IV. INFORMATION MAPPING

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Introduction
The purpose of this document is to report briefly on a preliminary investigation into the problems of mapping satisfactorily for policy purposes the domains of science and technology as applied to development (1). The matter in question is clearly of ever increasing concern within the international community as a whole, as indicated by a number of initiatives, many of them now being timed to focus discussion in anticipation of the United Nations Conference on the Application of Science and Technology to Development in 1979.

Part 1: Mapping

Nature of the problem

The problem of information in the field of science and technology as applied to development processes is reviewed in Part 2 under the following headings:

A. Quantitative aspects

B. Logical aspects; classification
   - Multiplicity of classification schemes
   - Failure to indicate functional relevance
   - Unspecified omissions and partial inclusions
   - Macro-level definition
   - Interdisciplinarity

C. Operational aspects; organizations and information systems
   - Multiplicity of organizations
   - Unrelated information systems

D. Comprehensibility
   - Comprehension overload
   - Issue reductionism
   - Communication mode preferences

E. Behavioural aspects
   - Interorganizational antipathy
   - Interorganizational territoriality
   - Interorganizational rivalry
   - Prelogical biases

F. "Mythical" aspects

G. Ignorance and lack of systematically ordered information on:
   - Scientific disciplines
   - Development processes
   - Technologies
   - Applications processes.

The first three of the above points are those most frequently discussed when examining the question, since they also tend to be those most susceptible to solution by modifying institutions or their policies and through appropriate use of information science and technology. The last four are those which are much less frequently discussed, partly because they include factors which undermine or oppose conventional solutions to the information problem.

This review shows that there are many severe obstacles, themselves intimately interrelated, which prevent a significant improvement in the accessibility of such information for policy-related purposes. It is not the purpose of this report to comment on conventional efforts to improve the situation or their relationships to the UNESCO/ICSU World Science Information System (UNISIST), SPINES, or the various development information systems. Whilst these may or may not achieve their respective objectives, in the light of the points in Part 2, it would appear to be useful to investigate completely new approaches which may result in information tools which respond to the problem at a more fundamental level.

Information selection and presentation

The heart of the problem seems to lie in the general attitude to information selection and presentation. This is reviewed in Part 3 where it is argued that much of the problem results from the reliance on word-oriented information systems. However in reviewing the alternatives, including computer manipulation of diagrams, it is shown that existing approaches fail to respond to the basic difficulty of how to improve the relevance of the questions asked to the problem complex faced by the policy-making process. How is the policy-maker, and those with whom he must communicate, to acquire a better "grasp" of the problem complex and the opportunities for improved application of science and technology to development?

Some criteria for a desirable solution

The kind of information assistance required could usefully have the following characteristics (2):

- contain a large number of elements relevant to science, technology and development
- elements well-packed for comprehensibility
- presentable in different (but integrated) forms corresponding to the tolerance of complexity of the expert, the non-expert and the general public
- disposition and presentation of elements should have a mnemonic value such that familiarity with the whole pattern may be gradually acquired and not immediately forgotten
- disposition of elements should reflect the knowledge of experts and not a superficial, "glossy", media-oriented impression of aspects of it
- disposition of elements should reflect in a dynamic manner the processes in which they are involved and any evolution in those processes over time

presentation should be complete, covering the whole range of elements, and not partial, although partial extracts from that whole could be made if required, provided they maintain their relationships to it.

- disposition and presentation of elements should reflect alternative perspectives and the behavioural dynamics to which they give rise.

- preparation and construction should lend itself to computer assistance (exploiting a data base) but constrained from a perspective of communicability and aesthetics.

Mapping: possibilities offered for a solution

The procedure known as "mapping" suggests a number of possibilities for incorporating the features identified above.

"Mapping" for policy purposes has been used very loosely, even to include a compilation of national science policy surveys in which the "integration" accomplished is limited to the physical assembly of the statements within the same document (3a). This usage will not be considered here since it is precisely this type of approach which is of such limited value in the light of the points in Parts 2 and 3. Before outlining the approach suggested here, it is noteworthy that the senior editor of one of the largest scientific publishing houses advocates the use of a spherical representation of the body of knowledge in discussing information transfer implications (3a).

The question is therefore whether a mapping technique can be used in conjunction with this spherical representation as a basis for incorporating the desirable features identified. The model identified in ref. 3a does not attempt to do this although a number of pointers are included explicitly or implicitly. It does not consider the implications of the large amount of quantitative detail which needs to be represented, or how it is to be represented.

Approaching the question from another angle, there is much to be learnt from cartography and the history of geographical map production. The first two-dimensional maps were extremely sketchy and are not too different from the primitive sketches that are produced in graphic models (see Part 3). Of great interest are the "terminological graphic displays" and sub-displays produced as a user guide to the UNESCO SPINES Thesaurus (as a controlled and structured vocabulary of science and technology for policymaking, management and development) of which the overall display is reproduced in Diag. 1. These lack many of the features indicated above (as well as being subject to other weaknesses identified in Parts 2 and 3) as does the courageous series of concept diagrams included as an anonymous addendum to the integrating volume of the new French-language Encyclopaedia Universalis.

What all these efforts lack is what might be termed a "topographical richness" onto which the massive amount of detail to be incorporated may be "hung" including logical continuities and distinctions, as well as functional indications arising from territoriality. But this topographical richness must be so represented as to facilitate comprehension at whatever level of detail is appropriate, and the mnemonic features must be preserved.

The radical approach advocated here is therefore to investigate the possibility of abandoning the schematic graphics (such as in SPINES) in favour of mapping the conceptual territory on a spherical surface with conventional topographical features. On the basis of a preliminary investigation, it seems to be possible to incorporate most of the features indicated above.

A further question is whether this approach can satisfactorily reflect the four aspects of the application of science and technology to development. Again, preliminary investigation indicates that this is possible by using four separate spherical representations. Each would contain cross-referencing co-ordinates to the others where relevant. In other words the relationship between a particular scientific discipline, a particular technology and a particular development process would be either explicit or implicit from the context. Clearly conventional projections onto plane surfaces could be used as well as transparent overlays, if required. But the relationship to the overall representation would be preserved.

Conclusion

A number of different approaches to selecting and presenting information can be interpreted as indicating a convergence on a solution which could offer many more satisfactory features to assist policymakers in their comprehension of the domains of science and technology in relation to development processes.

The approach advocated requires further exploration to determine in detail exactly how the different features could be incorporated and the limits imposed by this approach.

Part 2:

REVIEW OF THE INFORMATION PROBLEM

A. Quantitative aspects

It is understandable that there is a very large amount of "scientific and technological" information which may be considered relevant to "development". Even if it is only (say) 1% of the literature, this would amount to:

- 60 to 70 new articles and reports per working day (1970)
- a cumulative total of 200,000 to 300,000 journal articles (1970)
- 80,000 to 140,000 new documents per year (1965 est.).

But there is also a very large quantity of information about the application of science and technology to development and much new material is being generated in anticipation of UNCED 1979 (4a). The question is whether such information can be mastered and by whom, even if those who should have access to it have no problems in obtaining or assimilating it, which is seldom the case (5).

The usual practice is to ignore the mountain of documents already in existence and to prepare a quick "study of the key issues" based on some of the "key documents" available. Such an approach then justified by policy-making deadlines and similar pragmatic constraints. It is adequate if it is assumed that the few documents selected from society's prolific production cover the relevant issues. This assumption is however only valid if the majority of the studies is assumed to be of inferior quality, of limited relevance or a duplication of those selected (6).

There is no procedure whereby this can be proven in a particular case since relevance is defined more in terms of what the agency is constrained to do than of what needs to be done according to any wider perspective.

B. Local aspect; classification

Multiplicity of classification schemes

The device developed to ensure access to "relevant" information in any particular case is the (document) classification system and the associated thesaurus. There are many such systems, often based on the practice in international agency libraries or departments. As such they reflect a variety of perspectives. Effective integration, even at the conceptual level, has not proved possible (7).
Failure to indicate functional relevance

These remarks would be unnecessary if it was possible to use each such system to identify "relevant" documents. This is not the case (unless the user knows the document in advance), for the ambition of the classification system is generally limited to identifying the standard subject categories to which the document relates, usually on the basis of its title. Now policy matters and development problems are not experienced as subjects nested neatly in logical hierarchies, but rather as action domains embedded in a network of interrelated issues — where the relationships recognized depend in part upon the objectives and sensitivity of those concerned. The logical relationships between issues classified as subjects do not therefore reflect the functional relationships between interacting issues (e.g. problem A aggravates problem B). Classification systems therefore assist in locating documents on an issue but not on issues "relevant" to it.

Unspecified omissions and partial inclusions

Classification systems fail in another respect. For example, with a scheme purporting to cover "science", the user is seldom explicitly informed what categories have been omitted as not pertaining to science according to those who conceived the scheme (8). On the other hand, a scheme purporting to cover "development" may also incorporate large portions of "environment", and vice-versa each defining the other as a subset but failing, necessarily, to specify what is omitted and as irrelevant (9).

A factor contributing to this problem is the widespread disagreement as to what "sciences" should be considered as "science", with the social sciences frequently omitted in the anglo-american, tradition as pseudo-sciences. This conflict is embarrassingly explicit in Unesco activities (10).

