Operational Analysis in Relation to Administration of Government-sponsored Research

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ACCORDING TO THE BUSH REPORT (*3*), government expenditure for scientific research increased from approximately $50,000,000 in 1938 to $720,000,000 in 1944. An appreciable proportion of this increase was achieved by contracts with academic institutions through such agencies as the OSRD and the Engineer Corps, U. S. Army (Manhattan Engineering District). Since the war, government-sponsored research in academic institutions has been continued at an unprecedented rate, as compared with prewar practice, through the Army, the Navy, and the Atomic Energy Commission, and there is a possibility of further support through a National Science Foundation.

This trend has had its impact both on academic institutions and on government agencies. The former have had to learn that scientific research supported by government funds often involves considerably greater formality and detail in accounting, property control, and other administrative procedures than is characteristic of research supported, for example, by foundations. The latter have had to learn that restraint must be used in applying standard government practices to administration of research contracts, if the individual research scientist is to be permitted sufficient freedom to do effective creative work.

Although much progress has been made in evolving satisfactory relationships between government agencies and academic institutions for the sponsorship of research, the attempt to make adjustments that will enable such organizations to work together smoothly has resulted in certain difficulties. These appear to be due, in large part, to lack of understanding of the real problems involved.

We shall consider here some of these difficulties in the light of a method which may be used to discover and clarify the nature of the problems involved. The method may be called "operational analysis"—the examination of the relationships of abstract concepts, principles, or policies to operations, manipulations, or acts. Through this process, "operational definitions" are derived, and the abstract concepts, principles, or policies acquire "operational meaning." The latter is frequently different from the connotation which has been assumed by those concerned with administration of the policy or procedure. When this is made clear, difficulties can usually be resolved with comparative ease.

My own inclination to use this method for solving administrative problems related to wartime research contracts was the result of training in physics. Physicists are familiar with the operational definition of simultaneity as the basis of Einstein's special theory of relativity, and with the general method of developing operational definitions of concepts in physics, as discussed so ably by Bridgman (*2*), among others. The method is not confined to physics, however. The relating of abstract verbal or written language symbols to concrete acts or things has been developed by Korzybski and others (*5*) as "semantic analysis," and the investigation of the operational meaning of administrative and executive processes has been discussed by Barnard (*1*).

To illustrate the application of operational analysis, it will be instructive to consider some examples involving determination of the operational meaning of such expressions as "protecting the Government's interest" and "paper work." Government representatives frequently state that certain policies and procedures are necessary as a means of "protecting the Government's interest." Representatives of academic institutions may argue that the same policies and procedures merely increase "paper work" or "red tape."[1]

Such phrases have affective or emotional connotations. A loyal government representative might resent any implication that he is not trying to "protect the Government's interest." A self-respecting contractor's representative might, likewise, resent any implication that he is not trying to prevent increase of nonessential "paper work." Discussions involving abstract phrases having affective connotations are apt to end in illogical disagreements, unreasoned conclusions, and purposeless actions, unless both parties make a real effort to relate these phrases to the actual operations involved in the particular situation under discussion (*4*, *5*).

As a specific case, let us consider a contract for wartime research between X agency and A university. In order to "protect the Government's interest," Smith of X agency requests Jones of A university to mark outgoing shipments to Army bases in accordance with formal Army shipping instructions. Jones ignores the request on the grounds that it represents more "paper work" and "red tape." Important gear is shipped prior to the receipt of formal instructions, marked in accordance with information informally available to Jones. The gear remains at dockside for want of instructions intelligible to the load-

[1] According to the *Century dictionary*, "red tape" is an expression derived from the once customary use of tape dyed red or crimson for tying bundles of papers used in public or private business.

ing crews until, after long delay, the shipment is traced and appropriate information forwarded. In this case, certain "paper work" was essential for effective handling. This would have been clear to Jones, as well as to Smith, had they both investigated the operations involved in handling shipments instead of concluding their discussion in the realm of abstract terms.

