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Summary Report (October 1962 - June 1966): Information Processing Potentials in Large-Scale Operations

18 July 1966

Prepared for

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH,

OFFICE OF AEROSPACE RESEARCH

AF 19(628)-5166

Information Processing Potentials

TM-1128/100/00

TECHNICAL MEMORANDUM

(TM Series)

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This document was produced by SDC in performance of contract AF 19(628)-5166 AFOSR Information Processing Potentials, for the AF Office of Scientific Research, Office of Aerospace Research.

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ABSTRACT

In the study of large organizations, the information, communication, and governing processes have been extremely difficult to formulate. Towards such a formulation, the strategy of the Leviathan studies has been to pursue two lines of attack--theoretical formalization and computer-based simulation. By these means, Leviathan research has studied the interrelationships between (1) executive policy making and control and (2) system performance of large organizations, within (3) experimentally controlled laboratory environments.

In answer to the challenge of markedly enhanced computer capabilities just now being made available, practical and theoretical advances have been made in formalizing the communication and governing process in large organizations. These advanced formulations and their significance are explained.

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Simulating Social Organizations: Current and Next-Generation Leviathan Methodology

Large social organizations are among the most challenging and baffling objects of scientific study: They are integrated on diverse system levels. They resist reductive analysis--their constituent elements, such as their subsystems and individual human members, when excised from their organizational settings, do not continue to behave as before. The ultimate constituent elements of organizations (the transactions of individual persons who are their members) are mediated by symbols; hence humanistic and dramatistic elements are of the essence of social organizations. The constituent social transactions of organizations are not processes that are simply located on specific system levels.[1] Nor are organizational processes simply located in time--future potentialities and opportunities of organizations help determine what happens to them and what they become.[2] Many of the most significant organizational processes, furthermore, do not occur in regular cycles. Finally, organizations interact symbiotically with their social environments in diverse ways on their diverse levels.

Developments in computing technology over the last decade have opened promising paths for coping with the complexities of large social organizations. These developments include: (1) large computing systems and digitalizing buffering equipment that operate "on line" and in "real time" and that are uninterruptedly available over protracted periods of time; (2) computer routines that successively follow one another in sequences contingently controlled by executive cycling routines, that is, "time-shared" operations;

(3) computer routines that contain nonquantitative formulations ("logical" routines) capable of representing qualitative elements of and in the system environments; (4) computing systems that allow human decision makers to function as integral parts of system operation in military control systems.

Given such computing technology, social scientists can represent or simulate basic social processes common to many large organizations: First, the computer technology (the "software") is purged of applied reference to specific actual organizations. Abstract generality is thereby attained.[3] Next, a complex system of computer activities is formulated, programmed for the computer, and readied for operation in a laboratory; this system of computer activities is the operating vehicle. Then, paradoxically, some concrete myth is imputed to the elements of the abstract vehicle. Thereby, when next the computer is set into operation, its continual cycling of digits, coded qualitatively, is made to sustain a concrete, ongoing organization. Fourthly, live human decision makers are integrated into the entire enterprise, to manage, control and govern the evolving simulated organization.

Towards such a fourfold procedure, we began, some five years ago, to develop a method, called Leviathan, for conducting purely theoretical experiments on the organization and governance of large social systems. Shortly thereafter, the research directorate of the System Development Corporation made available for research a laboratory equipped with computing machinery capable of on-line, time-shared operations. In this facility, we have brought entire bureaucracies into simulated life. The bureaucracies include relatively large numbers of live human decision makers (currently up to 24) who interact with each other and with hundreds of robots over protracted periods of time (typically 120 laboratory-computer hours, in four-hour sessions, over three-month periods).

In what follows, we shall first describe how the Leviathan method has been exploited until now. Then we shall discuss the next generation of Leviathan simulations, which will come into being in 1967 in a new laboratory with greatly enhanced capabilities. Finally, we shall indicate the significance of the new Leviathan formulations for theory formation in the social sciences.[4]

CURRENT LEVIATHAN SIMULATION

THE SIMULATED ORGANIZATION

To study the governance of large organizations, our initial step is to bring into being in the laboratory a simulated bureaucracy that possesses characteristics essential to large organizations. Our taxonomy of the governing process in large organizations includes six basic elements, all of which have already been realized together in our laboratory simulations.

(1) Formal Authority: Varieties of formal organizational configurations, each consisting of a six-level managerial hierarchy, represent the formal authority system of large organizations. For each office in a pyramid of command, the configurations stipulate (a) its command level, (b) areas of responsibility and of formal authority for operations, (c) personnel resources (live and robot), and (d) functional specialization.[5]

(2) Technological System: A network of waiting queues and service stations, manned by the artificial agents, represents the logistic production system of large organizations. Units of work enter the system, are processed in cascades of

successive queues and stations, and are thence distributed to various consumer agencies. The "energy" of the robots is the resource by which the processing work gets accomplished.[6]

(3) Information Feedback: A hierarchically structured system of information reports simulates the data-handling and information-processing system of large organizations.[7] In any one experiment, about 12 different types of feedback information, selected from a total repertory of 20 basic types, are provided to the subjects by the computer. Every half hour, the computer generates more than 200 different individual reports, representing system and subsystem performance during one simulated day. Appropriate reports flow to the individual officers according to channels of formal authority.

(4) Linguistic Medium: A computer-based, dynamically evolving, pre-structured intercommunication language simulates the interpersonal communication system of real-life organizations.[8] Subjects use it to communicate with each other and to stipulate decisions and decision rules to the robots, which the robots interpret and implement. The computer records who talks to whom, when, and what is said.

(5) Organizational Charter or Corporate Image: Corresponding to the policy-formation and implementation system of large organizations is a complex communication process. Charter or image formation develops and evolves from a continuing interaction between the subjects operating in their organization and the experimenters in the guise of the higher-level embedding system. It depends on such computer-based operant devices as a teaching machine for indoctrinating subjects, quantified crisis scenarios, value-laden cues

incorporated in the intercommunication language, information feedback that automatically evaluates organizational performance, etc.