Macro-level definition

This links on to a further difficulty, namely the considerable intellectual effort devoted to the definition of "science" and its characteristics by philosophers of science of various persuasions (11). This is usually undertaken without taking into account the views of those sensitive to non-western cultural perspectives on science (12). A corresponding effort is being devoted to defining (or, more recently, to "redefining") "development" (13). Unfortunately these exercises focus on the "macro-concept" and fail to identify or to distinguish the "sciences" which constitute science (14) or the "development processes" which constitute the development process (15). The result is a large number of excellent studies, grouped within various schools of thought, but of very limited relevance to policy formulation concerning the application of science and technology to development. The studies reveal scholarly disagreement at their macro-level of focus (*) and fail to decompose the concepts to a level which is of practical significance (16).

Exercises in the redefinition of macro-concepts such as the "development process" within the politicized intergovernmental context, may mark a change in orientation but the nature of any relationship to the many unspecified development processes remains subject to confusion and discord.

Interdisciplinarity

Although "science" remains a focus of constant attention and a convenient label for a blurred domain, and although, in contrast, individual disciplines are relatively well-defined, the interdisciplinary relations even amongst the sciences remain a no-man's-land and a question of embarrassment or disdain within any discipline (17). This disdain is particularly tragic when extended through the "pecking order" of disciplines to the "applied sciences" and "technology". Yet the need for genuinely interdisciplinary applications of science to development is well-recognized and the weakness of superficial or token initiatives is acknowledged (18). But relevance of disciplines to a problem situation can only be settled non-scientifically now by weighted voting techniques in expert panels — if the politics of the situation resulted in their effective representation on the panel.

C. Operational aspects; organizations and information systems

Multiplicity of organizations

The application of science and technology to development involves national and international organizations. The intergovernmental number over 300 already, and the non-governmental number over 5,000 (19); the national remain unnumbered and unestimated within any country, in striking contrast to their populations (20). Clearly only a percentage of these will be considered of relevance to the development process by those producing the directories in connection with UNCSTED 1979, but the criteria by which relevance is determined will in all probability exclude many bodies which will continue to contribute, if only in their own eyes, to that process. The problem remains of providing some overview of which aspects of science and technology which organizations (or divisions of organizations) help to make relevant to which aspects of the development process — currently, potentially, and whether or not their initiatives are perceived as counter-productive by evaluating bodies, and irrespective of whether or not their activities are coordinated through some umbrella body or programme.

Information systems

Here again there are many unrelated systems of differing degrees of relevance to development processes. The additional problem which emerges more clearly than in the case of organizations is the lack of integration between the operational "modes" which the information systems are designed to serve. It is typical to find little, if any, system-level integration between information systems (even within the same agency) for: research, policy formulation, programme management, public information, education/briefing, and documentation — even when all of them are concerned with facilitating the same development processes. The reason is that the responsible organizational units in each case perceive the processes differently and have no reference framework within which to interrelate them. The information systems are not designed to facilitate comprehension of their own content (by those not oriented to their format and especially non-westerners) or of the content of systems with which they should be integrated.

D. Comprehensibility

Comprehension overload

Consider this dilemma: while our technological abilities to generate and disseminate potentially useful data have increased manifold in the past few years, man's physical capacity to register and process potentially informative data has probably increased very little, if indeed at all - (21). In policy circles, a widely favoured response to this constraint is to use inefficiencies (or even abuses) in procedures, and the consequent "lack of time", to filter out the majority of communications - and to require that the remaining issues be stated very briefly (22). The argument being that if the matter is important enough it can be stated briefly (however complex the chain of reasoning required to substantiate it) - and if it is too complex for this, it can be safely ignored because few people will have the attention span to be able to understand in order to protest (23). It

* There are pre-logical or temperamental biases which contribute to this disagreement. There are referred to under point E.
is unclear how many problems (such as environment and resources) may have been recognized too late for other than crisis action, because of this approach.

**Issue reductionism**

A more rational approach to the dilemma is to require that potential policy problems be identified and evaluated, so that the 6 (say) key or core problems selected can be reviewed for action in the policy formulation process (24). The seventh and remaining problems must await until they themselves reach crisis proportions (or acquire a political champion) before they are recognized (25). The only clue to the reason why 6 to 10 key issues are always selected seems to lie in evidence that this is the maximum number of different possibilities among which the human mind can meaningfully discriminate (26). It is also, roughly, the maximum number of divisions of any agency administration which would have to deal with a set of problems (27). Beyond the 6-10 limit lies confusion, according to current methods, irrespective of the number of problems out there.

**Communication mode preferences**

Another severe problem is the limited value of the written word for communication. Many will not read until they have heard, although others refuse to waste time listening unless they have found the basic points worthwhile through reading. Others demand a quantified argument, possibly expressed through equations, graphs or matrices. Others are innumerate, and demand visual images, diagrams, and films before they can comprehend an argument (28). To complete the circle, the latter are viewed with disdain by those who favour the discipline of the written word not recognized that they themselves are visually illiterate (29). Policy makers and those with whom they must communicate may belong to any of these categories, although the prevalence of a particular category may be culturally determined.

**E. Behavioural aspects**

**Interorganizational antipathy**

The behaviour of agencies, organizations and professional associations is not simply governed by programme directives, statutes and principles. The well-known antipathies amongst the UN Agencies and their competition for resources, are a matter of common knowledge as is the case amongst their creators, namely the equivalent national agencies (30). Such behavioural phenomena, often reinforced by political considerations (e.g. vis-a-vis the World Bank or non-universal bodies such as the OECD, the Council of Europe or the Commonwealth), are seldom acknowledged in writing (31). They are however evident in the absence of reciprocal arrangements and, more important, in omissions from documentation by each concerning other bodies relevant to the application of science and technology to development. The data provided deliberately conceals the behavioural phenomena, whether advantageous or disadvantageous to development and field-level coordination. In this sense, positive, cooperative public information and protocol statements may be counter-productive by concealing a situation which those less well-informed need to take into account if their initiatives are to succeed.

**Interorganizational rivalry**

Another aspect of this problem is evident in the information systems, classification schemes and thesauri produced by such international bodies or even within their own divisions. With respect to the application of science and technology to development, each has its own resources permitting, and will argue in all seriousness that they are the most relevant to its particular programme objectives (32). Needless to say the lack of relationship between them does not facilitate the development process with which they are, in principle, ultimately concerned (33).

**Interorganizational territoriality**

Related to this question is the marked tendency for issues to constitute the arena for interinstitutional territorial dynamics. With the division of intellectual and operational space into smaller and smaller compartments and the multiplication of institutions and professions which assume the management of each such territory, results the formation of a feudal system which governs the majority of science-related enterprises. Under the pretext of division of labour, each intends to be master of its own domain and to defend its position against enemies from without and emerging institutional and professional rivals from within (34). Because the arena is ill-defined and unmapped it is difficult to comprehend such dynamics.

When a new issue emerges, suddenly providing an expanse of unoccupied institutional territory, each body makes every effort to demonstrate its right to a portion of that territory, either by reinterpreting its past initiatives to show relevance or by redefining existing initiatives under appropriate labels. The succession of special UN Conferences (environment, water, population, habitat, etc.) may be seen as catalyzing such responses, whether they are made in a spirit of cynical opportunism or perceived as a fresh opportunity through which they at last become possible to define 'the good, the true and the beautiful'. And in this sense all the past unresolved issues get redefined under new labels in the hope that they may be resolved within the new framework. UNCSSTED 1979 is one such opportunity and the same dynamics will be repeated unless such dynamics are more adequately portrayed for comprehension.

**Pre-logical biases**

Finally, it is appropriate to note the existence of pre-logical or temperamental biases which determine individual (and, by extension, institutional) preferences for the nature and organization of information presented, namely the kinds of explanation that are felt to be satisfactory. As such they characterize not merely the physical theory that a society develops but also much of the legal, political, and social behaviour of that society. There is evidence that such prelogical biases may prevent logical consensus, such as on the nature of 'science' or 'development' (35)

**F. « Mythical » aspects**

Information on the application of sciences and technology to development is also distorted by a number of myths whose nature may be well described but rarely, if ever, in the same context.

There is the myth that science based on western values is neutral and universal (36) and that indigenous practices and folk wisdom are dangerous or charming nonsense. There is the myth that there is a scientific or technological solution to every real problem other problems being subjective. There is the myth equating development with economic growth and industrialization, which conceals the problems of development and the limits to growth. There is the myth that cultural development is a direct consequence of the application of science and technology to development, since it is assumed that the acquisition of science enhances a culture rather than eroding its values simply.

There is the myth of the problem as existing objectively and susceptible to properly organized remedial action. There is the myth that it is only the lack of political will, and the undue importance attached to non-scientific and non-rational arguments that prevents problems from being solved.

As mentioned earlier, there is the myth which limits attention to the 10 key development problems, as though each was nicely ordered in administrable units,
Networks

though it is widely recognized that it is their interrelatedness which is fundamental to any action strategy. This links to the myth which conceals the fact that existing institutions, and their associated bodies of knowledge, are (despite Ashby's Law) adequately structured to respond to complex problem networks (38). Underlying this is the myth that the fundamental problems are always - out there - and never in the attitudes, procedures and structures with which they are perceived and engaged. And there is the myth that if a responsible body is created to focus on a problem, then action will be seen to have been taken and because it will then cease to be perceived as a key issue for policy purposes, it may be assumed to be under control.

As in any primitive culture, such myths are necessary to create a semblance of order in the face of a reality to which no better response has yet been developed. New approaches are required and both science and technology should be used to assist in their development.

