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This description of how an electronic computer war-games the strategic air battle is the second of a series illustrating advanced methods in air targeting.

DEVELOPMENTS IN AIR TARGETING: THE AIR BATTLE MODEL

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In pursuit of its basic objective, the assessment of enemy strengths as targets for US air action, air targeting is developing a series of mechanized analytical techniques as an aid to its intelligence production. The Military Resources Model, described in the Winter 1958 issue of *Studies in Intelligence*, is intended to provide estimates of capabilities to build up or mobilize military resources for war or to recuperate from attack. The Air Battle Model, described here, will provide estimates of capabilities to carry out war plans in the face of opposing offensive and defensive air operations.

This Model provides a high-speed electronic computer simulation of the effects of an air war on both sides, portraying both air and ground support operations. It is dynamic, reflecting the interaction of forces over very short periods of time to represent a constantly changing situation. It is automatic for whatever length of time real-life operations can be pre-planned. It provides a chronological history of the war, reflecting in detail the momentary net capability of each side as the war progresses. In effect, it provides a measurement of the degree to which offensive and defensive plans can be implemented or disrupted.

In making use of this war game mechanism, intelligence may seem to be getting into the determination of strategy. Lieutenant General John A. Samford noted this problem when he wrote in the Fall 1957 issues of *Studies*,[1] "The extent to which intelligence should contribute to this process [of war

[1] "The Intelligence Necessary to the Formulation of a Sound Strategy," *Studies in Intelligence*, Vol. 1, No. 4.

gaming] may be disputable, but it appears certain that the intelligence necessary to a strategy will be better if an advanced war gaming process of some sort is kept closely in mind during all the processes of intelligence preparation." The Air Battle Model is designed to achieve precisely this purpose.

The Purpose of the Air Battle Model

The Air Battle Model was initially designed for analysis of what was called the BRAVO (or "Blunting") Objective. At one time the BRAVO Objective was "to destroy the military, logistic and control strengths of the Soviet Bloc that enable the enemy to deliver air weapons against friendly forces and installations and to resist penetration of his airspace." Over the past few years, significant changes in the philosophy of the BRAVO Objective have occurred. Two of the current purposes of warfare are now listed as: (1) to prevent unacceptable launchings of Soviet atomic weapons against the US and its allies, and (2) to neutralize or destroy the general threat of Soviet air action against allied Air Forces. The current basic strategic concept holds that in event of war we must (1) immediately stop atomic attacks against the United States, our allies, and our military forces abroad; (2) immediately disorganize and disrupt the enemy air defense system; (3) stop surface force attacks against our friends and our sea lines of communication, and then (4) calculate our relative net position and determine what remaining enemy strengths require destruction or denial in order to bring the war to a conclusion on our terms.

Old definitions of the BRAVO Objective called for intelligence estimates of the physical damage done to enemy resources by our air action, without much regard to the time factor or precise measurements of his immediate operational capabilities. Such estimates might say, for example, that attack on a certain target system is expected to destroy 80 percent of enemy bomber aircraft, 40 percent of his fighter aircraft, 90 percent of his bomber bases, 60 percent of his aviation fuel, and so on.

However, if the aim is to put an immediate stop to his atomic attacks, intelligence must measure the degree to which they are in fact stopped by our countering action. We need to know how many fewer weapons he delivers or sorties he flies by reason of our counteraction than he would have without it. An estimate that attack on a system of targets would destroy all enemy nuclear storage sites, bomber bases, bombers, missile launching sites, and missiles *without an indication of the timing of the attack relative to enemy use of these resources* provides no indication of whether the enemy delivered none or 100 percent of his nuclear weapons. Determining the degree to which enemy operational capabilities were affected by destruction of his resources requires consideration of where and when this destruction occurred. And this in turn requires consideration of our attack capabilities in order to estimate where and when we could effect such destruction.

If our recommendations for US actions are to be "consistent with the values of the US national strength involved," [2] we must determine what our strength will be at the time it is to be used, and we must consider attrition to our own forces from enemy attacks and defensive action. Further we must state this strength in terms of actual ability to deliver attacks under the operational limitations of weapons and aircraft availability, launching requirements, and navigational and bombing accuracies. Is it feasible for us to deliver a certain yield to a certain place in time to interfere with enemy attacks being launched?

Is the objective to stop enemy *delivery* of weapons rather than to stop launchings? If so, then the effects of our air defenses on launched enemy weapons must be determined, and intelligence should measure separately the attrition the enemy suffers at the hands of our defensive and offensive operations. We shall need to stop further weapons delivery after large numbers are airborne and even after large numbers may have been delivered, and this objective involves both our defensive and our offensive forces. Preventing delivery of enemy air weapons and preventing his resistance to our penetration of his airspace blend together; we cannot accomplish one without to some extent accomplishing the other. And all must be accomplished in the relatively short decisive phase in which overall air superiority will be attained or lost.

