radical and longer term actions. It is therefore important to show, also for the case of globalization issues, that not all conceivable actions are long term, difficult to realize, requiring radical organizational and institutional changes*.
A classification of globality issues shows that indeed they can be classified according to their 'range' (as local, regional, or global), and, even when having a real global range, that result can be obtained acting on components, or sub-systems.

An innovation plan to respond to global issues should make th following assumptions:
first assumption: the today 'system' (the global system, including the environment, the social and the S&T systems) certainly has 'slacks' available to adapt to the globalization challenges at least to a certain extent, without having to change its structure or prevailing values. Priority should therefore be given to take advantages of such slacks (component innovation changes);
second assumption: there are global issues which could not be dealt with unless innovation changes are aimed at sub-systems;
third assumptions: the long term challenges of globalization cannot be met unless basic changes in value and behaviour are realized (system innovation).

An innovation plan to deal with global issues has therefore, to be balanced, to include actions that have objectives at the three levels.

9 Applying the design paradigm approach to all innovation levels: the institutional, organizational and policy consequences

The design paradigm emphasize the client-designer interaction. The difficulty with many of the global issues is that not only the issues are far from clear (which is a characteristics of any design problem in the first phase of the problem-solving approach), but also that the client is not 'defined' or the role is played by an 'improper' client (at a level different from the issue's level). To pass from challenge perception to problem definition one will have, therefore, *to make institutional development as an intrinsic part of problem solving*.

The specification of the problem to be solved will depend from the 'client' values, which on their turn will become real values (action inducing) if the client together with the designer can perceive possible solutions. Out of metaphor, if the real client is the society at large, the first difficult task is that of resisting the idea that roles can be separated between society, politics and S&T. *The intermingling of S&T with the other society systems means accepting the intermingling of the respective uncertainties (in values, priorities, ideas for S&T poten tialities).*

The design paradigm can be applied here at a '*meta*' level: '*designing the design*' in order at the end to be able to start the real design process having established actors and roles (client/designer) and an agenda of issues classified in terms of dimension (local, regional, global) and of innovation objectives (component, subsystem or system changes). The examination of few different issues will show better the importance of the meta-design phase.

The deforestation issue. The challenge is perceived as a real one. However there is no consensus of what are the possible solutions (stop deforestation in the LDCs, start reforestation in the rich northern country, develop 'artificial forest' as a sink of CO_2, etc.). Examining the portfolio of ideas of potential solutions (applying the design paradigm) sorts the effects to point out how vague is the issue that we want to deal with. Is it deforestation an issue because of the potential effects on climate change or on loss of biological diversity, or on both? And what are the priority values: the longer term survival of human kind or the short term improvement of the poorer part of the world? Can S&T help with short term actions that at the same time could reduce deforestation and increase rentability of forest conservation for the LDCs? The looking for ideas now has to be shifted in new directions. The real issues for S&T might be that of finding uses (and therefore values) for the natural 'waste materials' produced by the forest, or of how to intervene on forest to increase production of useful materials in a synergetic approach with nature. At the end of the 'meta-design' exercise a panoply of issues with related potentiality of responses might emerge, which could be classified from very long term (needing new direction of basic research), to more practical short term ones (such as developing more effective mechanical ways to get materials out of the forest without destroying it).

Desertification. The case is quite different from that of deforestation where (apart from innovative approaches based on S&T) a simple solution might - naively - be considered possible if the richer part of he world is willing to pay for the value represented by keeping the forest. Instead, in the case of desertification the dynamic of the process is not well known and it will be in any case difficult to point to the 'culprits'. Desertification has certainly a very negative impact on local populations. However, are we sure that not only to stop the further desertification, but also to reduce the existing desert area is an objective to be pursued? What might be the induced effects on climate change? We know already that projects

to recuperate desert lands to agricultural activity, distort important water resources shifting problems to other areas. Could instead the human kind take advantage of the existing desert area with its clear skies looking for S&T cheap solar energy? A project along this line will certainly require huge resources that will produce return only in the long term. The problem is therefore that of proper allocation of resources. However the analysis of potential ideas might point to effects of '*virtuous* economic circle' of wealth generation with short term effects also on local population. The meta-design in such a case will result in changing a negative global issue in that of the exploitation of a resource.

