TITLE: Identifying The Future Threat

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VOLUME: 12 ISSUE: Fall YEAR: 1968

MORI DocID: 602141

STUDIES IN INTELLIGENCE

A collection of articles on the historical, operational, doctrinal, and theoretical aspects of intelligence.

Patterns of basic research as indicators of possible new enemy weapon systems.

IDENTIFYING THE FUTURE THREAT

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Although threats to the position or security of the United States include all conditions disruptive of world peace, such as political instability, hunger, and disease, we shall be concerned here only with threats of a predominantly military nature which derive from advances in the physical sciences and engineering, and we shall analyze the problem of projecting such threats from the research done to achieve the advances. Experience of the recent past with complex modern weapon systems has shown that in general a period of 10 to 15 years is required to bring a new system from the research stage to utilization. This is then the outer limit in time of such projection. At the near end, minor improvements which can be effected in periods of 5 years or less can generally be predicted by fairly straightforward extrapolation from current capabilities. The critical period in our anticipation of new enemy weapon systems therefore lies from 5 to 15 years ahead.

In order to be useful our projections must meet other criteria besides that of the future time they span. The first and foremost requirement is credibility: our data base and rationale must be sound and open to independent verification. Another important requirement is for sufficient detail and specificity to meet the operational needs of the consumer. At the highest levels of policy, details on how the projected weapon system may operate are not so important as its general characteristics and capabilities and a fairly precise time scale. At a somewhat lower level of management, more detail is required in order to make decisions concerning the allocation of intelligence resources to confirm the threat and development resources to counter it. At the research and development level, finally, even greater detail is required to enable our scientists and engineers to devise specific countermeasures.

Perhaps the most difficult constraint is the need to work with the kinds of information that are obtainable. The availability of information during the development of a weapon system follows a "bathtub" curve with time: during the early phases publication of basic research in the open literature is quite common; then as the applicability of this work to the weapon system becomes more immediate, the publication rate drops until information is almost nonexistent; finally, when the test and evaluation stage is reached, information can again be obtained through observation and technical collection. By this latter stage, of course, the time available for taking effective counteraction is short. It is in the early research phase, when open publication is still permitted and when there are still 10 to 15 years left in which to take counteraction, that an accurate prediction of the resulting system is both vitally important and extremely difficult.

Inductive and Deductive Methods

An obvious approach to such prediction is by induction or synthesis: one examines current R&D activities, identifies advances they are likely to lead to in basic science and technology, and then attempts to build up from these advances successively higher levels of development leading to new weapons. In this way one goes from new phenomena or properties of materials to new devices, components, subsystems, and finally a complete new weapon system. This is a logical and necessary method for the projection of future threats.

By itself, however, it is an extremely difficult one. While it may be possible to guess at advances in the basic sciences that will be made within a reasonable time ahead—say the next 5 years—the way these advances could be utilized in the construction of new weapon systems is a matter of much greater difficulty. Each basic advance can proliferate into many different applications, and to identify the most likely ones demands both knowledge of a vast number of applied scientific and technological fields and a great imagination and inventiveness. This is not to say that the approach should be discarded; the weapon systems that may emerge from new scientific advances are precisely the ones most likely to surprise us. It requires, however, that we learn how to handle problems having such uncertainty in data and so many different possible directions of development. Both the mathematical techniques and the intelligence sources needed will have to have considerable more study than has thus far been applied to them.

The second possible method of attack is the deductive. It proceeds from the postulation of possible or desirable objectives, in the eyes of the enemy, to the weapon systems, subsystems, components, devices, and basic R&D required to reach those objectives. This approach has the advantage that once a potential system has been identified the determination of its pyramid of required supporting activities is a more easily soluble problem than the reverse. Problems of this nature have been attacked with some success, notably for purposes of industrial planning. The procedure requires that at each descending level of complexity decisions be made as to the appropriateness of each of the possible means of building up to that level. When there are many different levels of complexity, as in a modern weapon system, the number of decisions and appropriateness factors becomes exceedingly large. They are manageable, however, by modern mathematical techniques, and in principle this procedure can be used to identify and label all the scientific and technological activities that would be required to carry out the whole development program.

Since the number of potential threats that could be postulated is very large, it is desirable to assign priorities among them in order to concentrate analysis on the most likely. This can be done on the basis of probable mission requirements as seen by the government of the country in question, say the USSR. Most broadly, one must determine first what the Soviet leaders believe the world looks like now and will look like 10 to 20 years in the future, then project missions which they might consider required to further their political, ideological, social, economic, and military objectives, then derive systems for the accomplishment of these missions, including weapon systems for military missions. This process provides a set of reasonable criteria for an initial assignment of priorities. It does not constitute a means of making final judgments as to the probability that a threat will actually be developed.

An alternative means of identifying potential threats for deductive purposes is to determine what the military posture and capabilities of the United States will be in the period under consideration. One may then propose that any Soviet system, defensive or offensive, capable of degrading our planned military capabilities would constitute a threat. The assignment of priorities among the systems so identified can now proceed on the basis of a priori probability or, as above, according to how they appear to fit in with Soviet philosophy or needs.