As a second case, consider a peacetime research contract between Y agency and B university. Green of Y agency insists to Brown of B university that records be kept of the location and disposition of all property items valued at more than $10. No agreement can be reached while the discussion remains in the realm of "protecting the government's interest" and "paper work." Study of the agency operation reveals that Green has been instructed to apply certain property-manual rules to contracts under his jurisdiction. Study of the university operation reveals that the work involves design and fabrication of elaborate equipment into which hundreds of items are incorporated, often after considerable modification. The facts developed show that the operations requested would involve diversion of scientists and engineers from research to record keeping, that the possibility of identifying many of the items in the end product would be questionable in any event, and that there is no clear use to which elaborate records of the kind requested could be put. In this case, it appeared that the operations requested would not protect the Government's interest but would be detrimental to it. The remedy was to modify the requirements so that the actual operations involved were reasonable, would serve a useful purpose, and were mutually agreeable to the parties concerned.

These two examples, one applying and one not applying operational analysis, are based on actual situations.

Operational analysis often reveals that common procedures fail to accomplish the purpose implied by the abstract principle or policy which gives rise to them. In some instances, the reverse of the implied purpose is accomplished, as shown by the operations involved in obtaining reimbursement from the Government for expenditures under certain cost-reimbursement research contracts.

Such contracts are customarily written on a no profit-no loss basis. The university is not expected to be out-of-pocket for any expense other than those resulting from fraud on the part of one of its principal officers. As expenditures occur, the university submits vouchers to the Government, together with various "supporting papers." To "protect the Government's interest," the vouchers must be certified as to correctness and propriety by a government technical representative and a government fiscal representative. If, however, one of these officers fails to certify, and the voucher is disallowed, the university can collect payment by charging the expenditure to a special account which covers various indirect charges, such as "overhead" and other items not reimbursable under the usual vouchering procedure.

A typical series of reimbursement procedures for a no profit-no loss research contract is illustrated as follows:

(1) Z university prepares and submits voucher for purchase of pill-making machine.

(2) Government technical representative disapproves, since purchase of a pill-making machine does not appear to be relevant to the work.

(3) Z university submits reclaim, with several letters from its scientists stating need for such a machine.

(4) Government technical representative approves and forwards voucher to fiscal representative.

(5) Government fiscal representative disapproves, since cost of pill-making machine is twice usual market cost.

(6) University submits reclaim to fiscal representative with letter explaining that this is special pill-making machine, hence the extra cost.

(7) Fiscal representative disapproves because it is not sufficiently special to warrant extra cost.

(8) University charges cost of pill-making machine to account covering "indirect expenditures."

(9) Government reimburses university through account covering "indirect expenditures."

These manipulations (carried out, it must be remembered, at government expense) appear to be largely meaningless, since reimbursement in one manner or another is the usual end result, regardless of the decisions made at the various stages of the vouchering procedure. It would seem that agencies could better "protect the Government's interest" in such contractual relationships by reviewing the technical and fiscal performances of each contractor periodically, at the site of the contract. Such reviews (including on-the-premises fiscal audits) could serve as the basis for adjustments, and for changes in policies or procedures applicable to future operations.

There appears to be considerable confusion as to the operational meaning of "technical administration"—a confusion which seems to occur both within academic circles and within government agencies administering research contracts. One way to make the operational meaning of technical administration clear is to examine categorical tabulations of research problems in order of decreasing levels of abstraction, as shown below:

Abstract

Radiant energy
Effects of radiation
Biological effects of radiation
Effects of ultraviolet radiation on cells
Effects on cells damaged but not killed
Effects on damaged, living yeast cells
Chemical changes in damaged, living yeast cells
Changes in nucleotide content of damaged cells
Analysis for nucleotide nitrogen
Determination of nucleotide N by Kerr and Blish procedure

Concrete

Such tabulations indicate that each step upward in the administrative hierarchy from research worker to group

leader, to research director, to government technical representative, etc., should involve decreased concern with the concrete problems of research and increased concern with the more abstract problems of choice of facilities and of research programs.

It is evidently fallacious to assume that research can be "directed" from "higher levels" by individuals who are out of contact with operational details. Scientists themselves sometimes avoid facing this issue squarely. This may be because it is difficult for scientists to admit that the more one becomes an administrator, the less one continues to be a research scientist.

