ARI Research Note 86-66

FORMAL "SYSTEMS LANGUAGES" IN DECISION SUPPORT SYSTEMS FOR MILITARY COMMANDERS

John Hawgood
Crook Hall, Sidegate

for

Contracting Officer's Representative
Michael Kaplan

BASIC RESEARCH LABORATORY
Milton R. Katz, Director

U. S. Army
Research Institute for the Behavioral and Social Sciences

June 1986

Approved for public release; distribution unlimited.

U. S. ARMY RESEARCH INSTITUTE

FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency under the Jurisdiction of the

Deputy Chief of Staff for Personnel

EDGAR M. JOHNSON
Technical Director

WM. DARRYL HENDERSON
COL, IN
Commanding

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARI Research Note 86-66	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) FORMAL "SYSTEMS LANGUAGES" IN DECISION SUPPORT SYSTEMS FOR MILITARY COMMANDERS		5. TYPE OF REPORT & PERIOD COVERED Final Report Period ending September 85
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) John Hawgood		8. CONTRACT OR GRANT NUMBER(s) DAJA 45-84-M-0278
9. PERFORMING ORGANIZATION NAME AND ADDRESS Crook Hall, Sidegate Durham DH1 5SZ England		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2Q161102B74F
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Research Institute Scientific Coordination Office, Europe; European Research Office, U.S. Army, London, England		12. REPORT DATE June 1986
		13. NUMBER OF PAGES 14
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Avenue, Alexandria, VA 22333-5600		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE - -

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

- -

18. SUPPLEMENTARY NOTES

Michael Kaplan, contracting officer's representative

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Systems Theory
Decision Support
Command and Control
Management Science

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This research note discusses the similarities and differences between the conceptual requirements of decision support in civilian and military situations, and introduces the idea of formal systems languages which vary as one moves through any hierarchy. The approach of "soft system methodology" is extended by the addition of the concept of mutually malevolent (mumal) systems. It is proposed that decision support systems for military commanders should be "taught" by means of the system language appropriate to the destined user.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

FORMAL "SYSTEMS LANGUAGES" IN DECISION SUPPORT SYSTEMS

FOR MILITARY COMMANDERS

INTRODUCTION

This report is intended to point out some similarities and some differences between the conceptual requirements of decision support in civil and military situations, and to introduce the idea of formal systems languages which vary as one moves through any hierarchy.

The first sections define the term "decision support system" (DSS) in a civil context by identifying the components of the managerial decision process and possible computer based aids for them. Then the relation between DSS, management information systems and expert systems is explained and the concept of the DSS generator is introduced. The importance of considering the interests of different "stakeholders" is emphasized.

The military situation is addressed by adding the notion of "mutually malevolent" (mumal) systems and by reinterpreting the stakeholder concept. Both in the civil and the military context, we can define formal "systems languages" that are different for managers or commanders with responsibilities for different parts of an organisation, and which need to be considered in the design of decision support systems and of DSS generators.

It is proposed that the DSS should be given information on the objectives, resources and other system factors for each point in the command hierarchy, in such a way that information can be presented to each commander in the form most natural and most relevant to his situation. That is, the DSS should use different "languages" for different commanders.

The usefulness of this approach could be tested in war gaming experiments.

The research reported in this document has been made possible by Contract number DAJA45-84-M-0278 from the U.S.Army Research Institute for the Behavioral and Social Sciences through its European Science Coordination Office at the European Research Office of the U.S.Army, London, England. The opinions expressed are those of the author and do not necessarily represent those of the U.S.Army.

TERMINOLOGY

The term Decision Support System (DSS) has been applied recently to many software products which are little more than packages for database access and/or spread-sheet modelling tools. I want to give it a wider but more precise meaning in this report. To explain my use of the term, I first take the three words one by one:

Decision implies the existence of a human decision maker (either an individual or a group), with some freedom of choice among several possibilities. This means not only that the decision will not normally be taken at random, but also that it may not be entirely rational. That is to say, it may not follow the direction suggested by any objective weighing of arguments for or against the different choices; emotional and subjective factors will be present also, especially in battle or other crisis situations.

Support for decision making in an organization may be given by a human colleague or staff, or by a computer-based system, or both. But in all cases, it is only support - the final choice rests with the decision maker (individual or group). Those who speak of computers making decisions, whether in defence, management, medicine or other fields, are hindering progress in the field both by overstating the capability and by frightening the human user. Any decision that seems to have been made by a computer must be pre-programmable - that is, it has really been made by the person who wrote the program or the person who told the programmer what to do. In this report I exclude such repetitive decisions that can be pre-programmed.