Problems of Induction

Let us return for a more detailed discussion and comparison of the two proposed methods. In the inductive approach the starting point was a large number of scientific and technological advances postulated to have arisen out of essentially undirected research. At least it is assumed that the reasons for engaging in this research are irrelevant to any weapon system that might be based on the advances. Addressing oneself to these advances with ingenuity, inventiveness, and a broad familiarity with the state of the art, one attempts to apply them through various levels of increasing complexity to create a new weapon system. Four such levels can be distinguished: creation of new devices or materials capable of performing either new functions or old ones significantly better; the combination of these devices or materials into components which perform more complex functions; the assembling of such components into subsystems, each of which contributes some major independent activity to the overall performance of the projected weapon system; finally this system itself, performing the mission assigned to it.

Since we are presupposing that the initial scientific and technological advances were made without the motivation of specific projected applications, there is no certain way of deciding in which of the many possible ways they might actually be applied to create new devices. Clearly, even inventing the various possible devices on the basis of a scientific advance which has not yet occurred is a very difficult step. Further, each of these possible devices might be used in many different combinations with other new or old devices to yield components with advanced or considerably different capabilities than previously available. And these components, again, could be assembled in various ways into subsystems with different capabilities. The characteristics of the ultimate system can then vary enormously, depending on the choices made all along this complex path.

There are various ways to try to thread this maze. One could give each alternative an equal probability and use statistical procedures such as the "random walk" or "Monte Carlo" methods which have proved useful in similar problems. Or one could use something like the PERT technique which has been successfully applied to systems development and management.[1] These approaches are being

[1] The Program Evaluation and Review Technique, developed for the Polaris missile program, performs a probabilistic analysis on uncertain input data and time relationships and calculates the probabilities for time or cost factors in a complete project.

examined, but it appears that a major simplification of the problem would result from an initial exercise of judgment in assigning probability weightings to the various alternatives at each level in the hierarchy.

Despite these major difficulties with the inductive approach, it can provide one with a view of totally new weapon systems that might arise from scientific and technological advances made during the next several years—threats of which the present-day state of science and technology is not an adequate base for prediction. The product of the inductive approach would be a set of predictions of developmental activities based on the probable uses of the postulated scientific advances. A number of different templates of such developmental activities would be produced, and actual activities subsequently observed would be compared with these templates in order to determine which of the several possible paths through the systems development maze the USSR had chosen.

We have passed rather casually over the matter of identifying the scientific and technological advances likely to occur in the next few years. Certainly precise identification of the details of an advance would presuppose sufficient knowledge to effect the advance immediately, something of a self-contradiction. It appears, however, that the general nature of the advances in any field of science can probably be foreseen through the use of such criteria as the current activity in the field, the need for a solution to particular problems, the absence of any fundamental laws prohibiting an advance, and the like. Consultation with scientists and engineers active in the various fields probably constitutes the best method of identifying the likely advances. Several groups concerned with technological forecasting have engaged in such consultations and manipulated the results in various ways trying to achieve some degree of unanimity among the expert consultants.

While this approach is the most promising one for the prediction of scientific/technological advances, there is one major pitfall that must be taken into account in using as one of the criteria for an area of probable advance the level of activity in that area. Since scientific research is largely supported by government funds, decisions by government administrators determine to a large extent the level of research activity in any area; and the decisions of these administrators are frequently weighted heavily toward areas considered important to particular objectives rather than having intrinsic importance in the scientific field. The inductive approach is thus contaminated by a priori decisions which must be analyzed deductively.

Problems of Deduction

In contrast to the inductive approach which works its way up from the simplest elements to the full complex system, the deductive approach requires the postulation of the full-blown weapon system and then attempts to work down to the individual advances in science or technology needed to achieve it. Although it is in principle possible to start with a list of all conceivable weapon systems and analyze each of these into the required subassemblies and elementary advances, this would require an enormous expenditure of manpower and time. We pointed out above how the list can be narrowed by giving first consideration to systems designed to perform various alternative missions contributing to the achievement of Soviet goals. Each of these systems can then be analyzed into progressively simpler component levels until the elementary R&D requirements are identified.

At each level in this procedural sequence the various alternatives must be examined and ranked in terms of desirability, feasibility, cost, etc. In other words, a series of criteria for selection among the alternatives must be established. One thus arrives at a matrix of alternatives versus criteria for each of the levels. The over-all procedure, commonly and understandably referred to as a "decision tree," is fairly widely used for developmental planning. In adapting it for use in the intelligence field, however, there are a number of problems to be solved.

The first problem is that the intelligence user is not planning a development program for himself but attempting to determine what the Soviets have done. Hence it becomes necessary for him to think at all times like a Soviet planner. This requires that the historical and cultural backgrounds of the Soviet planners be incorporated into the decision matrix; they will show up particularly in the criteria used for evaluation.