Operational analysis shows that it is generally true of all organizations, whether concerned with research or with other activities, that each successive step in removal from the actual physical operations involves decreased knowledge of the details of the operation itself, and increased concern with (1) correlation of activities, (2) choice of facilities, (3) choice of persons to carry out activities, (4) resolution of broad problems of human relationships, and (5) inspirational leadership. Thus, it appears that the problems which can be attacked effectively become more and more general at higher and higher organizational levels. This implies, first, that the detailed development of policies and procedures should be initiated at the operational level and, second, that authority and responsibility should be delegated from higher to lower levels to the greatest extent possible without loss of over-all correlation.

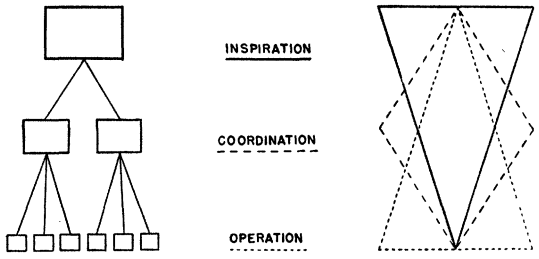

FIG. 1

At the risk of oversimplification, it is possible to indicate the functions applicable to various organizational levels by a diagram such as that shown in Fig. 1. According to such an analysis, the function of inspirational leadership is most important at the highest organizational levels; that of coordination, at intermediate levels; and that of operations directly related to the achievement of group goals, at the lowest organizational levels.

An investigation of the operational meaning of inspirational leadership impresses one with its abstract and symbolic character. A leader at a high organizational level is generally provided with a large salary and a luxurious office, is given special rights and privileges, and is included in ceremonies in which the organization or the external world joins with him in rites by which he is made to symbolize the activities and achievements of the organization as a whole. The leader, in turn, accepts certain obligations and restrictions. In arranging his life to conform with his symbolic functions, he may sacrifice considerable individual freedom.

This symbolic nature of the leader has been studied in the case of primitive tribes by Lévi-Strauss (*6*) and others. It does not appear to have been considered with particular reference to scientific leadership. As a consequence, scientists in high administrative posts are often regarded as responsible personally for "discoveries" and "advances" achieved within their organizations. The symbolic nature of public or organizational acclaim of leadership is forgotten. The individual is identified with acts which he did not and could not perform, rather than being considered as the symbol of acts carried out by other individuals within his organization. In my opinion, the fallacy that scientific research can be "directed" from above arises from this failure to understand clearly that the function of a scientific leader is largely that of acting as an inspirational symbol of the group.

Some writers assume that leadership exerts negligible influence on those concerned with actual physical operations. Such, for example, is the view expressed by Tolstoy in *War and peace*. From the operational examination of leadership, it seems that this is not the case. Positive influence seems to be exerted by leaders, but it appears to be limited largely to the conditioning of workers to the acceptance of group goals. In the paper referred to above, Lévi-Strauss makes it clear that, in the primitive society of which he is speaking, the leaders are already recognized as such by the group before they become so formally, as the chosen heads of small bands. Thus Strauss states: "The word *Uilikande*, the native word for chief, seems to mean 'one who unites,' or 'one who joins together.' This etymology suggests . . . that the leader appears as the cause of the group's willingness to aggregate, rather than as a need for central authority felt by a group already constituted."

Thus, it seems that the Tolstoyan hypothesis that the leader has no real influence on the group is fallacious. The leader is the group's symbolic representation of unity of purpose, and, as such, may exert influences (by engaging in ceremonies, issuing edicts, presenting speeches, etc.) which condition the members of the group to an acceptance of group goals. This is the reason for the differences that appear between a "weak leader" and a "strong leader"—a differentiation which would seem impossible according to Tolstoy's theory and which is yet apparent in reality.

What does operational analysis reveal about contractual relationships? Examination of the manner in which contracts are negotiated indicates that a contract is a written record of an agreement reached between various parties as to how they intend to enter into, and to carry out, a cooperative endeavor. This is consistent with the

legal interpretation of the meaning of contracts, with the further stipulation that a formal contract involves a legal obligation to carry out the agreement.