(6) Extra-Formal, Person-to-Person Interaction: As a simulation proceeds, the extra-formal, person-to-person interactions throughout the management pyramid come to life. How this culture evolves depends on how the experimenters manipulate the other five basic elements and how the group reacts to and assimilates them.

CONTROL OVER THE SIMULATED ENVIRONMENT

While the first step in studying the governance of large organizations is, as we have said, to bring a simulated bureaucracy into being in the laboratory, still, the achievement of this goal is not a single, one-time act. A large social organization is no unchanging, finished structure that can be held fixed while it is dissected by observation and analysis. Underlying the foregoing sixfold basic taxonomy is the notion that organizations are open-ended, developing, active, changing and enduring: work flows through their technological systems; information flows through their hierarchies; communications flow and change; the corporate image evolves; and extra-formal interactions continually take place.

Nor is all this seething change only internal. Like biological organisms, large social organizations continually interact with their environments--with their sources of raw materials and of productive energy, with their consumers, and with the large society in which each organization collectively acts. As an organization grows and develops, its impetus stems partly from within itself and arises partly in response to the buffeting of its environment;

the organization evolves partly at its own pace and rhythm and partly in response to push and pull of the outside.

As in the real world, so in the laboratory: What happens in the ongoing life of a simulated bureaucracy issues partly from its immanent self-determination and partly from the structure of its environment. But in the laboratory the environmental influences that help shape the growth of an organization can be rather rigorously controlled and structured. The experimenters can, to a great extent, direct and cultivate the evolution of a simulated bureaucracy.

Among the elements of the bureaucratic environment over which we have obtained control in our experiments are the following:

(1) In the authority net, we control (a) the formal authority and functional organization that structure the subjects' command hierarchy, (b) the authority the subjects are able to exercise over the robots, and (c) the size of the hierarchy.

(2) In the technological system, we control (a) the composition and load of input flow, (b) the pattern, sequence, and timing of work flow through the processing system, (c) available robot energy, (d) unit processing costs in terms of robot energy, and (e) valuations, made in the names of the consumer agencies, on different categories of finished work at different times.

(3) With respect to information feedback, we control the entire flow and distribution of feedback information described in the preceding section.

(4) With respect to the linguistic medium, we control the channels, means, and, in the computer-based intercommunication language, the very idiom of expression that can be used by the subjects.

(5) With respect to organizational charter, some of the more important controls have been mentioned in the section on organizational charter. In addition, a concrete myth is inculcated in the subjects. Thus, in our 1963 and 1964 experiments, the subjects were told that they were operating an Intelligence Communications Control Center in the National Intelligence Agency. The units of work in the technological system were interpreted to be communiques arriving from sources all over the world, which had to be processed through the center, and the consumers were agencies of the federal government.

Needless to say, not all these controls are manipulated simultaneously. Some settings are held constant throughout an entire experiment. Other settings are varied from phase to phase within an experiment. Still others (only one at a time, or very few at most) are continually altered during the progress of an experiment.

ASSESSMENT OF SUBJECTS' RESPONSES

To these controlled environments, subjects respond in two ways: first, by discussing, coordinating, organizing, and planning their actions, and second by making their technological system perform.

Both types of subjects' responses are constantly monitored by the experimenters. (1) With respect to subjects' interactions or transactions, some are directly observed from behind one-way glass and are recorded on sound tape, some are incorporated in handwritten messages, and others take place over the computer and are observed and recorded through it. Subjects' individual actions have been analyzed quantitatively in terms of their relationship to the collective actions of the group. We have counted how frequently individuals have contributed verbally, kinds of contribution, frequency with which an individual has questioned or opposed lines of action being followed by the group, and the extent to which they have only responded or to which they have initiated. In contrast to the individual actions of the subjects, their collective actions have been assessed qualitatively, in terms of the presence and absence of patterns of action and the change of these patterns. (2) With respect to technological performance, this all takes place exclusively over the computer. It is measured precisely and quantitatively, both at component and system levels, in terms of temporal flow of work, filtering of more important from less important work,[9] distribution of flow over the processing network, productivity, utilization of resources of robot energy, and the like.

CONDUCT OF EXPERIMENTS

The subjects make manifest their collective social development by the foregoing kinds of mutual interchanges and by their performance accomplishments. As this development unfolds, the experimenters repeatedly intervene by altering settings of selected environmental controls. A loop is thus established between the developing bureaucracy managed by the live subjects and the observing and intervening experimenters. Essential to the operation of this loop is the familiar notion that a bureaucracy's development stems partly from within. While experimenters can, by controlling environment, constrain, influence, incline, cultivate, and partly shape growth, they cannot wholly make organizational growth. Hence we do not follow fixed, preset schedules; instead, we time our interventions in tune with the emergence of specified patterns of interaction or specified levels of technological accomplishment. In this sense, most Leviathan experiments are open-ended. Freedom of the subjects to develop as a group is provided; as new forms of social structure and coordination emerge in the group, we, the experimenters, readjust the subjects' environment.

The basic strategy of an experiment has two facets. In some experimentation, we seek to elicit ever higher technological performance, without constraining the internal acts of coordination within the subjects' organization. Precisely those internal activities by which the subjects operate their organization, then, are what we usually wish to observe under controlled conditions. In other experimentation, we operate on the subjects' coordination, on their channels and supply of information, on their forms of access to one another, even on their formal organization, meanwhile measuring technological performance. The key experimental questions are these: Are there distinct modes of coordination characteristic of different levels of accomplishment, given specific internal and external environmental conditions? Can interrelationships be established between modes of executive transaction and bureaucratic accomplishment? What are these, and how do they operate?

INITIAL RESEARCH FINDINGS

Two series of five experiments each have been conducted, one series in 1963 and the second in 1964. The subjects in the 1963 experiments constituted a fixed group, while in the 1964 experiments about half the subjects were replaced after the second experiment. Approximately 24 subjects participated at a time. On the basis of these experiments, several findings are tentatively advanced:[10]

(1) In crisis environments, a close-tracking large organization having adequate resources can manage successfully if it is furnished with a suitable combination of component failure and system performance reports. When preoccupied with bare survival and with preventing a minimal and stationary level of performance from deteriorating, management can exploit this feedback combination to detect component breakdowns and to take immediate remedial action. This kind of organization--managing by exception--can indeed actually be impeded if it is furnished with detailed quantitative component feedback. The information feedback system can, furthermore, be formulated for and successfully imposed on an organization of this kind by its supervening authority.