A second problem is to determine the extent to which such a logical and carefully worked out decision process is applicable to Soviet planning. The primary reason for using the procedure in planning is that when the number of factors entering into a decision becomes larger than 25 to 50 it is almost impossible for one individual to make a knowledgeable decision. Since a major weapon system contains some millions of such factors, knowledgeable decisions about it are impossible unless assistance of some sort is provided. The decision tree provides this assistance by breaking down the complex problem into a number of decisions each small enough to be made knowledgeably, keeping account of all such decisions, factoring in their relative weight, and summing them all up. It is clear, however, that many major decisions are not made in this country in this way, and we have no real evidence that the Soviets make their major decisions in such a manner. If they do not, then we must be prepared for the decisions to show characteristics of illogic by the standards of the decision tree process. This is a problem not fully encompassed by the phrase, "Thinking like a Soviet."

Pattern Recognition

Assuming for the moment that these problems can be solved, our analysis will have provided us with a list of R&D areas that need to be emphasized in order to achieve a given weapon system. It will also have told us the *intensity* of effort required in each area relative to other areas, so that we have a sort of spectrum or template of needed R&D that will vary with time. This is the indicator which the analyst will then seek to identify in the all-source information available on current Soviet activities. The template might consist of a single unique area of R&D which would be a dead giveaway; alternatively it might be the over-all shape of the spectrum and its time-dependence.

As long as only one weapon system is being considered, it might not be especially difficult to identify the corresponding R&D pattern in the available information. If two or more systems are concurrently under development, each will have generated requirements for R&D and the spectra will then be superimposed. If these spectra were totally independent of one another their identification, though considerably more difficult than that of a single system, would still be amenable to fairly straightforward procedures, especially since the time element provides a useful filter. A complication is introduced, however, by the "commonality" factor: if systems x and y both require R&D in a certain area, it is reasonable to assume that the total effort applied will be less than the sum of the two requirements, allowing for a measure of efficiency in the combination. It therefore becomes necessary to estimate the extent to which the R&D requirements for any system are modified by the codevelopment of other systems with similar needs.

Having predicted through this process the pattern of R&D needed for the several high-priority weapon systems which it is estimated the Soviets might logically wish to develop, the analyst will look at the information on their current activities and compare it with his predictions. This process, analogous to what is usually called "pattern recognition," requires that the available information first be corrected for various disturbances. First there is the background "noise" of R&D that would be in process regardless of the needs of any particular system, the work being done for pure scientific or technological purposes. Second, there may be deliberate distortion, as by suppression through classification, although it is hoped that the early research phases will not suffer significantly from suppression.

The comparison of predicted pattern with actuality then proceeds and yields an estimate with the following kind of wording:

> There is a *q* percent probability that the Soviets have made the decision to develop weapon system *x* which will have such and such characteristics and capability and could be completed by the year blank.

Note that this estimate addresses only the decision to develop and does not attempt to wrestle with the decision to deploy or utilize.

Just as the inductive approach could not be totally stripped of deductive elements, so is the converse true. In working our way down a decision tree from the highest levels of national goals and policy through missions, weapon systems, etc., to the required R&D, we have thus far ignored any effect that research carried out for one system may have on another, unrelated system. Yet it is clear that scientific advances, no matter how generated or for what purpose, may significantly affect any system. In other words, any scientific advance acquires a life and influence of its own and can make possible new and different systems and capabilities which can be identified only by the application of inductive logic. At all times, then, these two methodologies must be carefully examined for their interrelationships and the effect each can have on the other.

A question frequently asked with respect to prediction is "How about the breakthrough?" The question points to a vulnerability in all prediction but involves an inherent contradiction. If a breakthrough is a major scientific achievement leading to totally new concepts which could not have been anticipated, it is unpredictable by definition and so cannot be factored into our projections in advance.

All one can hope to do is maintain a high state of awareness of activities in all scientific fields so that immediately upon the occurrence of such a breakthrough, or rather its recognition, steps can be taken to evaluate and factor in its influence upon our entire threat analysis, using the approaches which have been described above.

Status in Practice

Over the past decade and more, various attempts have been made to provide credible estimates of long-range threats, but without any consistent success. Within the past year a formal long-term attack on the problem has been mounted in CIA's scientific intelligence organization. Believing that a major impediment in the past has been the failure to develop a sound methodology before trying to come up with a quick answer, we have concentrated our principal efforts thus far on method. The foregoing discussion reviewing the kinds of approach that have been considered describes in particular, with some generality, the deductive technique, the one that has been selected for initial application. In spite of its acknowledged difficulties and limitations, this method is believed to offer the greatest promise of any thus far found. It is hoped that the difficulties can be overcome although it is not yet certain just how.

During the methodological study support has been sought and obtained from within the intelligence community and from external sources. As time goes on and the methodology is refined to a point where there is some confidence in its validity, the next step will be to begin to apply it and produce specific projections. For this it will be necessary to draw on the combined scientific and engineering knowledge of the government and the industrial and academic worlds. Large numbers of people will have to be consulted and vast amounts of information and open literature screened and evaluated. Suitable formats, computer programs, and data-handling capabilities will have to be developed. Steps in these directions are already being taken.

It is hoped that such a program may one day provide U.S. planners with credible predictions on the basis of which they can make maximum use of intelligence community findings to reach the decisions necessary for the security of the nation.