G. Ignorance and lack of systematically ordered information

The kinds of information available relevant to the application of science and technology to development reveal a number of important gaps:

Scientific disciplines

There is no framework within which is collected together the succinct descriptions of the special insights, sensitivity or integrative characteristics of each scientific discipline.

- in what way is it relevant to understanding or facilitating which development processes; what is its unique contribution (Even systematic identification of the key concepts and associated distinctions - unique to each discipline has not been made, nor is any attempt made to register systematically the laws or theories which govern the use of those concepts)
- conversely, what are its special 'blind-spots' or 'handicaps' as perceived by others and the excesses to which they give rise if uncontrolled by other factors (Namely, what tend to be the negative consequences for the development process resulting from irresponsible practice of the discipline or its inappropriate institutionalization)
- what other disciplines is the discipline dependent for its own effective development and appropriate application, and conversely which other disciplines are dependent upon it
- estimates by country or world-wide of (a) the number of practitioners of the discipline, (b) institutional costs of training a practitioner, and (c) annual institutional budget to enable a full-time practitioner to practise effectively. Where such information is available, it is scattered through a large number of publications. This is irrelevant to the practitioner of any particular discipline, whose education slowly gives him the mastery of a very small portion of this literature by which the dependence of society on his expertise is guaranteed. But to protect such dependence, the distinction is not made between (a) knowledge of the key aspects of disciplines (noted above) which should be widely available, at least within a policy environment, and (b) knowledge of how to use and manipulate them, which is the special skill of the practitioner. The information available in specialized encyclopaedias and dictionaries is either too diffuse, too detailed or inadequately ordered, in order to facilitate understanding of the relevance to development processes.

Technologies

There is no framework within which is collected together, and systematically ordered:
- the succinct 'primitive', description of each technology, whether 'outdated', modern or advanced,
- its special relevance, if known, to particular stages in development processes and problems,
- the interdependence between one technology and another in terms of (a) operations, (b) maintenance, and (c) substitution (whether by more advanced, less advanced, or same level),
- dependency of the technology on the expertise of practitioners of particular disciplines,
- the negative consequences to the economic, social and cultural environment which are unique to that technology as perceived by others and the excesses to which it may give rise if uncontrollable by other factors,
- estimates by country or world-wide of (a) the number of users of the technology, (b) institutional costs of training users, and (c) annual institutional budget to operate and maintain the technology,
- level of education required to operate and maintain the technology (specially in terms of the concepts and laws of a discipline with which familiarity is necessary).

Without systematically ordered information such as this, rational policy formulation is distorted by ignorance and lack or readily accessible overview.

Development processes

There is no framework within which is distinguished and systematically ordered:
- the succinct description of each development process
- the interdependence of development processes
- indications of the negative consequences of underdevelopment or over-development of that process, or of its relationship to other processes
- the dependence of the process on technology or various forms of infrastructure

Application processes

There is no framework within which is collected together and systematically ordered the succinct description of the different organizational or other instruments whereby science and technology may be applied to development processes, with an indication of their unique advantages and disadvantages in different developing country situations.

Part 3:

INFORMATION
SELECTION
AND PRESENTATION

In the field of information processing, documentation and classification there is an almost universal bias towards text and terms, since publications have titles and normally contain text. This is a very persuasive argument in favour of word oriented computers and classification schemes. It is associated with the generation of a plethora of costly bibliographical tools, abstracts, directories and encyclopaedias (39).

But even if all items in the total body of literature were identifiable and available at low cost (which is the aim of those who favour this approach), there still remains the problem of how to improve the relevance of the questions asked to the problem complex faced by the policymaking process. Retrieval is not the problem, it merely aggravates this more fundamental problem. Retrieval systems focus queries in the light of the user's existing knowledge and biases. They do not orient the policy-oriented user to knowledge and issues with which he should also be concerned in relation to his current preoccupations (in the light of qualified or alternative opinions). They do not bring to his attention where his preoccupation may fit in relation to other preoccupations. He is given no sense of scale, proportion or orientation - he merely gets what he asked for however much difficulty he has in formulating his question in appropriate words.
Explanatory power of diagrams

It is ironical that within any book or article, whenever the point to be made is too complex to be expressed in words, the author resorts to a diagram of some kind. This ensures that various elements are brought into appropriate relationship within a whole of which the reader has an overview. From that overview the reader can then select (a) how he wishes to explore the elements interrelated therein, and (b) those he considers significant as meriting further examination. Yet existing information systems are completely incapable of producing or manipulating diagrams as an aid to policy-making.

Computer-generated diagrams

The exceptions, to this statement are interesting as indications of the kinds of technology not available to policy-making in relation to the development processes:

- air-traffic control radar display screens
- computer-aided architectural and engineering design displays
- factory process control flow displays
- electronic circuit analysis and design displays.

In such case there are complex problems of choice and decision analogous to those in a policy-making situation. The examples are given to show that a technology is in use to manipulate such information. Unfortunately, however, that technology cannot yet be used satisfactorily in relation to development processes because the information is in the wrong form. The information available to policy-makers is contained in a multitude of lengthy reports supported by tables and diagrams. These can of course be put straight onto sophisticated computer systems in toto. But the basic problem remains how to ask the question relevant to the policy process – it is not a retrieval problem. Information systems give no assistance in this respect.

Media-oriented techniques

To go to another extreme, those concerned with facilitating understanding of complex issues by the public (and this may well include decision-makers) use media-oriented techniques. Great emphasis was placed on films at the UN Human Settlements Conference. Books attempting to describe social change make much use of mcluhanesque illustrations (40). But despite the gain in visual interest and emotional appeal, the value of such superficial displays for policy-making itself must be questioned. Aesthetic constraints too frequently conceal important issues.

Mathematical models

Another extreme is provided by the computer-based mathematical model interrelating hundreds or thousands of equations. These may be satisfactory where no policy problems have been avoided in constructing the model and there is consensus that it reflects the social reality it purports to model. This is rarely the case. Furthermore such models tend to be incomprehensible to all but their creators and critics. Again they do not help the policy maker to determine which questions to ask, but only answer those he chooses to ask (many "answers" having been built into the design of the model anyway).

Graphic models

An intermediate approach involves the use of graphic, two-dimensional, non-mathematical models. Such models are a symbolic representation of the various aspects of a complex event or situation, and their interrelationships (41). They are analogies which policy-makers may use to clarify their thinking about a relatively complex situation. They range from organization charts through to systems flow charts, including the many kinds of schematic diagram that are prepared on flip-charts or slides for presentation purposes. They are widely and successfully used. Their main disadvantage is that only a limited number of elements and relationships can be incorporated in the model if their comprehensibility is not to be lost – the extreme case being the complex system of network circuit diagram only comprehensible to the expert. None of these approaches is immediately relevant to improving the information problem in relation to the development processes. Each of them indicates constraints and some offer clues to a new approach.
In producing the UNESCO Thesaurus (Paris, Unesco, 1977), an unstructured list of descriptors was compiled of terms from the Macrothesaurus and from basic Unesco documents. In the course of indexing many terms were added and others deleted (p. 10). It is not clear what relation the two now bear to each other. Similarly the Unesco SPINES Thesaurus (Paris, Unesco, 1976) was published too late to be used as a major source. Although some terms were added after brief pre-publication access, it is not clear what relation these bear to the Unesco computer prepared list of terms on which its retrieval system is based.

(16) See previous paragraph (note 1). In the proposed International Standard Nomenclature of Fields of Science and Technology (UNESCO/NS/ROU/257 rev 1) reproduced in Unesco's Method for Priority determination in science and technology (Paris, Unesco, 1978) rev in the CASSAFRICA study (see note 3), no indication is given of what fields have been omitted, whether the list is complete, or what relationship it bears to the Unesco Thesaurus (see note 7)


(18) The UNESCO Interconcept Advisory Committee was that UNIST should devote its primary effort to the fine sciences and at the same time be sympathetic to a progressive inclusion of the applied and engineering sciences and eventually the social sciences on an equal footing with the former (UNIST Rapport, p. 155-6). But the Unesco Statistical Yearbook (1976) includes as fields of science the social sciences and humanities (p. 609). The SPINES Thesaurus does not mention the social sciences.

(19) Research work in the social sciences and humanities should be included within the scope of R and D activity. Most European countries do in fact use the term 'science' to embrace the whole range of human knowledge, and not in the more restrictive 'Anglo-Saxon' sense of natural and social sciences. Proposed standard practice for surveys of research and development, Paris, OECD, 1962, p. 18.

(20) Science is many-sided, and each tends to regard itself from the standpoint of its own particular experience and interest. Scientific Thought, Paris, Unesco, 1972, p. 5.


(22) The Development of Development Thinking, Paris, OECD, 1977 (Liaison Bulletin, No. 1). The UNESCO Interconcept Advisory Committee was that UNIST should devote its primary effort to the fine sciences and at the same time be sympathetic to a progressive inclusion of the applied and engineering sciences and eventually the social sciences on an equal footing with the former (UNIST Rapport, p. 155-6). But the Unesco Statistical Yearbook (1976) includes as fields of science the social sciences and humanities (p. 609). The SPINES Thesaurus does not mention the social sciences.


(26) Consider the lack of relationship between the UNESCO SPINES Thesaurus produced by the Science Policy Division and Unesco's valuable Classification of research and development activities in terms of development objectives produced by its Office of Statistics.