(2) In crisis environments, a large organization that has successfully surmounted a succession of failures and that is exerting its efforts toward contingency planning seems to be seriously hampered when its information feedback system provides component failure and system reports but excludes detailed quantitative component performance reports. When a large group is striving to attain a clear corporate identity or charter and to plan positively and creatively, it needs far more information (at least another order of magnitude) about its own internal hierarchical processes and about its performance accomplishments.

(3) In crisis environments, a large organization that habitually practices long-range policy and contingency planning and that is constantly raising its standards of performance seems to require all the information needed by the two previous organizations. So highly authentic or so well-functioning an

organization seems, however, to use failure reports as triggers to invoke pre-established plans.

(4) For all three of the foregoing kinds of organizations, an identical corpus of hierarchically structured feedback information can be used simultaneously to solve both component and overall systemic problems. This appears to be true, moreover, regardless of which basic type of formal organization is exhibited by the entire organization. Such information feedback, of course, is best exploited by the well-functioning organization in which executives on different levels of command, with different theaters of operation and different specialties (a) understand their own respective systemic roles and those of their colleagues--understand what their colleagues want and need to know--and (b) provide their fellow officers with access to relevantly filtered and interpreted data--thereby subordinating subsystem objectives to system accomplishments.

(5) Altogether, four types of formal organizational structures, represented by four different organization charts, were realized by the 1963 and 1964 subjects. Organizational achievement seems relatively insensitive to the formal structure imposed on the subjects.

(6) Organizational achievement does, however, seem to be strongly affected by a shift in organization from one basic type to another.

(7) In any of the four organizational configurations, the more clearly articulated was the corporate identity or image--the more it was readily accessible, adopted, and authentically interpreted throughout the management pyramid--the more effective seemed to be organizational performance.

The foregoing findings are the first fruits of a prolonged, systematic effort that included: (1) design of the parameterized computer program system; (2) development of techniques for staging the man-machine simulation in the laboratory; (3) marshalling, integrating, and managing man-machine resources, including engineers and operators of the computer-equipment complex, laboratory support personnel, and subjects; (4) evolution of the Leviathan method, with its experimental controls and quantitative measurements of organizational performance; and finally, (5) conducting the coherent series of controlled experiments that actually yielded the experimental results. Hence, more significant than the seven initial findings is the fact that results of this kind have been obtained. Our initial investigations demonstrate, by the fact that they have been performed, that the organization and government of large social hierarchies can indeed be experimentally investigated.

NEXT-GENERATION LEVIATHAN SIMULATION

Despite achievements to date, we have thus far had to omit many elements important for conducting experiments on large organizations. These omissions have stemmed from the limited capacity of the particular Philco computer that we have been using,[11] namely, the limited amount of drum storage on which to store our entire program system for rapid, real-time access during laboratory operations, the limited number of tape drives, and the peripherally unbuffered way in which the display equipment operates.

Corporate management at the System Development Corporation has, happily, decided to pool its computer resources in a central computational facility.

An extremely large computer system, the IBM 360-65, is being installed, together with a family of peripheral, high-capacity disc storage, fast-printing, and peripherally buffered display equipment. This system, in turn, is being heavily supported by software systems embodying advanced higher-level programming languages, data management program systems, and executive and time-sharing techniques. This entire facility--the hardware and the software--will be made available on a time-shared basis for on-line, real-time experimental research.

To exploit this advanced facility, we have been formulating a new generation of Leviathan simulations, and programming is under way. The new program system will become operational in 1967. This system has been designed to realize seven objectives, all of which are made possible by the new disc file and the buffered display equipment. The seven objectives follow.

RADICAL AUTOMATION OF DATA ACCUMULATION AND REDUCTION

Our first objective is to increase radically the scope of automation that we have already achieved. High levels of automation have already been attained in the areas of simulated technological operations, of reduction of data on these operations in real time as experiments progress, of intercommunication via displays, and of information feedback reports. Until now, however, we have had to rely heavily on traditional methods of experimental observation, data collection, and data reduction, such as the use of sound recording tape, observation via one-way glass, and manual item analysis and coding of collected data. Now our objective is to abandon or, at the very least, to minimize drastically our use of these traditional techniques of observation. Why?

Intercommunication in our simulations resembles that of large organizations in real life: In both, the process generates voluminous information. To be sure, we do not aim at realistically imitating in the laboratory the massive detail of real life; nevertheless, the indispensable minimum of information that we allow to be generated is still very large. We have found that the sheer logistics of managing this indispensably minimal flow is very costly in human resources.

This burden will now be alleviated. Nearly all human interactions will be automated. The computer will carry almost the entire recording, coding, and analyzing load in a continuous flow, without manual assistance; and--literally--man-years of data handling, reduction, and coding effort will be abridged.

In addition to these logistic gains, radical automation of data handling will have an even greater payoff--it will greatly facilitate control of our experiments. Leviathan experiments, we saw, are open-ended, embracing subjects and experimenters in an interacting loop. Subjects and experimenters constantly inter-influence one another, the subjects by their interactions and their performance and the experimenters by responsively controlling the subjects' simulated social environment.[12] This methodological approach requires that rapid, ever-current feedback information be available to the experimenters concerning the subjects' patterns of interaction and concerning their systemic achievements. Many items of information have to be continually updated as a session unfolds; others have to be supplied within a few hours, at most, after its termination.

In our 1964 experiments, feedback to the experimenters was only partially satisfactory. (a) Discrete feedback on subjects' performance accomplishments, both at system and at component levels, was indeed provided to the experimenters on an ever-current basis, period by period. But (b) perspective over time was obtained only by having a team of students scan, analyze, and manually post the information as it was generated by the computer. Computer-generated trended information was not available on a current basis; it could be had only after the close of each laboratory session, when the computer produced it off line.