System is a term that can be used at many levels, from the cosmological to the atomic; the military hierarchy is essentially a set of nested supersystems, systems and subsystems, all being "human activity systems" including both people and equipment of various kinds. Most of the second half of the paper is devoted to exploring the military system concept. In using the term "decision support system" I might be referring either to a human activity system or to a purely mechanical system such as a computer. In this report I shall only be concerned with the latter level, but it is worth bearing in mind that most of the DSS functions described are now normally carried out by humans (the decision-maker's staff).

I intend to restrict the term DSS to computer based systems for supporting non-repetitive unstructured or semistructured organizational decisions. One tends to think of such decisions as being confined mainly to strategic levels and to the long term, but semistructured decisions do also have to be taken at lower levels for short and medium term (tactical) problems, and I do not exclude such cases from this discussion.

THE MANAGERIAL DECISION PROCESS

The type of decision with which we are concerned (non-routine and semistructured) tends to be taken in a very interactive and iterative way in civil life, with the decision maker(s) hopping, apparently at random, between analysis and action. The process can be regarded as consisting of three main subdivisions - problem identification, solution development and selection between alternatives, but not usually worked through in a linear sequence. Within each of these subdivisions there are recognisable cognitive tasks, again not carried out in any fixed sequence and not all figuring in every decision:

> Problem identification comprises situation monitoring, problem recognition, knowledge inventory and diagnosis; situation monitoring and problem recognition require information about the environment and an overview of the organization, both interpreted in the light of knowledge about critical success factors, stakeholder objectives, key variances and the significance of competitors' actions; diagnosis requires more detailed information and knowledge concentrating on the problem area, guided by a detailed and comprehensive inventory of available data, models and experience.
>
> Solution development includes the search for possible existing solutions, design of new solutions and short-listing of options worth further study; the search for existing solutions which have been applied or proposed in the past requires both careful classification of problem characteristics and lateral thinking to spot surprising analogies; design of new solutions requires first creativity, then the ability to organize and detail its results; short-listing of options requires knowledge of organizational aims, political possibilities and financial constraints.

<u>Selection between alternatives</u> involves evaluation of the possible outcomes of alternative policies against organizational and stakeholder objectives, negotiation, judgment, and finally authorization of a chosen option; evaluation requires both some means of predicting consequences of alternative policies (often using simulation models) and a way of weighting incommensurate attributes of different options to make choices between policies which may further certain organizational or stakeholder objectives but not others; negotiation requires a clear understanding by the different parties of each others' interests and the extent to which alternative policies may satisfy or injure them.

The word "stakeholder" which appears twice above needs some explanation: it refers to the interest groups whose objectives may be furthered or hindered by policy changes. Examples in civil life are shareholders, employees, managers, customers, suppliers, hospital patients, taxpayers, etc. Particularly in governmental or other public-sector organizations, organizational objectives cannot be expressed in financial terms. It is necessary to define what is meant by effectiveness, in order to measure cost-effectiveness (which can be regarded as the quotient of non-financial effectiveness and financial cost). Effectiveness can be measured best in relation to the objectives of the different stakeholders, and this can be done at every system level.

Even in commercial organizations, ostensibly guided by the profit motive, the interests of employees and other stakeholders are considered as well as those of shareholders in formulating policy.

The military decision process is more formalized, through training, but the same components are present in different proportions; negotiation looms smaller and competitors' (enemy) actions much larger. The stakeholders play rather a different role - we can no longer measure effectiveness usefully at subsystem levels in terms of the interests of the more remote stakeholders such as the taxpayers who pay for the defence forces; their interests must be represented by political interaction at the supersystem level only. It is still reasonable to include the safety of the service personnel as one of the direct effectiveness measure at subsystem levels, of course. This is further discussed below.

Obviously the judgment and authorization tasks are exclusively for the human decision makers; the others could in principle be computer-aided, but the incomplete DSS so far available, are confined to the knowledge inventory, diagnosis and evaluation tasks. The reason is that existing DSS are almost all fundamentally tools for providing different modes of access to existing organizational databases, and/or financial modelling tools; they therefore only address problems already identified. A few DSS are now beginning to be offered which go a little beyond these functions, but none yet approach what I would regard as completeness. Also, most DSS confine the user's attention almost entirely to factual and numerical data.