Marginal agriculture. An important global issue is that of inhurbation and abandonment of the agricultural land. On one side this is the result of the increased productivity in agriculture. On the other, it is simply the abandoning of agriculture activity because of non redditivity. The phenomenon produces great unbalances: abandoning of marginal land (such as hills and mountains) in rich countries (with the consequence of decaying biological process and soil erosion); abandoning of potentially rich soil in underdeveloped countries which lack the investment resources needed for an high productivity agriculture (with the consequence of reduced income and of population migration); increasing environmental damage due to the use of pests and fertilizer; reduction of the variety of species because of selecting only the most productive ones; protection of agriculture in rich countries through custom barriers (a cost to the rich nations with further effects on poorer countries that see reduction of export markets for their agricultural products, which are often the only products that could be exported). What are here the real issues? What tasks can be put forward for S&T? In rich northern countries one issue is that of keeping people on the land for the importance that the human presence has on geo-biological equilibrium. In such a case should the objectives for S&T be that to develop technology that make profitable agricultural activity on marginal lands? Or the objective is different, and one should look for an occupation of the territory for other economic activities with surplus income destined to a good housekeeping of the territory (not so much to produce agricultural products, but to assure a good biological and geological soil maintenance: peasants as gardeners?)? Since the existing system of protecting an high productivity agriculture has a cost to society (see the case of the EC Common Agricultural Policy) will the issue (to be translated in terms of S&T) in such a case be a better occupation of the lands at a lower global cost to society? Or, could new agricultural process be developed that at the same time reduce the productivity, assure occupation and good-housekeeping of the territory and also a profitable activity? Can we separate the issues of rich countries and LDCs, or the solutions should be developed in an unitarian scheme?

The agricultural case shows, even more clearly than the other cases, how intermingled are economic, social, technological, international aspects; how issues definition depends from values definition and perception of potential solution, from a balanced mixture of competition and cooperation between different society sectors (agriculture, fisheries, industrial, service) and between poor and rich countries, between the ones with food surpluses and the one dying of famine. The '*meta-design*' exercise, will point to radical new ideas as well as to some more short term ones, with related tasks for S&T. The clear definition of issues and potentiality of solutions will be a preconditions to get the determination needed to allocate resources in so radically new ways with respect to consolidated today approaches.

S&T will help the phase of transforming challenges into specific issues by contributing ideas of possible solutions. The completion of such a phase and the definition of actors, is a precondition for the real contribution of S&T. However, accepting the basic interactive na-

ture of problem-solving, one should consider that each actor in the "loop" not only has to react to the inputs he receives from "above", but also to 'pro-act' producing feedbacks that will change, later on, such inputs. In other words, in an interconnected decision-making / problem-solving situation, there is no excuse for any one actor to stay still, waiting for clear and better inputs.

S&T actors should therefore start their own planning for actions. But how to plan S&T? A plan is always a mixture of a top-down and a bottom-up approach. In practice the methodology suggested is the following:
i) assume that the information on the issues at stakes - as vague and uncommitted as they might be - represents a first sketch of a top-down settings of general objectives and finalities;
ii) evaluate the existing portfolio of ideas classifying them in term that can more easily and directly refer to the globalization issues;
iii) spot, with the help of such classifications, underway directions of S&T development that are susceptible of covering the areas of concerns for the given issues and plan for priority actions to continue R&D along such directions;
iv) identify S&T areas of potential interest on which no activity is underway and make an effort to define objectives and ideas to initiate R&D on such areas and domain.

Such analysis will at least provide a way to measure how consistent are today directions of S&T development and the need to change them or the related priorities.

10 In synthesis: apply the complexity "wisdom" to globalization

The word "rational" for a problem-solving approach bear an intrinsic analytical/reductionist flavour. To deal with the globalization issues, we need a better and less compromised word. We propose that the approach is better represented by the use of the word "wisdom".

Our basic hypothesis is that "*wisdom*" is available that allow us to deal with complexity. The suggestion is that such wisdom should be applied to the the very complex case of globalization.

From the experience of problem-solving in complex situation we point to the "*design paradigm*" as the one that capture the intrinsic features of complexity. In fact the design paradigm accept: vagueness of problem statement, strong interactions and blurring of roles of the different actors involved. However, it also provide a "recipe" to find ways out from an endless looping of interactions.