(27) See note 7.

(28) Points made by Georges Guddorf (see note 17), particularly in an article on inter-disciplinarity for the French-language Encyclopaedia Universalis.

(29) Investigated by W. T. Jones with respect to the long-standing debate on the romantic period and then applied to various sciences. The Romantic Syndrome: toward a new method in cultural anthropology and history of ideas. The Hague, Mouton, 1961. He distinguishes seven axes of bias which determine pre-logical positions and then govern the subsequent positions taken in any 'rational or logical - debate.


(32) The number of such reference tools is now so great that reference guides are required to them.


Other references

INTERRELATING VIEWPOINTS IN COMPLEX MEETINGS

the Horus wall-display technique (*)

by Anthony J.N. Judge

with the assistance of David Horton Smith

Summary

This note responds to the problem encountered in meetings of many kinds when a complex of interrelated issues is discussed by participants having very different standpoints and approaches. Usually each participant's contribution is received politely, but very little is achieved towards linking it to others presented, especially when the papers and presentations are lengthy and somewhat difficult to digest. No satisfactory integrating perspective exists (a) to guide the evolution of the meeting; (b) to help participants to see the points of agreement and disagreement in context, or (c) to show participants what they have achieved (or failed to achieve). The note outlines a proposed method for maintaining and developing, during the course of a meeting, a visual representation or overview of the basic substantive points which are determining the evolution of the meeting (**). The method is presented here in a way which permits one or more different methods of representation to be selected for use on a particular occasion, depending on need.

Type of meeting

The display envisaged should be useful for a wide variety of meetings

- in a small group meeting (possibly within the meeting room as a wall display or on a blackboard);
- in a small conference (possibly located in the foyer, if not in the plenary room);
- in a large conference (in the foyer).

In this description it is envisaged that the display could be used in:

- scientific meetings, in which "rational", "factual" presentations are made;
- programme-oriented meetings, in which an attempt is being made to elaborate a programme of action;
- other kinds of meetings, in which much greater emphasis may be placed on values, insights, people-participation, experiences, etc.

Limitations appear to be:

- if the meetings topics are perceived as well-ordered and treated as effectively separate (with no immediate interest or concern as to their interrelationship), then little purpose is served in trying to handle them all on one display. Separate displays could then be used for each topic, although in such cases there may be little desire or need to do so;

- if the presentations are by key resource people intending to inform participants, rather than to stimulate discussion and evoke immediate responses, there may be little motivation for preparing such a display or observing it. This would tend to apply in the case of many conventional meetings.

Use of the display is indicated when:

- part of the concern of the meeting is to interrelate complex issues, presented by people with very different viewpoints and approaches, to participants with differing viewpoints and sympathies;
- it is intended that interaction between participants should move the whole meeting towards a new level of understanding whose gradual emergence needs to be supportively represented;
- there is concern that discussion may drift from point to point, stimulated by each presentation, and that the challenge and opportunity of the compatibility and incompatibility between points will not result in any creative response leading to the emergence of a new level of significance or synthesis;
- part of the difficulty lies with finding a more meaningful method of ordering the predefined issues and relating them to those which emerge during discussion;
- participants are prepared to recognize the reality of the dynamics opposing or linking groups of participants advocating different viewpoints, especially when this is seen as a step towards appreciating their complementarity.

Distinguishing basic points (1)

A conventional presentation of whatever kind contains basic points and associated comments. The various kinds of basic point can usually be briefly formulated in one sentence statements. The associated comments tend to require many sentences or paragraphs. The challenge is therefore to extract the basic points from a presentation and to display them in relation to those from other presentations or interventions.

In Table 1 is given a structured list of the kinds of suggested basic points (or primary elements of inquiry or concern). The list of items included under each heading is not necessarily complete, nor are the items necessarily mutually exclusive (i.e. there may be overlaps). The headings themselves are merely the result of a first effort to distinguish between different types of basic points. An effort has been made to respect the kind of points which emerge in rational discussion as well as those which emerge in other (or broader) kinds of interaction.

Clearly in a given case it may only be useful to extract a few of these points, or to regroup them into a small number of categories. Of course, other kinds of points could also be selected.

The associated comments, or secondary elements of inquiry and concern, include the following:

- historical background and its interpretation;
- prior research;
- current facts and data;
- explanatory comments, discussion, argument


(**) Horus: Holistic Overview and Representation of Underlying Structure.
- implications, elaborations, predictions
- discussion of alternative explanations or models
- definitions of terms, concepts, etc.
- formal deductive elaboration of theory, including derived propositions and hypotheses
- methodological considerations, operational statements
- advocacy, exhortations, anecdotes
- illustrative examples.

This proposal is not concerned with developing any new method of handling this type of information.

Relationships between basic points

Relationships are established or emerge between basic points either
(a) during the course of a conventional presentation,
(b) in the discussion stimulated by it, or
(c) as a result of group discussion initiated independently.

The challenge is to find a way of representing these relationships as a means of providing a contact within which the significance of any particular point can be seen in relation to the whole.

In Table 2 relationships have been grouped under headings. As with Table 1, the grouping is only tentative and the list of relationships under each heading is not necessarily complete.

It is surprising that research has not yet established a comprehensive typology of relationships, although partial typologies abound (2).

Clearly in a given case it may only be useful to distinguish a few kinds of relationship, regrouping them into a smaller number of categories (e.g. agreement, disagreement). Alternatively, others could be added reflecting different kinds of linkage.

Representing the basic points and relationships

The display envisaged would consist of a large wall-space, e.g. 2 metres by 3 metres, or more (3).

This could be:
- a conventional blackboard, in which case chalk markings would be used
- a cork-board, in which case the surface would be divided up by coloured thread or ribbon between pins, with writing on cards
- a plastic surface (whether hard or soft, roll-up, material), in which case marker pens would be used, possibly with writing on cards attached with tape
- a metallic surface, in which case the surface would be divided up by coloured thread or ribbon between magnetic markers (also used to attach cards).

Clearly any such surface can be divided into areas and sub-areas. Attachable cards can be used to carry various kinds of information (e.g. the statement of a

Table 1 - Types of basic point (tentative)

| I - Issues: | II - Initial intellectual position: |
| Domain of inquiry or concern | Basic statements about nature of domain of inquiry or concern |
| questions | principles |
| problems | assumptions (a priori) |
| - needs, requirements | - position statements |
| - sources of anxiety | |
| - constraints | |
| - empirical | |
| - basic facts | |
| - philosophical | |
| - constraints | |
| - deduction (logical) | |
| - consultation of authority (law, chief, oracle) | |
| - revelation | |
| - action, demonstration (talk is counterproductive -). | |
| - self-criticism, introspection | |
| - devotional process | |
| - aesthetic/dramatic participative portrayal | |
| - identification with external reality | |
| - law-governed, definable processes | |

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Table 2 - Types of relationship between basic points (tentative)

| A. Evaluative (positive): | B. Evaluative (negative): |
| Namely a positive evaluation of one basic point, which could be linked to another point in terms of which it is so evaluated | Namely a negative evaluation of one basic point, which could be linked to another point in terms of which it is evaluated |
| - valid, correct | - invalid, wrong |
| - acceptable | - illogical, self-contradictory |
| - elegant | - contradictory |

C. Comparative (positive): Namely a positive comparison between two basic points
- supports
- complementary
- compatibility
- agreement.

D. Comparative (negative): Namely a negative comparison between two basic points
- contradictory
- inconsistent
- incompatible.

E. Comparative (logical): Namely the standard logical relationships between two points
- identity
- included in
- included by
- overlaps.

F. Comparative (structural):
- isomorphism
- equivalence.
basic point) and may therefore be of different colour, shape or size. Card pins (or other forms of attachment) may be used to qualify information (e.g. evaluative comment, as in Table 2). Thread/ribbon (or marked lines) between cards may be used to denote various kinds of relationship according to colour or size. A qualifying comment might be attached in the form of a small card, if necessary. Lists can be used to accumulate (e.g. on the outer perimeter of the display) information which would result in a clutter of unnecessary cards.

If desirable, cards may carry additional information like 'originator of statement' (e.g. group, session, or participant name or number). Participant numbers could also be indicated on card pin heads, particularly for evaluative comments (see below).

Allocating significance to display possibilities

This description deliberately avoids stressing a particular display formula since it is much better for the organizing group to adapt the possibilities to the scope and preoccupations of their own particular meeting (and/or to adjust the display in the light of usage). However, as a guide to the process of selection, Table 3 is provided. This matches the basic points and relationships against the dis-
Table 3 - Display design: Matching wall-display options with meeting content

<table>
<thead>
<tr>
<th>Display options</th>
<th>Area options</th>
<th>Cards</th>
<th>Lists</th>
<th>Links</th>
<th>Card pins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meeting content</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Predefined topics</td>
<td>Ellipse/ circle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emergent issues/ subtopics</td>
<td>Rect./ square</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial positions</td>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intellectual approach</td>
<td>colour</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contextual approach</td>
<td>shape</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explicit values</td>
<td>size</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preliminary preferences</td>
<td>colour</td>
<td></td>
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<tr>
<td>Outcomes/ conclusions</td>
<td>position</td>
<td></td>
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<tr>
<td>Other (Integrative)</td>
<td>with</td>
<td></td>
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<tr>
<td>Evaluation (positive)</td>
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<tr>
<td>Evaluation (negative)</td>
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<tr>
<td>Comparison (positive)</td>
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<tr>
<td>Comparison (negative)</td>
<td></td>
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<tr>
<td>Comparison (logical)</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Comparison (structural)</td>
<td></td>
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</tr>
</tbody>
</table>

N.B. - Mark appropriate positions in this table to aid in design of display. Only a few categories need be used; they may also be grouped (see Table 4, for example).
play possibilities. It may be filled out in the light of particular requirements.