HARD AND SOFT DATA

The higher the manager or commander, the more he or she tends to work with "soft" information, that is, with comment, explanation, rumour, opinion, prediction and gossip, as opposed to "hard" historical facts or numerical data. As remarked above, most of the so-called decision support systems now on the market are basically oriented to factual retrieval and financial modelling; these functions are certainly important but only provide part of the information required for high-level decision making. One or two of the DSS's now on offer do provide for retrieval of textual information - usually from external information sources such as abstracting services. None in the civil field, to my knowledge, has yet successfully combined these three functions (factual retrieval from organizational databases, financial modelling and retrieval of textual information from outside sources), or tapped the "organizational soft data" consisting of colleagues' opinions and judgments, and of subordinates' comments about the hard data in their reports. But of course in the military context things are very different - the crucial part played by intelligence information and subordinates' opinions has always been recognized, hence soft data is an integral part of most command and control systems.

SPECIFIC DSS AND DSS GENERATORS

A decision support system for a manager or commander in a particular organization should permit access to data and models appropriate for that organization or theatre of war. It should also be tailored to the individual's function (so that data about the organization is expressed in appropriate terms and at an appropriate aggregation level), and to his or her individual preference about presentation. Such a DSS is known as a specific DSS - it needs to be developed with the particular organization or theatre and the individual user very much in mind.

It should be possible for the user, or a member of his or her staff, to develop a role-specific DSS if provided with a set of software tools known as a DSS generator, already prepared specifically for the organization. This would need to include database tools, model-building tools, tools for handling "soft" information, presentation-tailoring tools and a store of re-usable models, program modules and special application packages appropriate to the organization. The tailoring of the DSS generator itself for the organization would be an operation involving both professional effort and the availability of a comprehensive software design system. No complete DSS generators exist as yet. Several packages sold as DSS contain quite sophisticated hierarchical consolidation facilities (permitting database information to be expressed in terms appropriate to a particular organizational role) as well as financial modelling and presentation tools; such packages also come some way to meeting the requirements for DSS generators.

DSS, MIS AND EXPERT SYSTEMS

I would define the proper field of (management) decision support systems as being the intersection of the neighbouring fields of organization modelling, management information systems and expert systems:

By organizational modelling, I mean both mathematical modelling of financial, logistic or scheduling problems facing the organization, and the building of simplified models of the organization itself and its environment. Such models are used in routine operational decision making, and also for simulating possible effects of policies being evaluated.

Management information systems (MIS) are the data processing systems for the day-to-day administration of the organization, sometimes used actually to "take" routine decisions which have been programmed in advance, but more often just providing information to aid routine decision-making by managers at all levels. MIS include financial accounting systems, customer order processing and invoicing, inventory management, production scheduling, sales forecasts, personnel records, etc. etc., sometimes integrated into a single package but much more often loosely coupled or wholly incompatible. The processing is done entirely algorithmically, that is, in set sequences which can be determined in advance.

Expert or "knowledge-based" systems (KBS), on the other hand, encapsulate subjective and unformalized knowledge, often expressed as "if-then" heuristics (rules of thumb learned by experience) rather than as deterministic algorithms. They do not replace experts, but can make them more effective by providing advice based not only on their own experience but on that of others inside or even outside the organization. An important requirement, not very well met in most existing examples, is that the expert system should explain the reasoning behind its advice, so that the user can evaluate it with confidence.

So far, the knowledge based approach used in the expert system area has not had much influence on DSS actually available. But it is clear that there is scope for the KBS approach in several of the phases of the decision process, for example in the intelligent retrieval of soft information, in identifying previous solutions that might be useful, in developing new solutions and in evaluation of alternatives. It is certainly not true yet that all DSS are KBS, but that is the direction of future development - one could describe the process of deriving a rule base of heuristics for an expert system as being analogous to the collection and classification of existing solutions to organizational problems, necessary for the solution-generation task in the DSS, for example.

In the defence field, we need to distinguish two distinct components which form the military equivalent of the MIS: the operational command, control, communications and intelligence system (C^3I) and the administrative data processing systems dealing with the supply and reinforcement of the fighting services. The military DSS may be regarded as occupying the area of intersection of C^3I, logistic modelling, administrative data processing and knowledge based systems (the last named normally being provided by human brains at present).

MUTUALLY MALEVOLENT SYSTEMS

Usually, analyses of the system-structure of an organisation and its situation in society and nature allow for a multiplicity of other systems with their own purposes, and for an environment which is, on the whole, neutral. But in defence analysis we must recognize the existence of mutually malevolent systems (which will be called here "mumal systems"); these are dedicated to each others' frustration and destruction.