Operational analysis of the contractual relationships between complex organizations, such as government agencies, universities, and subcontractors, indicates that the parties to the original agreement are not necessarily in a position to foresee the problems which will be raised by the agreement at all operational levels within their several organizations. This is illustrated in Fig. 2, where

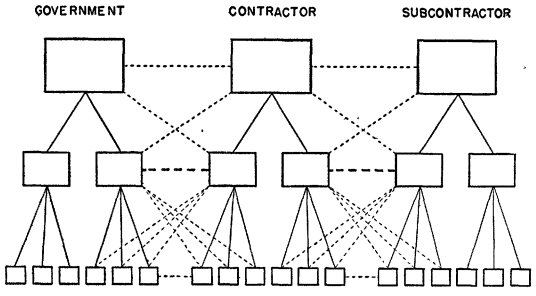

FIG. 2

the formal contractual relationships are indicated by dashed lines and some of the additional informal working relationships by dotted lines. Thus, operational analysis suggests that contracts should not be regarded as fixed and inflexible if the most harmonious cooperative working relationships between organizations are desired. Instead, they should be regarded as modifiable by mutual agreement in so far as unforeseen or changing conditions appear to make such action advisable.

Finally, operational analysis reveals certain interesting aspects of the meaning of judgments. Many administrative judgments require decisions concerning approval or disapproval of certain acts. Consider an instance in which a university contractor is required to obtain prior approval from a government representative before purchasing equipment or supplies exceeding a specified dollar value. The government representative can either approve or disapprove each case. This may lead him to attempt to apply to his decisions the law of the excluded middle, a "two-valued orientation" in which every case is considered to be either *a*, (suitable for approval) or *not-a*, (not suitable for approval). Operational analysis of the cases will reveal, however, that they extend through a more or less continuous range from those which should clearly be disapproved (being, perhaps, errors, or being totally unrelated to the contract work) to those which should clearly be approved (being, perhaps, essential and urgently needed).

Thus, examination of the operational nature of the judgments involved indicates (a) that the extreme cases can be disposed of quickly, leaving more time for consideration of the difficult middle range, and (b) that judgments with regard to the middle range involve so many factors that differences of opinion are normally to be expected. The second point is important. Hesitancy and fear in making decisions often stems from failure to realize that the use of categories in forming judgments is an arbitrary procedure, adopted for the sake of simplicity and convenience, and that the two-category, excluded-middle analysis is particularly arbitrary. Administrators who do not realize this fact are apt to worry and fret because they find so many cases which are not clearly either *a* or *not-a*.

If one operates with a system of symbols entirely removed from any relation to reality, it is possible to set up systems of operation which are strictly categorical, as in mathematics. The beauty of such abstract, completely symbolic operations is appealing. Clear rules can be set up for the operations. The correctness of any manipulation may be determined with certainty. As soon as symbolic operations are related to physical operations, however, the principle of uncertainty begins to apply.

It appears that much difficulty in administration arises from the endeavor to make the operations of judgment neat and free from uncertainty. This is accomplished by translating physical things into operational symbols—check marks on bits of paper, grades, numbers after dollar signs, etc. The operations of judgment are then carried out with the symbols, with little or no attempt to determine the operational meaning of the symbols in relation to the physical world.

This tendency appears to be especially marked in large organizations, of which the Government is an example. Extensive use is made of forms and symbols and of elaborate rules and procedures for operating with such forms and symbols. When it is realized that judgments based upon these formal operations may be inadequate, the tendency is to "back up" judgments with additional symbolic representations—memoranda, endorsements, statistical information, more elaborate forms and procedures, etc. Thus, the tendency is for symbolic operations to lead to additional symbolic operations. In extreme cases, administrative leaders may work in what amounts to a dream world of symbolism, almost completely out of touch with reality.[2] The obvious remedy is direct contact with reality. To accomplish this it is particularly essential in large organizations to delegate broad responsibilities and authorities to those who are proximate to the actual physical operations.