(N.B. - This table is not the display, but a guide to designing one).

As a guide to further reflection about the possibilities, one interesting distribution of areas is presented in Diagram 1. A circular form is convenient because it allows interrelationship between concentric and sectoral zones; in addition the centre can be highlighted as a point of focus or integration. The ellipse is slightly more practical in that it is easier to read cards (with typescript) pinned high up on such a wall-display rather than a circular one. In Table 4 two possibilities for using the areas in Diagram 1 are given. Table 4 is a simplified form of Table 3. The differences between the two formulae illustrate the flexibility of the technique.

Use in practice
There are of course a variety of ways in which the display could be used in practice. Although not necessary, it is probably desirable that the display be prepared before the meeting on the basis of background papers or ideas. 1. Changes to the display could be made after deliberation by a suitably motivated workgroup on the basis of the evolution of the meeting, and group or faction consensus on particular basic points.

2. Changes to the display could be made on request by participants to the person(s) responsible for it (and standing by it). Participants could formulate basic points directly onto cards, or have them typed. Relationships could be inserted at their request. A record of such requests could possibly be kept, particularly if the originators of each change are not identified (or if some are entered for other participants).

3. Changes could be made to the display by participants themselves with or without the guidance/assistance of a responsible person. Clearly, the last approach makes the whole exercise much more participative, which may be highly desirable in certain meetings. On the other hand some thought should be given to protecting the display from casual or deliberate misuse. This is specially the case if use is made of the evaluative option (Table 2: A or B as a vote). Some of the possibilities for this include :

1. Evaluative indications could be made via a special workgroup (Procedure 1, above).

2. Evaluative indications could be made by selected participants (e.g. those who have contributed to debates). The card pins could identify the participant by number. (This corresponds to Procedure 2, above). Alternatively, if many participants use this facility, their names could be transferred (if necessary) to a list on the edge of the display.

3. Such indications could be made by any motivated participants (Procedure 3, above).

It is with the last approach that difficulties may arise, depending on the nature of the group and the capacity for self-restraint (in the absence of filters and gatekeepers). On the other hand, the openness is a considerable stimulus to a new form of participation which combines some of the advantages of voting and wall messages. An appropriate choice must be made by the organizing group and modified in the light of on-the-spot experiences. It is important to note that a very simple form of the display may be used by grouping categories to correspond with the visual tolerance of participants.

Table 4: Examples of two formulae for the display form above (Diagram 1, p. 544)

<table>
<thead>
<tr>
<th>Meeting content</th>
<th>Design options</th>
<th>Predefined topics</th>
<th>Basic points</th>
<th>Relationships (agreement)</th>
<th>Relationships (disagreement)</th>
<th>Card location in sub-zones</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td>Individual viewpoint</td>
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<td></td>
<td>Subgroup viewpoint</td>
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<td></td>
<td></td>
<td></td>
<td>Group viewpoint</td>
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<tr>
<td><strong>FORMULA I</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sectoral zones</td>
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<td></td>
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<tr>
<td>Concentric zones</td>
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<td></td>
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<tr>
<td>Card colours</td>
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<tr>
<td>Ribbon colours</td>
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<tr>
<td>1-7</td>
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<tr>
<td>1-4</td>
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<td>b</td>
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<tr>
<td>c</td>
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</tr>
</tbody>
</table>

| **FORMULA II** |                |                   |              |                          |                             |                           |
| Sectoral zones |                |                   |              |                          |                             |                           |
| Concentric zones|                |                   |              |                          |                             |                           |
| Card colours    |                |                   |              |                          |                             |                           |
| Ribbon colours  |                |                   |              |                          |                             |                           |
| 1-5             |                |                   |              |                          |                             |                           |
| 1               |                |                   |              |                          |                             |                           |
| 2               |                |                   |              |                          |                             |                           |
| List            |                |                   |              |                          |                             |                           |
| a-b             |                |                   |              |                          |                             |                           |
| c               |                |                   |              |                          |                             |                           |

N.B. - This is a simplified (and modified) version of Table 3 with options taken for the two cases. Switching the significance of the sectoral zones and card colours results in very different displays.
Further possibilities

1. In certain circumstances it may be worth using parallel or subsidiary displays, particularly where it is necessary to handle questions internal to some issue area.

2. In some cases it may be useful to relate such structural displays to displays of illustrative images (photos, etc.). Cards referring to locations on the image display could be inserted on the structural display at appropriate locations (and vice versa). Similar cards could be used to refer to film showings.

3. It would be useful to prepare standard roll-up displays (e.g. on a plastic surface) on which are faintly pre-printed in some detail a complete range of basic points and relationships. Points made in the meeting would then be superimposed where relevant (6).

4. Displays, especially when pre-printed, could give particular attention to time, from two completely different viewpoints:
   - the dates between which a particular basic point or relationship was advocated, to show historical development, where relevant (namely phylogenetic development)
   - the education/age levels between which a particular basic point or relationship is recognized, to show when new perspectives become appropriate (namely ontogenetic development)

5. If a display changes rapidly during a meeting, it can be periodically photographed as a visual record of the evolution of the meeting.

6. Special areas may be provided on the display:
   - for basic points commenting on the display itself ("this whole approach is manipulative...", etc.) by those alienated by such a technique
   - for integrating comments which set out to interlink the viewpoints emerging on the display (see below). In a circular display, this could be the central area, for example.

7. A circular or ellipse display may be used to emphasize any integration between perspectives. Positions closer to the centre may be used for more central points. Relationships of agreement (or compatibility) between such points may be used to "pull" them to positions closer to the centre, whereas those of disagreement may be used to "push" them out to the periphery. The pattern of agreement/disagreement (coloured ribbons) could provide a very graphic indication of the relative integration/fragmentation of the meeting (7). The development of this possibility could be very significant as a chart of meeting progress.

Photo: Unesco/B. Hersog.
8. The relationship to such meeting procedures as Syncom could be explored, since the display could provide a visual record of what is occurring within and between the Syncom sub-groups.

9. With the increasing interest in computer conferencing and conferences linked via satellite (8), there are two further possibilities:

- displays may be maintained and used to provide a visual link between participant verbal contributions on particular points;
- computer conferencing software may be designed to relate typed contributions to positions on such a display, or possibly to generate update cards for insertion on maps at each terminal location.

10. The relationship of such a display to the computer-assisted production of participant group «mental models» could also be considered (9).

11. The relationship of such a display to the recording of the evolving relationships between factions or affinity groups (10) within a conference could also be considered. Such a display should facilitate such an evolution.

12. Especially when such a display is used in a small meeting room, there may be a need for meetings in which participants can focus their comments in relation to the display (as with a blackboard). In the interplay between discussion and changes to the display, any evolution in the pattern of agreement/disagreement (11) can be visually supported to counterpoint to the need to obtain integrative clarity when it has been achieved.

An alternative approach

A somewhat different approach that merits investigation may be envisaged in the light of network presentations such as for CPM (Critical Path Method), PERT (Program Evaluation and Review Technique) and in citation analysis. In CPM and PERT networks a single node is indicated as the start point from which the network develops, with a single node as the end point to which the network converges. However as illustrated by Diagram 2, if many independent start points are allowed, they can be positioned around the circumference of a circle by sector (e.g. according to topic, as discussed above). Points derived from (or subsequent to) others on the circumference are positioned towards the centre. Further development leads to convergence of the network as a whole on the centre from its circumferential origins. Unlike CPM and PERT, at any particular time the «end point» remains undefined and dependent upon further development of the encircling network (12).

The difference from the previous displays is clearly that new contributions which do not build on existing achievements are seen as (a) reinforcing those achievements, either usefully or unnecessarily, or (b) undermining them, as the case may be. Two contrasting possibilities, for example, are to use the circumferential points to represent specific factual details or, alternatively, abstract general standpoints. In the first case convergence on the centre can be used to record progressively more abstract points. In the second, convergence records emergence of more concrete practical viewpoints (e.g. a specific action programme).

The concentric rings can in each case be used to denote points at different levels of abstraction. If an effort is made to juxtapose associative topics (represented by sectors), then citation links to points in distant sectors (i.e. across the centre) are less frequent. If a new approach is recognized, an extra sector could be added.

This is therefore a method of ordering information which makes it evident which points need to be considered in order to move on to a new level of significance or synthesis. Variations of it could be developed to focus group discussion or policy debates.

References:

1. I am indebted to David Horton Smith for extensive discussion of the contents of this section and the following one. He should not be held responsible for their present inadequacies. A.J.


3. In special cases it may be possible, or useful, to use a nonflat surface, such as a cone or a sphere, e.g. if it was desired to stress some integrative or wholistic concept. In the case of a flat surface, it may be an advantage to be able to raise and lower the display to permit adequate access to the whole surface, particularly to read cards, (e.g. some blackboard systems)

4. Horus, the name suggested for this wall-display approach, is derived from: Holistic Overview and Representation of Underlying Structure. The eye, an ellipse, is a symbol of the Egyptian god Horus.