Of course from the perspective of the historian, the diplomat or even the politician, today's mumal system may be tomorrow's ally. But for the purpose of this paper we shall suppose that there is a clearly defined enemy, who will be known - following war game convention - as "Red" while the friendly systems are "Blue".

At each level, the commander sees his own system - that part of the organization which is his responsibility - set within a supersystem commanded by his superior, and containing subsystems commanded by his subordinates. The supersystem itself is probably contained within a succession of larger systems enclosing each other in turn, but it is our contention that the commander whose point of view we are taking - let us call him "Commander C" - will not be conscious (and should not be conscious) of the detail of this superstructure.

He will, of course, need to be fully aware of the structure of subsystems and sub-subsystems within his own system (System C), but when thinking at Level C he should not allow himself to be distracted by details which are the concern of his subordinates, or of their subordinates. Sometimes he will need to play the role of a lower commander, in the sense of thinking at that lower level, but this should be a conscious change - it is the contention of this paper that any computer system provided to aid Commander C's decision-making should also be able to see things from different levels explicitly.

Similarly, Commander C will be aware of "the enemy" as a mumal supersystem, and vitally concerned with his directly opposing commander C* and his system, dedicated to the destruction of System C. Neither C nor C* will have full and accurate information about each other's systems; this is further discussed below.

Diagram 1 shows mumal supersystems A and A* confronting each other, from the point of view of C. Therefore we can see Blue subsystems inside System B and C, but not the structure inside their mumal systems B* and C*. Also, we can see sub-subsystems inside C, but we do not see the detail of sub-subsystems inside B, as this is not directly relevant to Commander C. (If it became relevant, his superior A could arrange for C to get the detailed information about subsystems D, E and F).

COMMAND LEVELS AND SYSTEM ROOTS

Conceptualization of an organization in system terms is not supposed to correspond with the theoretical "wall-chart" hierarchy but with the realities of power and authority as seen by people at different positions. There will, perhaps, be as many versions of the conceptual system as there are commanders, when we consider a military force. No doubt each individual commander will think of all the lower-level commanders in his area of responsibility as being part of 'his' system - but they may hardly be conscious of his existence, if for example they are on a mission which requires them to take orders from a higher level of command, and to report there directly.

This corresponds to Jaques' [1] identification of the next level of abstraction in bureaucracy with the notion of who is seen as "the real boss" from the lower level. The present author has previously suggested [2] that the same notion can be used to define the structure of management subsystems.

In Checkland's [3] formulation of "soft system methodology", great importance is attached to the "root definition" which pertains not only to every system and subsystem, but also is separately expressed for different points of view (e.g. by different stakeholders) for the same system. He introduces the mnemonic CATWOE to remind us that we must include all the following in every root definition:

Clients served by the system:

The "Blue" civil population, in a military system

Actors carrying out the system's functions:

The personnel of the defence forces

Transformation from inputs into outputs - the system's purpose:

Blue personnel and equipment into maximum Red damage, delay and defeat with minimum casualties and damage to Blue

Weldanschaung - the point of view considered:

High command, parallel command, subordinates, innocent bystanders

Owners who can decree the system's extinction:

Blue taxpayers through Blue politicians

Environment within which the system operates:

Diplomatic, societal, cultural, economic, climatic....

The clients, the actors, the owners and the innocent bystanders are all stakeholders, of course. For analysis of defence systems, we suggest that the mnemonic could become COWMEAT, with the addition of:

Malevolent systems - the enemy and all Red stakeholders.

SUPERSYSTEM "LINGUA" AND SUBSYSTEM DIALECTS

Every occupation and concern of human beings develops its own special language (or jargon or dialect or argot) with detailed nomenclature for concepts of particular interest and, at a deeper level, implicit recognition of a shared perception of what is important to the people using the language.

It is suggested that this familar subdivision of natural language by occupation or by location should be carried over as part of the formal conceptualization of the organizational system, with a recognition that every root definition (that is, each stakeholder view of each system or subsystem) is in a sense a dialect-generator. It is important to realise that the word language is being used in a special way, corresponding neither to mother tongue nor to machine language. It is, however, possible to think of system languages as forms of natural language, because they are natural in the context of the human activity system.