As for feedback on the social transactions of the subjects with each other and with the robots, (c) only a fraction of this feedback was accessible in computer-coded form. (d) Verbal interactions, furthermore, were monitored through traditional one-way mirrors, later transcribed manually, and still later encoded and analyzed. (e) Also, systematic review and codification of the subjects' handwritten messages (there were more than 10,000 in 1964) were not available during laboratory operations.

With the new program system, the computer will provide the experimenters with constantly updated trended information, graphically plotted representations, and evaluations of performance achievements. But more important, because the computer will now monitor almost all subjects' transactions, it will provide ongoing current records of them as the experiments progress. These kinds of automated, computer-generated feedback will, taken together, facilitate the open-ended conduct of Leviathan experiments.

RADICAL AUTOMATION OF MAN-MACHINE INTERCOMMUNICATION

Our second objective is to perfect our man-machine intercommunication techniques. As early as 1962, we developed and applied the principles and techniques for achieving structured, codable, natural-English dialogue directly with the computer, on a real-time, time-shared basis. This was accomplished by means of the Leviathan General Operator-Computer Interaction (GOCI) programs.[13] Extensive use of the GOCI system, however, could not be made, because of two drastic limitations imposed by the Philco computer. First, during our simulations, GOCI had to be interrupted every 15 minutes, in order to operate the rest of the Leviathan program system.[14] During the periods while the display scopes were blank, we permitted the subjects to substitute handwritten, free-form messages for GOCI messages. Second, even while GOCI was operating, the Philco computer limited the expressive range of our pre-structured command language. Despite its inventory of three million well-formed expressions, the total vocabulary of the language was confined to less than 400 words taken from natural English. Hand-written messages, consequently, could not be entirely eliminated even while GOCI was operating.

The core, drum, and disc capabilities, and the speed of the new IBM 360-65 computer system, will henceforth allow all component programs of the Leviathan operating system to be interleaved with one another and mutually time-shared. With the resulting parallel processing, it will no longer be necessary to inactivate the GOCI interaction language during any phase of the laboratory sessions. Hence GOCI will be fully available to carry the burden of subjects' intercommunication. In addition, the new computer capabilities will eliminate the second constraint: Now the vocabulary, and hence the expressive range, of the computer-based, command language can be greatly amplified.

TRANSACTION ANALYSIS: BASAL CODING AND CLASSIFYING

GOCI is structured as a tree; every route through the tree, starting at the trunk and terminating in a leaf, is pre-established as a well-formed English sentence. The alternate routes constitute the individual alternatives available to the subjects for expressing decisions. The propositions that the subjects select from this tree-formed possibility space and the occasions of each selection constitute the history of the subjects' decision responses to their experimentally controlled environment.

Each individual route through the tree means something different from all the other routes. Some routes are specific to the formal functional subsystems of authority in the hierarchy of command; along these routes are formed sentences by which the subjects transfer robots from one squad to another, establish priorities, direct the robots to route traffic over the processing stations in the technological system, and the like. Other routes are used to request specific forms of subjects' information feedback on the performance of their technological system; others to establish contingency plans; and still others to organize and reorganize the live-robot structures of authority and functional specialization.[15] All these possible routes through the trees can be classified by the experimenters. Such classifications would constitute ways of coding, differentiating, and counting subjects' responses.

All the foregoing classes of activities will be automatically interpreted by the computer in the new formulation and tallied according to individual officer-subjects in the chain of command. They will also be aggregated for groups of officers managing specific functional subsystems of formal authority, for levels of command, and for the entire system.

Still other types of classification will be made. The greatly augmented capacity of the new display equipment will enable the subjects to choose from among incoming messages according to sender, degree of urgency, and content-classification of message. As the subjects make these choices, the computer will record recipients of messages, senders, times of receipt, delays in transmission, orders of choice; these will be associated with the specific routes through the tree selected by the subjects in the respective messages. If, in addition, a given message occasions a reply, that message's association with the reply will also be recorded.

Finally, the foregoing coding, counting, and correlating of subjects' decisions will be correlated with environmental changes imposed by the experimenters, and with different levels and kinds of performance accomplishments being achieved by the subjects.

These forms of coding, categorizing, counting, and correlating, being incorporated in the new Leviathan formulation, will make realizable an aim long envisioned but not previously attainable by researchers into large social organizations. Hitherto, because of the difficulty in collecting data during an experiment and coding it, the study of decision interactions among the members of a group has been restricted to the domain of small, face-to-face groups; and even in this domain, there have been almost insuperable obstacles to the obtaining of objective and rigorous coding. With GOCI and with the increased capacity of the new computing machinery, however, strict and rigorous 'transaction' analysis will become practicable in the study of large organizations.

CONTROL OVER FORMAL ORGANIZATION GIVEN SUBJECTS

Our fourth objective is to provide our subjects with autonomous and ongoing control over their own formal organizational structure. Hitherto this was not possible because of computer constraints. Only the experimenters were able to impose new formal organizational structures on the simulated organizations that the subjects managed. Basic formal organization therefore had to be exclusively an independent variable. Nor was there any way to preserve ongoing corporate continuity through organizational change. Each time a new organizational configuration was imposed by the experimenters, the subjects had to start up a new organization from its very beginning.

Now, in contrast, (a) the subjects will be free to alter formal organization at their discretion and at times of their own choosing. (b) They will be able to do this piecemeal or in toto. They will be able to change functional authority, territorial domain, and hierarchical assignments on the live command levels. And, in the robot technological system, they will be able to change basic configurations and processing activities. Every type of command that a live subject can give to a robot will be controlled by the subjects themselves: who may issue what kinds of commands, in what territory, and at what period of play. (c) Finally, the subjects will be able to maintain the organic continuity of their simulated organization through whatever formal reconfigurations they elect to adopt.