5. Yona Friedman has advocated a form of this for conferences of the World Future Studies Federation. Another form is of course favoured in China.

6. Since many of the basic points have been established in many meetings, such a display should be available anyway to focus discussion.

7. The «eye» of Horus could appear very «bloodshot» as a consequence of the degree of disagreement in some meetings - if a red ribbon is used!

8. For example the World Symposium on Humanity (April 1979) is schedule to link, via satellite, meetings of 3,000 people in Los Angeles, Toronto and London. Both video and computer conferencing will be used.


11. Although hopefully more subtle patterns will become acceptable, based on complementarily between a diversity of «incompatible» perspectives. The agreement/disagreement duality is crude in comparison.

12. The diagram could also be seen as representing a ringed tube or tunnel, with new segments appearing in the center as one «advances» down it - this old segments passing out of the field of vision. In some cases it may be useful to envisage the tunnel as looping back on itself in a circle (or even forming the throat of a torus). The sectoral dividers could also be envisaged as spiralling towards the centre.
Mapping World Problems — a technique illustrated by relations between IGOs and INGOs, particularly for the case of the United Nations system.

Introduction

It is becoming widely accepted that world problems do not exist in isolation from one another. They are linked together in complex networks of cause-effect relationships. Social problems contribute to economic problems which both interact with education problems, health problems and agricultural problems. We have not yet begun to understand all these interlinkages. The Club of Rome sponsored study(*) at M.I.T. under Dennis Meadows attempted to study some key relationships using computer techniques. This project has sparked off much enthusiasm and further projects (**) — but it has also given rise to much counter-criticism. The situation is not clear, but whatever the outcome there is a consensus that we need to be able to look at networks of problems. The following paragraphs describe a very simple technique for clarifying one's own perception of any network of problems with which one is concerned.

Objective

Any executive faced with a maze of problems in his organization's environment can usually, note down 5-10 key problems. If asked, he can usually show some of these problems are dependent upon other problems — but beyond that point the exercise becomes unprofitable because the situation gets too complex and it is not clear how he could usefully display the interrelationships in a manner which he and his colleagues can comprehend. It was precisely this difficulty that faced the Union of International Associations in preparing for its Seminar on the Philosophy of International Nongovernmental Organization (Milan, 17-19 May, 1972) in attempting to show the linkages between all the different issues surrounding the current crises in the relations between IGOs and NGOs.

Technique

At first an effort was made to note down all the problems in boxes on a large sheet of paper and draw in the cause-effect arrows between them. This proved totally impracticable because there were too many groups of linked problems and no satisfactory means of juggling them all into position on one satisfactory diagram. This approach was therefore abandoned, except as a useful way of looking at groups of closely related problems in a comprehensive manner.

The method finally adopted was to:
1. Note down each problem on a separate card (12 x 8 cm);
2. Number each card in sequential order (in the UIA case it was from 1-88 marked in the upper left-hand corner of the card);
3. Use the same identifying numbers to label the linked problem boxes on the sketches prepared in the preliminary attempt.
4. Mark the linkages (identified in the preliminary attempt) between the problem boxes into the set of cards.
5. The object is then to sort out the cards in a manner which groups closely related problems together. There may well be a space limitation (e.g. getting the complete problem map onto double-folio) which will govern: a) the size of boxes to be allocated to the text on each card, b) the number of columns of boxes c) the number of rows of boxes. The sorting operation is a matter of time, patience and successive approximation to a best fit.
6. Once the cards are sorted, the text on the cards can be typed onto a sheet with columns of empty boxes already drawn for all the problems. The numbers of the problem should also be typed in (from the upper left-hand corner in the UIA case).
7. Arrowed lines can now be drawn between each numbered problem box on the basis of the other numbers on the cards, indicating to which problems give rise to or aggravate the problem on the card, namely outgoing links, or are clearly marked (in the UIA case, in the bottom right-hand corner of the card in question). Any new linkages between two problems can of course be marked in at any time.
it is linked (i.e. in the UIA case, the numbers from the lower left and right hand corners of the cards). These are the inter-problem linkages. The numbers in the boxes may now be erased. The above procedure gives a comprehensive map of all the problems and their interlinkages. Inspection of the finished map however may suggest other linkages which should also be drawn in.

Preparation of the problem map in this way may over-emphasize some problems at the expense of others. To compensate, it is of course possible to look at a particular problem and decompose it into subproblems (i.e. replace one box by several interlinked as a system), or alternatively to combine several into one.

Example
The map on the following double page in the result of the UIA exercise at looking at many of the problems touching on the relationship between IGOs and NGOs (†). The boxes are grouped together into problem sub-systems whose boundaries could have been marked by dotted lines. This was not done because it increased the visual complexity of the flow-chart in this case.

An attempt was made to have the fundamental causes in the top left hand corner, and the final results in the bottom right hand corner.

Comment
A map or flow-chart of this kind does serve to show the degree of interlinkage of problems normally treated in isolation (‡). It is a reminder to those who wish to focus on a particular part of the whole system that their actions affect other parts, either aggravating other problems or resulting (feedback) in a magnification of the difficulties in the area with they are concerned. (This was a principle conclusion of the Club of Rome study). Once a study of this kind is completed the key question is do the lines of communication and information flow between the departments and organizations responsible for each group of problems match the pattern linkages between the problems themselves.

(†) This map was originally started with a view to inclusion in : A.J.N. Groom and Paul Taylor (Eds.) Functionalism; theory and practice in international relations. London. University of London Press, 1973.

(‡) For those interested in the use of computers, there is no reason why this sort of approach should not be developed to look at very complex networks of problems and produce the maps automatically.

It is appropriate to quote (once more) Stafford Beer’s adaptation of Le Chatelier’s Principle to social systems:

* Reformers, critics of institutions, consultants in innovation, people in short who ‘want to get something done’, often fail to see this point. They cannot understand why their strictures, advice or demands do not result in effective change. They expect either to achieve a measure of success in their own terms or to be flung off the premises. But an ultrastable system (like a social institution) has no need to react in either of these ways. It specializes in equilibrial readjustment, which is to the observer a secret form of change requiring no actual alteration in the macro-systemic characteristics that he is trying to do something about. (***)

Contextual Knowledge
Advances in information, communication, and computer capability, advances in our ability to coordinate, etc., are useless, if not properly mobilized. Consider the problem of poverty among minority groups. Our nation is committed and is likely to remain committed to reducing poverty. We do not know how to approach solving the problem without creating other undesirable conditions in the process. Our government comes at a problem, like minority group poverty, from many directions: some officials are convinced that all that is necessary is to stimulate economic growth, others call for better education, still others advocate a direct transfer of income, and of welfare. This is much like many blind men feeling parts of an elephant and then being asked to describe it. The man who describes a trunk is as right as the man who describes a leg both are partially right. Division of problems into subproblems without knowing their over-all dimensions hardly ever contributes to a situation. But, it is precisely this division into subproblems that must be achieved, however badly, if an organization is to effectively pursue an objective or execute a program. Without knowing the structure of a problem, it is difficult, if not impossible, to efficiently design solutions or government organization.

USE OF INTERACTIVE GRAPHIC DISPLAY TECHNIQUES

Description: The suggestion has been made (see Appendix 5) that the representation of the relationship between theoretical entities (concepts, organizations, problems, etc.) could best be accomplished using methods based on graph theory, network theory, and topology. The relationships registered in this project could be plotted manually as networks. However, particularly since the relationships are already coded on computer tape in a suitable format, there are three major disadvantages to this manual approach:

- graphic relationships are tiresome and time-consuming to draw, and are costly if budgeted as ‘art work’ (for a comprehensive review of the current possibilities and limitations, see ref. 1);
- once drawn, there is a strong resistance to updating them (because of the previous point) and therefore they quickly become useless (as is frequently the case with organization charts);
- when the graph is complex, multidimensional, and carries much information, it is difficult to draw satisfactorily in two dimensions. The mass of information cannot be filtered to highlight particular features - unless yet another diagram is prepared.

These three difficulties can be overcome by making use of what is known as ‘interactive graphics’ (2). This is basically a television-type screen attached to a computer. The user sits at a keyboard in front of the screen and has at his disposal what is known as a light-pen (or some equivalent device) which allows him to point to elements of the network of concepts displayed on the screen and instruct the computer to manipulate them in useful ways. In other words the user can interact with the representation of the conceptual network using the full power of the computer to take care of the drudgery of:

- drawing in neat lines;
- making amendments;
- displaying only part of the network so that the user is not overloaded with ‘relevant’ information.