Within the concept of system language we need to recognize the need for commanders to communicate with their superiors and their subordinates. At the level of Commander C there is a certain root-definition giving his view of the system, with overlapping but not identical definitions of the purposes and activities of the same system by other "actors", generating the conceptual language of that system. Usually the aims of System C as seen by all the actors in it will nearly but not quite coincide with the aims of its immediate supersystem (System A); a slightly different set of aims may be appropriate for System B, at the same level as C but forming a separate subsystem of A [see diagram 1].

The commander of the supersystem A must be able to talk to Commanders B and C in a common language or "lingua franca" - this will be called the "supersystem lingua" and it is used to express concepts at the A level. For example, measures of performance of systems B and C are concepts at the supersystem level and will be expressed in the supersystem lingua. But when talking to his own subordinates G and H, Commander C will need to translate this into Language C, and when they talk to their subordinates commanding sub-subsystems (IJKL) they will use the appropriate dialects generated by the root definitions at the lower level.

To put the same point another way, the briefing from Commander A to his subordinates B and C will set the overall objectives and provide relevant intelligence information about the mumal supersystem's dispositions and intentions, all expressed in system-wide terminology and with the supersystem root-definitions: that is, the briefing will be carried out in the supersystem lingua - the common language of A, B and C. But if A wishes to discuss detailed tactics with B, he will change slightly to the B subsystem dialect, not quite the same as that for C because referring to a different function or a different geographical area, with different problems and different tactical objectives.

The existence of the mumal system structure brings another difference between lingua and dialects: they will express intelligence about Red intentions and dispositions differently: what is an imminent threat to subsystem B may only be of marginal concern to C, threatened from some different direction and/or by some other Red subsystem. The differing prioritizations are manifestations of the differing dialects.

CONSEQUENCES FOR DECISION SUPPORT SYSTEMS

Suppose for the moment that there exists an omniscient controller - as in a war game - with accurate information about both sides' dispositions and intentions. His C^3I system would have everything right and in detail, but none of the players would have access to this accurate information; their versions would be incomplete and distorted.

The low-level commanders on both sides would have relatively accurate and detailed information about their own command, and reasonably good knowledge of friendly forces on their immediate flanks and perhaps of enemy forces immediately opposite. But they would have only very general notions of the overall battle picture, possibly quite wrong and probably out of date.

On the other hand the high-level commanders would need to see the up-to-date big picture and would only be distracted by full detail of front-line positions and events - though on occasion they would need to take the point of view of one specific front-line commander in a particularly sensitive situation. In doing so, the supersystem commander would change to thinking in subsystem dialect. It would be best if his decision support system could do the same, when instructed. That is, the DSS should be able to look at the database from different points of view, and present information at different levels of aggregation with different time-horizons and with different nomenclature - that is, in different system languages - for the different commanders. It would be quite reasonable to provide facilities for the supersystem commander to obtain information in the subsystem dialects, but not for the subsystem commander to have access either to the full supersystem picture or to those appropriate to remote subsystems. As implied above, he might be specifically authorised to have access to the information on flanking subsystems or others of immediate relevance to his own job.

The mumal dimension is interesting, because a Blue commander would want not only alternative possible interpretations of incomplete information on Red dispositions, but also some idea of how the Red commander might interpret Blue intentions with incomplete knowledge. That is tantamount to asking the DSS to work in two languages about both sides: one "high-threat expectation" language and one "low-threat expectation" language. Perhaps, rather than call these different languages, one should regard them as different modes of the same language - just as, in Japanese, one may speak politely or familiarly or officially by using different grammatical constructions.

Analysing this further, we are essentially postulating a DSS which can play part of the role of a systems controller, by internally varying completeness and accuracy of information in order to give its user the opportunity of temporarily playing the role of an enemy commander with imperfect information, in an attempt to hypothesize about his possible behaviour.

TESTING THE CONSEQUENCES

To test the hypothesis of the previous section - which we can express as a prediction that commanders will perform better, when provided with decision support systems that are adaptable to different viewpoints, than with single-viewpoint systems - it is suggested that war gaming experiments should be performed.

At one of the existing computerised war gaming centres a series of games should be run from a few standard starting scenarios and with a properly designed mix of changing individuals and changing decision support systems. The basic experimental design could be like that used by D.W. Daniel in his experiments at DOAE, West Byfleet [4], except that instead of providing only different levels of data quantity, one would present the data in different ways - or, in the terms of this paper, in different languages.