An attempt has been made above to show the efficacy of operational analysis as a procedure, rather than to draw specific conclusions, which, as implied by the discussion of judgments, must necessarily be relative to particular cases. There are, however, two general factors in administrative operations which the analysis of the preceding cases illustrates. One is the tendency for the exten-

[2] Operations of this type are not unknown in academic circles. Thus, I am told that a committee, made up partly of scientists, recently awarded a scholarship to A instead of to B solely on the basis of respective cumulative average grades of 4.65 and 4.60.

sive use of symbolic representations and abstract categorizations to insulate administrators from contact with reality. This factor can be decreased in importance by constantly emphasizing the abstract nature of symbols and by stressing the importance of relating symbols to physical operations or things. The second is the tendency to misunderstand the relationship of the leader to the group and to expect operations to be "directed" from the top because of this misunderstanding. This factor can be minimized by achieving a clear understanding of the operational meaning of leadership, whereby the functions of leaders are seen to become increasingly abstract in progression from the operational level, through the coordination level, up to the inspirational level.

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Clinical Experience With Hemoglobin-Saline Solutions

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In collaboration with C. Martin Rhode and Mrs. Joye J. Jennings, a method has been devised for the preparation of hemoglobin-saline solutions suitable for intravenous injections in clinical cases. Injections have been made into 14 patients, 7 of whom have received more than one.

In the multiply-injected group there were five cases of secondary anemia due to hemorrhage or infection. Of these, three patients showed definite improvement after treatment, exhibiting reticulocytosis and an increase of blood hemoglobin and hematocrit values. In a fourth patient the effect of the injections could not be evaluated, since hemorrhage continued. In none of these four cases did oliguria develop. In a fifth patient the secondary anemia developed from a severe hemorrhage post partum, which led to a state of shock. Administration of hemoglobin-saline (2,300 cc. in five injections) restored blood pressure to normal. The patient appeared to be recovering, but developed oliguria and died on the ninth day. In one case of lymphatic leukemia and one of agnogenic myeloid metaplasia no improvement was observed after repeated injections. Urine flow remained normal.

In the singly-injected group no beneficial effects were observed. One patient showed oliguria, with recovery. Another patient died two hours after injection, without pyrogenic reaction or other clinical signs.

Although definite oliguria was observed in only two cases in the series, indications of renal impairment (by NPN or clearance values) were observed in three other cases, two of the multiply-injected group and one of the singly-injected group. In the last-mentioned patient, after injection of 200 cc. of hemoglobin-saline, both glomerular filtration rate, as measured by mannitol clearance, and renal plasma flow and Tm, as measured by PAH clearance, were reduced to about one-third of the original values, with later recovery to normal. Liver function tests remained normal in the three cases tested.

In most cases the solutions exert a pressor effect which endures for several hours. The rise in blood pressure is accompanied by bradycardia.

In some cases injections up to a volume of 500 cc. (= 50–60 grams hemoglobin) have given no rise in temperature or other reactions. In other cases usually mild, but occasionally severe, pyrogenic reactions, complicated by other reactions, have been observed.

No evidence of anaphylactic reactions caused by hemoglobin was observed in any case.

The solutions do not agglutinate cells of the four main blood groups.

Methemoglobin does not accumulate in the plasma, even after large injections of these solutions.

In 6 patients the average amount of hemoglobin which appeared in the urine was 18 per cent of that injected.

New Effects in Superconductivity

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With the aid of a grant from the American Philosophical Society, an investigation was undertaken in 1938 to survey the possibilities of using superconducting metals as electrical thermometers for measuring very small amounts of thermal energy. During the recent war a need arose for fast-acting devices for measuring small pulses of infrared radiation, and it was found that bolometers capable of measuring as little as 10^{-6} ergs in 10^{-8} seconds could be made of superconducting alloys. This corresponded to temperature changes of the order of 10^{-7} degrees. It appeared that the infrared was absorbed directly in the superconductor with a coefficient of about 50 per cent, contrary to the expectation that a superconductor might be a perfect reflector.

The sensitivity of such bolometers was limited by the inherent thermal fluctuations in the superconductor. By observing the fluctuations in strips of columbium nitride, it was found that just above the superconducting transition the random fluctuation had a peak-to-peak average of 0.01 μv