In effect the graphics device provides the user with a window or viewport onto the network of concepts. He can instruct the computer via the keyboard to:

1. move the window to give him, effectively, a view onto a different part of the network - another conceptual domain;
2. introduce magnification so that he can examine (or ‘zoom in’ on) some detailed sections of the network;
3. introduce diminution so that he can gain an overall view of the structure of the conceptual domain in which he is interested;
4. introduce filters so that only certain types of relationships and entities are displayed - either he can switch between models or he can impose restrictions on the relationships displayed within a model, i.e. he has a hierarchy of filters at his disposal;
5. modify parts of the network displayed to him by inserting or deleting entities and relationships. Security codes can be arranged to that (a) he can modify the display for his own immediate use without permanently affecting the basic store of data, (b) he can permanently modify features of the model for which he is a member of the responsible body, (c) and so on;
6. supply text labels to features of the network which are unfamiliar to him. If necessary he can split his viewport into two (or more) parts and have the parts of the network displayed in one (or more) part(s). He can then use the light pen to point to each entity or relationship on which he wants a longer text description (e.g. the justifying argument for an entity or the mathematical function, if applicable, governing a relationship, and have it displayed in an adjoining viewport);
7. track along the relationships between one entity and the next by moving the viewport to focus on each new entity. In this way the user moves through a representation of ‘semantic space’ with each move, changing the constellation of entities displayed and bringing new entities and relationships into view;
8. move up or down levels or ‘ladders of abstraction’. The user can demand that the computer track the display (see point 7) between levels of abstraction from sub-system to system, at each move bringing into view the context of the system displayed;
9. distinguish between entities and relationships on the basis of user-selected characteristics. The user can have the ‘relevant’ (to him) entities displayed with more prominent symbols, and the relevant relationships with heavier lines;
10. select an alternative form of presentation. Some users may prefer block diagram flow charts, others may prefer a matrix display, others may prefer Venn diagrams (or ‘Venn spheres’ in 3 dimensions) to illustrate the relationship between entities. These are all interconvertible (e.g. the Venn circles are computed taking each network node as a centre and giving a radius to include all the sub-branches of the network from that node);
11. copy a particular display currently on the screen. A user may want to keep a personal record of parts of the network which are of interest to him. He can either arrange for a dump onto a tape which can drive a graph plotter as suggested in Appendix 7, or a microfilm plotter, or copy onto a videotape, or, in the future, obtain a direct photography;
12. arrange for a simultaneous search through a coded microfilm to provide appropriate slide images or lengthy text (which can in turn be photocopied);
13. simulate a three-dimensional presentation of the network by introducing an extra coordinate axis;
14. rotate a three-dimensional structure (about the X or Y axis) in order to heighten the 3-D effect and obtain a better view ‘around’ the structure;
15. simulate a four-dimensional presentation of the network by using various techniques for distinguishing entities and relationships (e.g. ‘flashing’ relationships at frequencies corresponding to their importance in terms of the fourth dimension);
16. change the speed at which the magnification from the viewport is modified as a particular structure is rotated;
17. simulate the consequences of various changes introduced by the user in terms of his conditions. This is particularly useful for cybernetic displays;
18. perform various analyses on particular parts of the network and display the results in a secondary viewport (e.g. the user might point a light-pen at an entity and request its centrality or request an indication of the interconnectedness of a particular domain delimited with the light-pen);
19. use colour (when a colour screen is available) to distinguish between different concepts or networks of relationships on the same display. Several hundred colour codes are available under computer control (3);
20. experiment with the generation of paths for the construction of topological networks of conceptual units (e.g. organizations) from available smaller units, as suggested by equivalent work on computer-assisted design of complex organic syntheses (4).

In every current use of interactive graphics there is some notion of geometry and space, but the geometry is always the three-dimensional conventional space. There is no reason why ‘non-physical spaces’ should not be displayed instead - and this is the domain of topology. The argument has been developed by Dean Brown and Joan Lewis (5):

‘Both geometry and topology deal with the notion of space, but geometry’s preoccupation with shapes and measure is replaced in topology by more abstract, less restrictive ideas of the qualities of things...Being more abstract and less insistent on fine points such as size, topology gives a richer formalism to adapt as a tool for the contemplation of ideas....

Concepts can be viewed as manifolds in the multidimensional variate space spanned by the parameters describing the situation. If a correspondence is established that represents our incomplete knowledge by altitude functions, we can seek the terrain incognitae, plateaus, enclaves of knowledge, cusps, peaks, and saddles by a conceptual photogrammetry. Exploring the face of a new concept would be comparable to exploring the topography of the back of the moon. Commonly heard remarks such as ‘Now I’m beginning to get the picture’ are perhaps an indication that these processes already play an unsuspected role in conceptualization...

By shifting between the three-dimensional perspectives on the screen and ‘rotating them on the tips of his fingers’, one internalizes ideas non-verbally and acquires a sensation of sailing through structures of
concepts much as a cosmonaut sailing through constellations of stars. Such new ways of creating representations break ingrained thought patterns and force re-examination of preconceived notions. A mapping is correspondence is an analogy. Teaching by analogy, always a fertile device, can be carried out beautifully by topological means... Topological techniques are useful at even the most advanced levels of scientific understanding. The fundamental importance of interactive graphics, in whatever form, is its ability to facilitate understanding. Progress in understanding is made up of different symbol structures, some of which would lead to social systems: states.

"Every person in his private life and in his community life uses models for decision making. The mental image of the world around one, carried in each individual's head, is a model. One does not have a family, a business, a city, a government, or a country in his head. He has only selected concepts and relationships which he uses to represent the real system. The human mind selects a few perceptions, which may be right or wrong, and uses them as a description of the world around us. On the basis of these assumptions a person estimates the system behaviour that he believes is implied... The human mind is excellent in its ability to observe the elementary forces and actions of which a system is composed. The human mind is effective in identifying the structure into which separate scraps of information can be fitted. But when the pieces of the system have been assembled, the mind is nearly useless for anticipating the behavior of the complete system. A computer is ideal. It will trace the interactions of any specified set of relationships without doubt or error. The mental model is fuzzy. It is incomplete. It is imprecisely stated. Furthermore, even within one individual, the mental model changes with time and with the flow of conversation. The human mind assembles a few relationships to fit the context of a discussion. As the subject shifts, so does the model. Even as a single topic is being discussed, each participant in a conversation is using a different mental model through which to interpret the subject. And it is not surprising that consensus leads to actions which produce unintended results. Fundamental assumptions differ but are never brought out into the open."

These structured models have to be applied to any serially ordered data in card files, computer printout or reference books to make sense of that data. Is there any reason why these invisible structural models should not be made visible to the system designer? Is there any way that computer-processing of such invisible models? The greater the complexity, however, the more difficult it is to use mental models. For example, in discussing his examination of an electronic circuit diagram, Ivan Sutherland writes (7):

"Unfortunately, my abstract model tends to fade out when I get a circuit that is a little bit too complex. I can't remember what is happening in one place long enough to see what is happening somewhere else. My model evaporates. If I could somehow represent that abstract model in the computer to see in a circuit animation, my abstraction wouldn't evaporate. I could take the vague notion that 'fades out at the edges' and solidify it. I could actually see bigger circuits. In all fields there are such abstractions. We haven't yet made any use of the computer's capability to 'form up' these abstractions. The scientist of today is limited by his pencil and paper and mind. He can draw abstractions, or he can think about them. If he draws them, they will be static, and if he just visualizes them he can't really manipulate them. Can the human mind have any internal image?"

"With the computer, we could give him a great deal more. We could give him drawings that move, drawings in three or four dimensions which he can rotate, and drawings with great mathematical accuracy. We could let him work with them in a way that he has never been able to do before. I think that really big gains in the substantive scientific areas are going to come when somebody invents new abstractions which can only be represented in computer-oralical form."

The availability of devices to restructure information in this way would seem to offer some hope that insights could emerge which respond more adequately to the recorded complexity of societal structure, whilst at the same time being more easily comprehensible to the initiated - because of the ease with which such devices can be used as educational tools to develop understanding and comprehension of the same structural data from which the research insights are being derived. Such displays of course lend themselves to videotape recording for wider distribution.

Implications of Computer Augmentation of Intellect

There are important intellectual implications emerging from work on advanced computer systems. Of particular interest is the work of Douglas Engelbart's team at the Center for Augmentation of Human Intellect (Stanford Research Institute) which is a centre for the US ARPA Data Network (which links the computers of major universities in the USA). Engelbart has worked on the means of creating an 'intellectual workshop' to facilitate interaction between conceptual structures (8). He considers that:...

"Concepts seem to be structurable, in that a new concept can be composed of an organization of established concepts and that a concept structure is something which we might try to develop on paper for ourselves or work with by conscious thought processes, or something which we try to communicate to one another in serious discussion. A given structure of concepts can be represented by any of an infinite number of different symbol structures, some of which would be much better than others for enabling the human perceptual and cognitive apparatus to search out and comprehend the conceptual matter of significance and/or interest to the human. But it is not only the form of a symbol structure that is important. A problem solver is involved in a stream of conceptual activity whose course serves his mental needs of the moment. The sequence and nature of these needs are quite variable, and yet for each need he may benefit significantly from a form of symbol structuring that is uniquely efficient for that need. Therefore, besides the forms of symbol structures that can be constructed and portrayed, we are very much concerned with the speed and flexibility with which one form can be transformed into another, and with which new material can be located and portrayed. We are generally used to working on a computer symbols as a pattern of marks on a sheet of paper. When we want a different symbol-structure view, we think of shifting our point of attention on the sheet, or moving a new sheet into position."