Not only will the subjects be able to reorganize, but also the very scope of their organizational control will be extended. Hitherto, again because of computer constraints, the responsibilities of live officers on the lowest level of command were highly restricted in three of their four functional specialties. In the new formulation, the lowest-level live officers (the subjects) assigned to these three functional specialties will be able to intervene with the robots in many more significant ways than were previously possible. This will enable the subjects to distribute their decision-making responsibilities to a far greater extent across the several levels of command. In turn, greater autonomy will be possible in every office throughout the hierarchy.

Introducing these two features into our simulations--unrestricted reorganizational autonomy and enriched subject responsibilities--opens a new and important area for experimental investigation: the area of delegation and distribution of authority and power in large organizations. The ability of our subjects to reorganize on their own initiative and on an ongoing basis enables us to convert organizational change into a dependent variable. Reorganization can now become a response of the subjects to the environment imposed upon them by the experimenters. That this capability is of basic importance to the future of large-group experimentation becomes manifest when we reflect that a fundamental response of large organizations to challenge and stress consists precisely in reorganizing their formal structures of authority and power.

TRANSACTION ANALYSIS: ENCODING OF CHARTER AND NORM DEVELOPMENT

Whenever reorganization occurs, to any degree or extent, in the life of an organization, a kind of strategy- and policy-making activity takes place.

Executives reflect, implicitly or explicitly, on their organization's charter, image, goals; they endeavor to translate these into operating assignments, procedures, and norms within the organization. We have, as indicated above, considerable preliminary evidence that this translation process can be a most important element in improving organizational performance.

Our new computing facilities enable us to make such charter and norm development fully overt and operational, without infringing on our subjects' decision-making freedom. This we accomplish as follows: Henceforth, when subjects assign and reassign specific responsibilities to one another as an experiment proceeds, these assignments will no longer be a matter of simple verbal expression, merely something that is said in spoken or written words and enforced by tacit consent of the live managers. In the new formulation, the subjects must communicate to the computer all assignments of authority and responsibility among themselves. The computer then monitors and enforces all <u>uses</u> of authority: The subjects can compel the computer to report to specific individuals any transgressions of authority, that is, actions taken by individuals who have not been authorized. Even more, subjects can compel the computer to give or to take away the power of any individual to take specific actions over his computer interface equipment. Furthermore, the very conditions for giving or taking away power, or for reporting transgressions, can, themselves, be specified to the computer by the subjects and established in it--for example, the subjects may establish that only when two-thirds or more of the members of the executive committee concur can the computer be used to expel any of its members from it.

By use of the foregoing techniques, the entire realm of the socially permissible and the socially impermissible, of standing modes of carrying on the official activities of a large organization, of bureaucratic negotiation and cooperation and conflict, can be freely evolved and structured by the subjects themselves, specified overtly to the computer, encoded and thereby "institutionalized" by the computer, and laid open to experimental observation and measurement. Needless to say, freedom to exercise any of the above computer-implemented controls can be given by the experimenters to the subjects, or systematically withheld, according to the design of a particular experiment.

COMPUTER-BASED CONTINGENCY PLANNING

In the new formulation, it will be possible for subjects to declare individual interventions and entire sets of preplanned interventions to the computer in a conditional or standby mode, to be implemented at a later period. In this way the subjects will be able to build up, in the computer, families of contingency plans, any one of which they can then implement either en bloc or piecemeal, in response to agreed-upon situations. This kind of planning will, in the new programs, encompass not only technological operations of the robots, but also higher-level policy decisions and even entire schemes of reorganization. In particular, in some experimental designs, the subjects will have the opportunity to form coalitions that will prepare, in various degrees of secrecy, contingency plans for the enhancement of their power.

Coherence and internal consistency will not be imposed by the computer on the planning processes. As in real life, the relevance, efficacy, consistency and coherence of plans will be achieved only through the efforts of the live officers. The creative use of systematically ambiguous planning will not be inhibited by the program system.

The importance of contingency planning in large organizations makes obvious the significance of the foregoing capabilities in the new program system. Not only will the subjects be compelled to formulate their plans explicitly over the computer, thereby making manifest to the experimenters their basic attitudes towards their organization and its objectives, but also the process of developing these plans will be monitored and observed by the experimenters through the computer. Indeed, with greater automation of data handling, we also foresee the possibility of using the computer to enhance the experimenters' contingency planning. For example, by using the computer to predict the outcomes of subjects' policy decisions, experimenters can gain time to plan for contingencies under which appropriate experimenters' interventions can be taken to shape subjects' future activity.

ENLARGED SCOPE OF REAL-TIME FEEDBACK INFORMATION

The new capabilities of the subjects to reorganize dynamically and piecemeal, to evolve procedures and norms, and to establish contingency plans will all require us to develop further our already highly flexible capability to furnish subjects with feedback-knowledge of results.[16] Improvements will stem both from better means for delivering information to the subjects and from increased capacity of the computing machinery:

(a) Electronic Transmission. It will become possible to deliver a large proportion of feedback information by electronic means directly over individual display scopes, and, shortly thereafter, for reference purposes, in hard-copy form over individual printing machines located in the individual booths. Once such feedback is available to a subject, he can elect to ignore it altogether or to receive it at his convenience. The order in which he receives individual items will be according to his choice. The timing and selection of choices will of course be recorded as part of the observational data collected for the experimenters. Not only will the timing of the receipt of feedback be far more accurate than heretofore, but it will also become far easier for the experimenters to be assured that received feedback information actually is scanned by the subjects and to know for what feedback the subjects are willing to pay in terms of their resources of robot energy.

(b) New Forms of Feedback. The computer will be able to maintain far more complete records of events as they occur within the robot-operated technological system that the subjects manage. As a result, important new forms of feedback information on technological operations will be made available to the subjects on an ongoing basis. Furthermore, whereas, with the present computer system, feedback information is presented only for the operation of the robot technological system, in the new formulation it will be possible to extend such feedback to encompass the reorganizing, the procedure- and norm-developing, and the planning and strategy-making activities of the executives.[17]

(c) Evolving, Real-Time Data Base. In the existing program system, real-time computer-generated feedback has had to be restricted to a span of one simulated day. In several experiments, the subjects have themselves, from time to time, obtained larger temporal perspectives of the history of their organization by manual techniques. In certain experiments we supplemented their on-line computer-generated feedback with trended information prepared between laboratory sessions, but it has not been possible to provide such information on a regular basis during laboratory operations.