J.H. 13.9.85

References

1. Elliott Jaques "A general theory of bureaucracy" (Heinemann, 1976)

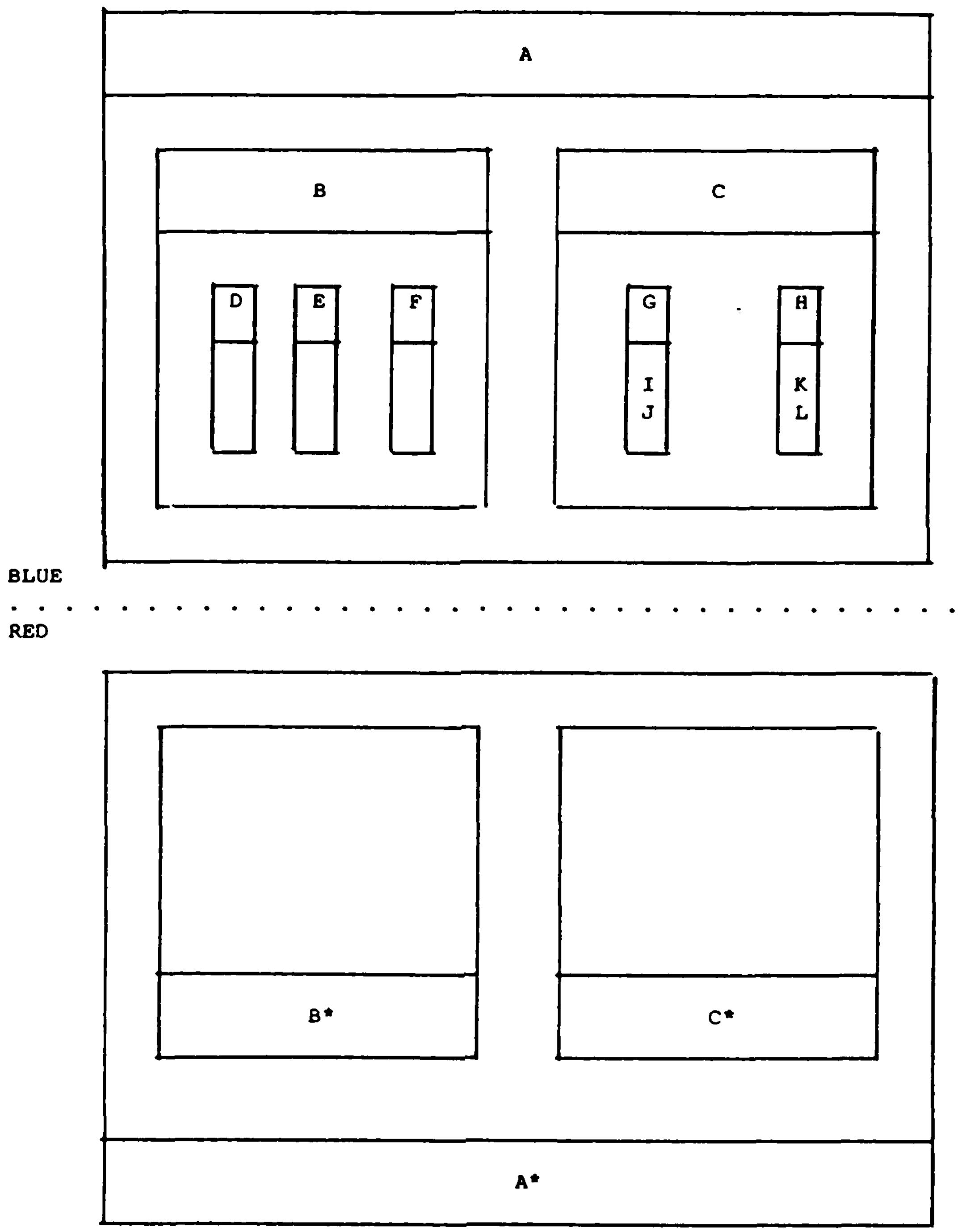
2. John Hawgood "Information morphology in bureaucratic subsystems" in L.B. Methlie (ed.) "Knowledge Represetation for Decision Support" (North-Holland, 1985)

3. P.B. Checkland "Systems thinking, systems practice" (Wiley, 1981)

4. D.W. Daniel "What influences a decision? Some results from a highly controlled defence game" OMEGA Vol. 8 No. 4 pp 409-419 (1979).

DIAGRAM 1

MUMAL SYSTEMS
(seen from point of view C)



END DA JA45-84-M-0278

14861