With a computer manipulating our symbols and generating their portrayals to us on a display, we no longer need think of our looking at the symbol structure which is stored as we think of looking at the symbol structures stored in notebooks, memos, and books. What the computer actually stores need be none of our concern, assuming that it can portray symbol structures to us that are consistent with the form in which we think our information is structured. A given concept structure can be represented with a symbol structure that is completely compatible with the computer's internal way of handling symbols, with all sorts of characteristics and relationships given explicit identifications that the user may never directly see. In fact, this structuring has immensely greater potential for accurately representing a conceptual structure than does a structure an individual would find it practical to construct on use on paper. The computer can transform back and forth between the two-dimensional portrayal on the screen, of some limited view of the total structure, and the aspect of the n-dimensional internal image that represents this 'view'. If the human adds to or modifies such a 'view', the computer integrates the change into the internal-image symbol structure (in terms of the computer's favored symbols and structuring) and thereby automatically detects a certain proportion of his possible conceptual inconsistencies. Thus, inside this instrument (the computer) there is an internal-image, computer-symbol structure whose convolutions and multi-dimensionality we can learn to shape to represent to hitherto unattainable accuracy the concept structure we might be building or working with. This internal structure may have a form that is nearly incomprehensible to the direct participant for accurate analysis of a conceptual structure than does a structure an individual would find it practical to construct or use on paper.

These insights have been incorporated into the design of an operational computer system which is now being developed so that it will be possible to use computer devices as a sort of 'electronic vehicle with which one could drive around with extraordinary freedom through the information domain. Imagine driving a car through a landscape which, instead of buildings, roads, and trees, had groves of facts, structures of ideas, and so on, relevant to your professional interest. But this information landscape is a remarkably organized one, not only can you drive around a grove of certain arranged facts, and look at it from many aspects, you have the capability of totally reorganizing that grove almost instantaneously. You could put a road right through the center of it, under it, or over it, giving you, say, a bird's eye view of how its components might be arranged for your greater usefulness and ease of comprehension. This vehicle gives you a flexible method for separating, as it were, the woods from the trees (9)."
Conclusion

Application of this kind of technology to an understanding of the world problem complex has not been attempted. As explained above, such devices offer a means of developing improved conceptual (and associated organizational) structures to contain the complexity with which humanity has to deal at this point in time. Of vital importance is the ability of these devices to portray the information in a more meaningful (or 'iconic') form than emerges from conventional quantitative studies. This is particularly important in communicating with the informed public but specially so with the policy-making community, as Harold Lasswell notes (10): 'Why do we put so much emphasis on audio-visual means of portraying goal, trend, condition, projection, and alternative? Partially because so many valuable participants in decision-making have dramatizing imagination-... They are not enamoured of numbers or of analytic abstractions. They are at their best in deliberations that encourage contextuality by a varied repertory of means, and where an immediate sense of time, space, and figure is retained.'

References
3. On colour graphics with computers, see Ivan Sutherland Scientific American, June 1974
5. Dean, Brown and Joan, Lewis. The Process of Conceptualization; some fundamental principles of learning useful in teaching with or without the participation of computers. Educational Policy Research Center, Stanford Research Institute, Menlo Park, California, pp16-18

Successive changes in relationship between molecular structures displayed in 3-D under computer control.

Photo: Louis Katz, Columbia University (used by Henry M. Sobeil, University of Rochester, in an article 'How Actinomycin binds to DNA,' Scientific American, August 1974)
A first step towards putting "interorganizational space" on paper. The same technique as that used for visualization of molecules (see left right facing page) has been used by the author to show a group of 18 organizations and associated bodies. The structure has been turned (to reveal its configuration from a specific viewpoint) and enlarged (to study a specific relationship). The spheres (knots) representing the various bodies and their identification-marks have been added or removed. This technique could be used in the study of thousands of different organizational networks.

(Photographs taken by the author of the screen of the IDIOM computer belonging to Information Displays Inc., USA)
Acceptability of network maps is now considered quite acceptable in many major cities to print and make available to the general public (often on notice boards or in tourist literature) various schematic maps: the subway (underground, or metro) network; the urban bus network; and the suburban railroad network. Travellers are also accustomed to exposure to documents showing the airline network. Other kinds of network are mapped for the benefit of workers in specialized sectors (e.g. production networks, electronic distribution networks, telephony networks, military communication networks, goods distribution networks, etc.). The most complex map of this type would seem to be that used to summarize (on a surface 100 x 132 cm) the relationships between over 1,000 biochemical compounds involved in metabolism (See: GerhardMichal. Biochemical Pathways. Mannheim, Boehringer Mannheim GmbH, 1974, also, but less complex: D E Nicholson. Metabolic Pathways. Colnbrook, England, Koch-Light Laboratories, 1974).

The point is that people are now very familiar with such maps in one form or another and use them, like road maps, to organize their thinking about the movement of themselves or items with which they are concerned between distant points embedded in a complex network. No such network maps are currently available to show the relationships between distant points representing particular features of the social system. As a result thinking about the social system and its problems is somewhat chaotic, as would be any discussion about travel in the absence of adequate maps to provide the necessary frameworks for such discussion.

Reasons for the lack of societal network maps

1. There is much confusion concerning the kinds of entities that can be distinguished in the social system, due to overlapping systems of categories, needs, and the maze of associated terminologies.
2. Where clarity emerges, it is usually in relation to one particular entity (e.g. one holding company and its network of subsidiaries, or one government agency and its associated bodies); any maps produced then have that body as the central reference point.
3. Much of the required information is scattered through a variety of reference books and no research has justified its systematic organization.
4. Systematic sociological research in the past inverts the focus so that, for example, instead of determining how many organizations (problems, etc.) there are in a sample in order to determine the number per capita, the mean number of personal relationships to such entities is determined on a per capita basis, so that there is no means of determining how many distinct entities there are to which the relationships are established.
5. Where such information is collected it is often considered secret because of its political or economic significance. Examples are (a) the collection of data on organizations in every country by the civil or military intelligence units; and (b) the secrecy associated with the subsidiaries owned by a major (multinational) corporation at any one time and their interrelations.
6. Where the data can be collected, and there is a strong case for doing so, there is often reluctance to do so because of the problems of data handling. This is best seen in the (non-societal) case of mapping ecosystem food webs in which animal species are embedded. There is a multiplicity of inter-specific ‘food chains’, together with many branches and cross-connections among food chains making a structure of interactions called ‘food webs’. The complexity of these food webs is such that no one has yet worked out the complete pattern of food relationships and interactions in any natural community. The relationships between 50 species in a given community results in a diagram ‘so suff of lines that it is difficult to follow’ and this only represents one quarter of the 210 known species in a ‘simple’ community. (David Pimental. Complexity of ecological systems and problems in their study and management. In: K E F Webb (Ed) Systems Analysis in Ecology. New York, Academic, 1966, pp.5-35).
7. Where the research has been done, there is a reluctance to produce maps because of the time, space-consuming and often costly nature of the task of doing so (also discussed in Appendix B), particularly when the networks are complicated.

Psycho-social significance of maps: a parallel

The current ability to map the societal system may be usefully compared to that of the European geographical mapping ability during the Middle Ages and earlier. The changing psycho-social significance and status of maps, since such early times, provides many clues for understanding the present situation. Maps in that period were often closely guarded secrets, for military and economic reasons. And just as the understanding in Europe of non-European continents was very limited at that time, so today there are only a few well-known problem areas (such as population, food, peace, etc.). Each such territory (or ‘Feudal state’) is more or less poorly controlled by a few major organizations (the ‘cities’) with a few well-established links between them (the ‘roads’ or ‘rivers’). The relations between these feudal states are the limit of concern. Few people travel long distances and when they do, in the absence of readily available maps, they use ‘experts’ to guide them from point to point. Other continents are only vaguely known (and are widely held to be populated by mythical monsters). Each group is content with artistic or impressionistic two-dimensional maps centred on its own organization (or field of concern), confidently held to be the prime mover in the social system as perceived from that point of reference. The significance of any three-dimensional representation is not recognized and a flat-earth perspective prevails.

Under such conditions, it is easy to understand the psychological and communication difficulties which make it impossible to achieve any general galvanization of political will in response to world problems. Each sector is content with its own sketchy local map (if any is held to be required) of the problem environment, and there is little concern for whether such local maps mesh together with those of neighbouring territories or into a general map of the region. Communication therefore frequently breaks down and moments of solidarity are soon forgotten. Warring between feudal territories is common. The state called ‘energy’, clashes with that called ‘environment’. Alliances are formed and each state has imperialistic ambitions: ‘development’ wants to incorporate ‘environment’; ‘environment’ lays claim to the territory of ‘development’, and all are claimed by the territory called ‘peace’. Lacking maps, assemblies of individuals and groups from different problem territories are pathetic. The people from ‘heavy rainfall’ areas cannot understand the constant harping on water by people from ‘desert’ areas; the people from ‘arctic’ areas cannot relate meaningfully to those from ‘tropical’ zones.

The history of the evolution of geographical perceptions, and the tools that have been required to move humanity towards a global perception, indicate the kinds of difficulty which have to be faced. (The much-used NASA photograph of Earth from space is only significant as a symbol because people know that they can relate its features to the map of the world, or new relationships between organizations, etc.) New versions of such maps, or hypothetical maps (e.g. of organizational systems) could be fed into later sessions of the same meeting or used as one form of summary of the achievements of the meeting.
MAPPING ORGANIZATIONAL METABOLISM

- metabolic pathways in living organisms as one suggestive illustration of ways of representing alternation networks

Metabolic pathways: a laboratory wall-chart (reduced from the normal 92 x 72 cm size) reproduced, with permission of the designer, as an illustration of the ability of biochemists to display a complex network in a compact form for use in a work context.

Designed by D E Nicholson, Department of Microbiology, University of Leeds, England.
Published by Koch-Light Laboratories Ltd, Colnbrook, Buckinghamshire, England.