In the new program system, the computer will be accumulating quantitative information in real time concerning all phases of the evolving organizational activity and will combine these into a unified, developing data base. Once this data base is brought into being, computer routines will continually update it. Then subjects will be able to interrogate this compilation at will for specific kinds of information and to obtain from it, upon request, historical information trended over varying spans of time.

The more expansive the time-horizons of information feedback, as the literature attests, the greater is the likelihood of more creative and more relevant high-level policy formation. Our new data-base and interrogation facilities should enable our subjects to attain levels of policy creation and implementation beyond any realized thus far.

The kinds of feedback and on-call information just described play a major role in the everyday, real-life management of large bureaucracies. Provision for their optional controlled introduction into our simulations will facilitate and promote the rigorous study of communication and information potentials in large organizations.

TOWARDS A FORMALIZATION OF SOCIAL TRANSACTIONS

The foregoing seven developments in simulation technology extend computerization to the domain of social transaction. In our new formulation, as we have seen, our subjects will be using the computer to exercise their more highly developed management authority, to structure their technological system, to establish and enforce standing procedures and to assign and monitor all uses of authority among themselves, to establish contingency plans that can be implemented as wholes, to reorganize the formal structure of their management hierarchy either piecemeal or totally, and to structure the entire flow of feedback information through their hierarchy. Such radical computerization has more than practical or logistic implications; by its means, a degree of formalization hitherto unattainable in the social sciences will become possible. We shall now outline the elements and the theoretical implications of such formalization.

ELEMENTS OF THE FORMALIZATION

Transaction as Prestructured Unit: To take any action over the computer, a subject intervenes with an overt, physical, button-pushing act. Using the General Operator-Computer Interaction (GOCI) program, he may say, "Transfer agent *x* to squad *y*;" or, "Assign priority *x* to work units of kind *y*;" or he may say, "*x* is authorized to issue *y*-type orders at stations *z*; or, "*x*-type authorization requires concurrence of officer *y*." Each such intervention is built into the computer programs as a prestructured transaction[18] or atomic intervention and is available in the computer for use by a subject when the subject elects to use it.

Possibility Space for Transactions: When a subject takes such an action, he selects it from the total domain of pre-established possible atomic transactions made available by the program system. Selections are made under constraints or boundary conditions imposed by fellow subjects or the experimenters.

Range of a Transaction: The range over which each kind of intervention operates is prescribed by the computer programs. Specific values in a range are represented as variables in the atomic transactions. Examples of these variables are signified by x, y, and z in the four atomic transactions just cited. Thus, when a subject elects to take a social action--for example, when he authorizes a colleague to declare decision rules of a specific kind--the subject tells the computer who is authorized to issue what kind of decision rule to the robots at which station in the technological system. The range of his transaction includes live agents, decision rules, and territory.

Freedom of Choice: While the conditions under which a social action can be taken and the extent of its range are prescribed for a subject, he is completely free to elect which action he will take and to which elements of its range of reference it will apply. The timing, sequence, and combination of transactions are all within the free choice of the subjects. As a matter of fact, the number of possible alternative constellations of transactions that the subjects can realize during an experiment is supra-astronomical.

Consequences of Choice: All such actions translate the subjects' intents into overt changes in the organization: A resource is transferred, a new decision rule is given some robots, a new authorization or sanction is established, and so forth. Once any such action is taken, it thereafter affects the evolving social world in the laboratory.

Comprehensive Domain of Choices: These computer-furnished transactions provide the subjects with their entire repertory of possible social expression. The actions are mutually comprehensive; no possible social behavior lies outside this domain of actions, except for free person-to-person discourse, as permitted.

An analogy can be drawn to making music. A musician cannot make music without tones or an instrument; the instrument furnishes him with tones; hence his instrument supplies him with his entire domain of possibilities of musical expression, thereby prestructuring his musical universe of discourse; but he is free to select tones, to make them in specific ways, to time them, to sequence them, to group them; and this is how he "freely creates" music. Similarly, the prestructured possible social actions within the computer's program system can be viewed as the idiom with which each subject expresses his organizational existence; what he expresses with this idiom is his response to the environments into which the experimenters take him. The subjects are completely free to develop their own rules, norms, and sanctions and to act as they see fit; neither the computer nor the laboratory setting constrains this freedom.

Entitative Social Structure: The outcome of all the subjects' choices is the building, organizing, and continual development of a common social structure. As this structure crystallizes and changes, moreover, it assumes definite properties, coherence, and a palpable reality of its own, a reality that comes to resist some changes and to facilitate, even induce, others.

Independent Observation by Computer: Whenever a subject acts, the computer automatically observes the action, without intruding upon the subject. Observation is totally extrinsic to and independent of subjects' actions; the experimenters do not interfere with probes, questionnaires, or face-to-face interrogations that can affect the very phenomena they are designed to study.[19]

The Behavior that is Observed: By making the computer the instrument through which the subjects take their social actions, we compel the subjects to express their decisions in overt, external, and observable behavior. What is observed, furthermore, is not subjects' opinions or interpretations of their own behavior, but rather the overt, realized social activity itself.

Conceptual Encoding of Transaction: Computerizing social transaction provides the basis for its conceptual encoding. A necessary condition for any action to take place over current digital computers is that the operation be a manipulation of Boolean sets or their members. In consequence, such computerized actions are classifiable, countable, and transformable by rule. The computer therefore formulates the very acts of social behavior in forms that are directly amenable to measurement, correlation, and subsequent higher-level formalization.