We have also pointed out the need to avoid going against system trend and trajectory so to put system intrinsic forces to work. Cooperation/competition is one such system features that should be put to work at all sytem levels.

Referring to the design paradigm permits to point to very simple general "*wisdom*" recipes (such as that of recognizing the "*dimension*" of the problem in order to choose proper actors) for the behaviour of each actors, even before starting the real problem-solving activity. It also provides more detailed "*wisdom*" recipes for problem solving.

The design approach can be applyed to the S&T realm, to develop its role on globalization.

In the problem-solving loop, there is no privileged points to start the process. Responsibility is diffused and each actors can start the process. In particular, S&T actors have a responsibility of their own, reacting to the request from other actors to intervene, but also pro-acting anticipating future requests and even predisposing for such requests to become possible.

11 Proposal for an experimental approach to globalization: develop the client role for EC

What the EC can specifically do to approach globalization and global issues? We propose that the first priority action should be that to develop the role of the *client.*

Globalization represents a change in human system complexity. To deal with it, it is necessary to assure variety of responses and flexibility.
We need a creative approach on all the components of the action process: from organisation, to problem definition, to solution design.
Because of the uncertainties even in the definition of what the real problems at stake are, to assure a variety of approaches is more important than the attempt to select priority issues or to better focus the actions. We need to learn how to deal with the globality issues: so the approaches should assure, through variety and flexibility, that even errors will contribute to such learning.

All that makes difficult to converge the necessary will power and resources to develop practical actions: in fact we are too used to consider that action programmes should be well spelled-out and assure selection of priority.
We should therefore have the courage to admit that a clear and well focused programme will be misleading.
What we need is an experimental approach, vague enough to assure the creative contribution from different sources, and the possibility to make change of directions and priority as we learn from the progress of the actions.
To assure variety and flexibility one should avoid a centralised approach and look for multipolar interventions. Nevertheless, it is important that a proper climate be developed to alert on the needs for multipolar interventions, to provide leverage effects on actions (no matter where they come from), to assure a frame of reference for debate, co-operation, stimulation.

With that in mind, we can underline the important role that the EC will have in providing such climate to induce actions.
We should therefore propose that the EC will launch an experimental programme on globalization that will *foster multipolar initiatives*, call for creative contribution from a multiplicity of actors (both public and private), *provide a starting frame of reference* and the seeds for new initiatives.
The EC should try to experiment the role of the client for globalization issues.
The EC experimental programme - even if focused on the S&T contribution - will itself be multipolar.

We propose the following types of intervention:

A. Play the role of the client by making use of the current R&D Framework Programme to incentivate as much as possible the attention to globalization issues, such as, e.g.:
    1. provide a financial premium for R&D projects that not only respond to each action lines terms of reference, but also foresee the participation of LDCs institutions or firms to the research,
    2. add a specific item on each line of action that calls for ideas and preliminary investigations on problems having a globalization dimension.

B. Stimulate the emergence of new clients by incentivating the convergence of public and private financing to set up Trusts and Foundations, each one aiming at a specific objective or approach on globalization matters, such as, e.g.:
    1. develop new products and production processes that respond to the local needs and capacity in LDCs,
    2. incentivate creativity and innovation in new products design (suited to new needs coming from globalization issues) by means of instruments such as product contests and prizes,
    3. assure the accessibility of advanced technology to design products (and related manufacturing processes) for local needs, by favouring the concept of flexible design using high technology components (both for products and processes) which could be put together to local ones (hybrid technology solutions),
    4. promote and support networks of R&D institutions.

C. Enlarge the client dimension by developing international initiatives (in co-operation with governments, GOs and NGOs) to launch the first phase (problem identification and preliminary solutions development) of S&T for major globalization issues, such as, e.g.:
    1. attack environmental global issues,
    2. exploit global commons
    3. develop low cost, socially acceptable shelter technology for massive inhurbated area,
    4. experiment marginal agriculture technologies,
    5. develop a multimedia new encyclopaedia of technology and know how’s.

D. Act as a client in search of good ideas for ill defined problems, by setting up an "open counter" initiative to incentivate with financing any kind of unsolicited proposals that can contribute to develop a portfolio of ideas and globalization issues.