Higher-Level Constructs: The conceptual encoding of social transaction that we have just outlined is only the beginning. Even the most tentative look ahead indicates that higher-level constructs, built on the foregoing encoding (or mathematization) of transaction, will be hierarchically organized. A natural structuring of levels is shown in Table 1. Besides the hierarchy shown in Table 1, there are other hierarchies that can be established in the computer; an example is the hierarchy generated by the following requests to

Table 1. Kind of Action and Example, by Level, in a Structure of Social Actions That Will Be Taken over the Computer

Level	Kind of Action	Example
1	Direct Robot Action	A = Transfer agent a to squad s
2	Decision Rule	B = Assign priority p to work units u
3	Control Authorization	C = Officer O may take action B
4	Meta-Authorization[20]	D = Authorization C requires concurrence of officer O'
5	Plan	E = Meta-authorization D will be implemented after t intervals of time
6	Contingency Plan	F = Plan E is to be instituted when contingency c eventuates
7	Policy Authorization	G = Officer O" may institute contingency plan F

the computer: Report A to officer O, report B to officer O', . . ., report G to officer $\hat{O}$, where A, B, . . ., G are the actions shown in Table 1. Ordinarily these seven kinds of reports would not all go to any single office in the command pyramid, because the lower-level reports would be too detailed to interest the higher authorities and the higher-level reports might be too privileged to go routinely to lower-echelon authorities.

A hierarchy similar to that of reports would be generated by this request to the computer: Seek concurrence on X from officer Y, where X successively takes on the values A, B, . . ., G of the transactions shown in Table 1, and Y represents appropriate officers.

It should be emphasized that the hierarchy in the foregoing structures is a logical one, escalating from the lowest to the higher levels. In actual operations, "de-escalation" is necessary--no specific action can be taken on the technological levels without licit (or illicit) invocation of an entire higher-level authority structure.[21]

SIGNIFICANCE OF FORMALIZING SOCIAL TRANSACTIONS

Norwood Russell Hanson, in his book, Patterns of Discovery: An Inquiry into the Conceptual Foundations of Science,[22] declares:

> Physical theories provide patterns within which data appear intelligible. . . .A theory is not pieced together from observed phenomena; it is rather what makes it possible to observe phenomena. Theories put phenomena into systems. They are built up 'in reverse'--retroductively. A theory is a cluster of conclusions in search of a premise.

The systems that Hanson has in mind are, of course, quantitative, and the quantities range over orders of properties. To group phenomena into sorts and to relate these sorts--which he holds to be the accomplishment of theory in physical science--the phenomena first have to be drained of their qualitative particularities. The physical phenomena have to be formalized, and the formal concepts substituted for the particular phenomena. Precisely such a program of formalizing social phenomena is what we are undertaking, in order to provide the foundations on which a theory of organizations can be built.

The initial step toward theory construction in the social sciences is to recognize what are the ultimate constituent elements of large social groups. We, in common with other social scientists, acknowledge these to be transactions. By focusing on transactions, we can begin to unravel such complexities of large organizations as those mentioned at the beginning of this paper. An identical transaction, an authorization, for example, can simultaneously enter into subsystem integrations on diverse levels in different contexts in a social hierarchy, as it does in successive delegations of authority down and across a pyramid of formal authority. A transaction (again take an authorization as example) can be multiply located on these diverse levels in these different hierarchical contexts. Of the essence of a transaction (such as an authorization) are its symbolic, humanistic, and dramatistic aspects. Although a transaction can take place at a specific moment of time (for instance, when an authorization is pronounced), the transaction is not simply located in time. Indeed, if the transaction is an authorization, it is a pure potentiality until exercised and ordinarily does not terminate in any specific use of authority. To continue with the example of an authorization: the uses of authority generally occur intermittently, not with any regular cyclical flow. And a transaction (such as an authorization) can enter into multiple interaction with social environments, as when an agent of an organization successively speaks in its name, binds it in a compact, dispenses of its resources.

In real organizations and in simulations as they develop in the laboratory, every transaction is unique, particular, and non-recurrent. Each has its individual affective tone, is uttered just once by a real person, accomplishes a specific effect at a historical, unrepeatable moment of time. For theory construction, however, we are not interested in transactions for their individual idiosyncracies or eventuation in historical time, as might be a drama critic or a psychiatrist. Our concern instead is to formalize transactions, reduce them to basic types, and render them operational and overt. But just such a draining of particularity, such a formalization, can be achieved in a computer-based laboratory. Subjects can translate their human, dramatistic intentions into overt behavior.[23] This they can do, if they declare their intentions to a computer whose cycling digits have been coded logically or qualitatively and have been made to sustain a concrete, ongoing bureaucracy. In front of the laboratory facade, transactions are particular, palpable, and humanly meaningful events--the transactions support conflict, negotiation, control, governance. In the computer, behind the facade, the transactions become purged of particularity and are rendered abstract and formal. They can then be recorded in the course of public (nondramatic) clock time, grouped into sorts, counted, and correlated with each other and with events in the laboratory environment.

These formal translations of social actions are, then, the elements that can be united in intelligible patterns. It is precisely this abstract formality that renders subjects' concrete actions intelligible. Higher-level patterning or theory construction--when social scientists shall have the wit to discern such patterning--will increase intelligibility. With superior intelligibility will come control, by social scientists, over their phenomena. And with control, an ascending spiral of experimentation and higher-level theoretical construction will come to pass.

FOOTNOTES

1. Hierarchies of this kind present problems of fundamental importance for modern symbolic logic. A theoretical discussion of the failure of contemporary logic to represent their structure is contained in our "Formal Representation of Intentionally Structured Systems," Information Retrieval and Machine Translation, Kent (Ed.), Interscience, New York, 1960, Chap. 12.

2. See our discussion in "Leviathan: An Experimental Study of Large Organizations with the Aid of Computers," Studies on Behavior in Organizations, Bowers (Ed.), University of Georgia Press, Athens, 1966, pp. 259-274.

3. Abstract generality is achieved by formulating the system of computer programs in highly general terms. The same system can then be used to simulate elements that are common and basic to a considerable variety of organizations. Any specific simulation is mounted by punching decks of parameter cards and feeding these into a computer (or by reading parameter values directly into data input terminals of a computer). The computer program system itself is indeterminate until it is supplied with its parameter values. Therefore the program set is invariant from any one possible simulation to any other, and it is common to all. This guarantees that the basic formulation underlying all of a set of simulations is theoretical and general. Abstract generality can accordingly be realized.

4. Development of the formal and quantitative theoretical aspects of the Leviathan research program has been supported in part by the U. S. Air Force Office of Scientific Research (Information Sciences Directorate), of the Office of Aerospace Research under Contract No. AF 49(638)-1188. The Leviathan computer programs have been and are being realized principally by Mildred Almquist and Robert E. Krouss. Laboratory manager is Stanley Terebinski.

5. Four types of formal organization have been realized to date in the laboratory. These are described in our "Communication and Large Organizations," SDC document SP-1690. (Published in somewhat condensed form as "Programming the Bureaucratic Computer," IEEE Spectrum, 1(12), December 1964.) Single copies of this and other SDC documents referenced in this paper may be obtained by writing to the Technical Information Office, R&T Div., SDC, 2500 Colorado Ave., Santa Monica, Calif, 90406.

6. Ibid., pp. 21-24.

7. Described in our "Leviathan and Information Handling in Large Organizations," Electronic Information Handling, Kent and Taulbee (Eds.), Spartan Books and Macmillan, Washington and London, 1965, Chap. 16, pp. 170-184.

8. See Electronic Information Handling, pp. 165-170; "The Leviathan Technique for Effecting and Monitoring Live-Artificial Communications," SDC document TM-761; "GOCI: A General-Purpose Vehicle to Assist System Communication," by Mildred Almquist, SDC document TM-805.

9. See our "On Assessing the Effectiveness of Administering Priorities in Information Systems," Proceedings, Tenth Military Operations Research Symposium, 2(2), Part I, Fall 1962 (also available as SDC document SP-1059). An error in this document has been corrected in the operating program.

10. These are reported in initial form in "Communication and Large Organizations," in Electronic Information Handling, pp. 184-191; and in "Leviathan," SDC Magazine, 8(4), April, 1965, pp. 21-25.

 Other findings are treated in our "Humanistic Research in Large Social Organizations," in The Challenge of Humanistic Psychology Today, Bugental (Ed.), McGraw-Hill, New York, N. Y., in press.

11. 16K 49-bit word core, 32K drum, eight tape drives.

12. Open-ended strategy of this nature is generally characteristic of decision-theoretic experimentation, in which results shape an evolving design during the conduct of an experiment.

13. See Note 8 above.

14. GOCI was taken off the air and replaced by a series of programs that first interpreted and implemented the subjects' commands to the robots, then simulated the productive work of the organization, next analyzed the results of this simulation in a data reduction program, and finally caused the high-speed printer, operating on-line with the computer, to prepare hard-copy feedback information for the subjects.

15. Many of these routes cannot be implemented with the existing computing machinery but will be implemented in the new facility described below.

16. See Electronic Information Handling, pp. 161-192, for descriptions of some of the present capabilities.

17. All these activities will incur overhead costs, i.e., they will draw on the subjects' resources of robot energy.

18. Transactions constitute a subset of human actions, namely, those actions which are intrinsically social. An example is the Hebraic notion of a covenant, compact, or contract; to contract is not meaningful unless more than one agent is involved in the action.

19. The subjects are, of course, told initially that their actions over the computer are recorded.

20. Authorizations can themselves generate a hierarchy of authorizations by recursively requiring higher-level authorizations. Ordinarily each higher-level authorization is vested in an office that is higher in the chain of command than that which authorizes a lower-level authorization. The ever-ascending chain of authorizations of authorizations ultimately ends in the sovereign authority, and delegation ordinarily breaks the chaining of recursions.

21. These hierarchical structures serve to formalize basic elements in the social "Lebenswelt" of contemporary phenomenological investigations; the phenomenological discussion, however, is outside the scope of this report. These also are intentional structures of the kind that would be treated symbolically were intentional logic formalized: cf. "Formal Representation of Intentionally Structured Systems," Information Retrieval and Machine Translation, "Class Inclusion, Class Membership, and Intension," pp. 471-72.

22. Cambridge, 1965, p. 90.

23. Hence operant shaping of subjects' development is effected by experimenters with human subjects. Two advantages over animal instruction are possible in computer-based environments of the kind we are describing: First, the rewards and punishments need not be extrinsic (pennies, candy) but can be intrinsic, namely, the subjects' social achievement in making their organizations operate at higher levels of accomplishment. Second, the behavior to be inculcated need not be determined in advance. Rather than training a pigeon to dance a predetermined figure eight, subjects can be brought to develop qualities that they first exhibit to experimenters in incipient form. The experimenters, like any competent teachers, opportunistically seize on any forms of excellence that manifest themselves in the laboratory and, by controlling subjects' environments, enable them operantly to shape their own rise to higher perfection.

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* System Development Corporation Santa Monica, California	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

Summary Report (October 1962 - June 1966): Information Processing Potentials in Large-Scale Operations

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

5. AUTHOR(S) *(Last name, first name, initial)*

Rome, B. K. and Rome, S.C.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
18 July 1966	40	23

8a. CONTRACT OR GRANT NO. AF 19(628)-5166 AFOSR Information b. PROJECT NO. Processing Potentials for the AF Office of Scientific Research, c. Office of Aerospace Research d.	9a. ORIGINATOR'S REPORT NUMBER(S) TM-1128/100/00 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this document is unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY

13. ABSTRACT

In the study of large organizations, the information, communication, and governing processes have been extremely difficult to formulate. Towards such a formulation, the strategy of the Leviathan studies has been to pursue two lines of attack--theoretical formalization and computer-based simulation. By these means, Leviathan research has studied the interrelationships between (1) executive policy making and control and (2) system performance of large organizations, within (3) experimentally controlled laboratory environments. In answer to the challenge of markedly enhanced computer capabilities just now being made available, practical and theoretical advances have been made in formalizing the communication and governing process in large organizations. These advanced formulations and their significance are explained.

DD FORM 1 JAN 64 1473

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Information Processing						
Large Organizations						
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Computer-Based Simulation						

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