The targets of air attack can no longer be determined by static analyses of the effects of an assumed successful attack. Most of the key questions in current planning require analysis

[2] Lt. Gen. John A. Samford, *op. cit.*

of what happens during the period in which the attack is being carried out. The questions almost invariably involve measurement of the degree to which the attack can be successfully carried through. It is imperative that we have methods for providing measurements appropriate to such questions. The Air Battle Model provides an initial methodology for this purpose.

The Air Battle Model supplies measurements of specific capabilities and the extent to which such capabilities can be realized. Capabilities must be made specific to be analyzed. The statement of a capability to attack must specify with what kind of weapons, with what kind of success against air defenses, with what weapon delivery accuracy, with what scale of attack, with what degree of warning to the other side, and with what probability of retaliatory damage to the attacking side. This is to say that capabilities must be examined in terms of their individual components, and expressed as plans to use available resources in specific ways.

The basic Objective therefore requires an intelligence analysis of target systems with the following characteristics:

1. It must be two-sided, and short-term effects of one side's operations on the capabilities of the other side must be taken into account as soon as they occur.
2. It must be dynamic; the constantly changing short-term net capabilities of both sides must be continuously estimated and recorded, giving a chronological history of the war.
3. It must examine specific plans for use of resources in order to measure the degree to which specific capabilities can be actualized.
4. It must interrelate offensive and defensive capabilities of both sides.

Such an analysis of the air battle also meets the need generated by many particular problems in strategic and tactical planning. Over the past several years there has been an ever increasing demand for estimates of the effects of attack on target systems in order to plan missile and manned bomber mixes and deployments, base hardening and aircraft dispersal or evacuation policies, weapons stockpile configurations, the use of decoys, and other penetration plans to minimize attrition.

On these and many other questions alternative decisions are weighed against each other in terms of their effects on the air battle.

The planner wants to know: If I make this decision rather than that one, what difference in effects can I expect in case of war? Further, although I am considering this course of action to obtain a specific effect in a specific area, I cannot clearly see just what other areas will be affected or to what extent they will be affected. What other fields are affected by my decision? In addition, I need to know how confident I can be in the estimates of effects on which I base my decision, and this confidence must be estimated from at least two points of view. First, since chance and real-world uncertainties would result in differing effects each time I tested my decision, what is the degree of probability of a particular effect? Secondly, since a variety of conditions may obtain in a real-war test of my decision, I need estimates of its effects under a variety of conditions.

These questions carry a number of implications for the intelligence analysis designed to answer them. First, there is an implied need for a "big picture" analysis. The planner needs to see clearly where the decision under study fits into overall plans. The analysis should assist him in determining both pre- and post-hostility effects of his decision. Suppose, for instance, that our planner is concerned with the possibility of pulling back some overseas tactical forces into the United States to improve their mobility for limited wars. A typical pre-hostility problem would be what effect, if any, this redeployment would have on the role of overseas bases for wartime deployment of both tactical and strategic forces. What load changes on them may be expected? A post-hostility problem would be whether the TAC withdrawal would allow a significant change in Soviet concentration of effort on SAC pre-strike deployment bases. If the planner can review his problem in the light of an overall analysis of the key points of most of our war plans, then his decision is much more likely to be the right one.

The second, and more frequent, need is for comparative results of alternative decisions. The planner needs to be able to estimate effects while holding all facets of the problem constant except those linked with his decision while varying others which might influence the effect of his decision. For example, a decision made for the current time period may be carried over into a future period in which many of the factors bearing on its effects may have changed.

Comparative estimates are required of the effects of a decision as varied by chance factors and estimates of the probability of any one effect. Chance elements are bound to be introduced in bombing errors, navigational errors, mechanical failure of aircraft, misinterpretation of radar scopes, inaccurate interceptor firing passes, and many other unplanned events. These affect the results of attack on a target system. If a certain battle is fought and refought many times, always with the same initial conditions, then on the average there is a most likely outcome of the battle, and on this most likely outcome the planner of the past would base his decision. But if a battle is to be fought just once, it is not enough to know only what the most frequent result in a series of such battles would be. The planner should know what the range of error associated with a certain predicted outcome may be. A plan which has a lower predicted probability of success may also carry a narrower range of possible outcomes, the worst loss being not so bad as that associated with another plan in which the most probable result is more favorable.

To answer the planner's questions, intelligence working with others must provide comparative estimates under many different conditions. Certain uncontrolled factors which must be assumed may have a significant influence on the effects of war. For example, the time of day of the initiation of hostilities, the time of year, the weather, and many conditions which the enemy controls will require assumptions for analysis of a war situation. The planner should know whether or not such assumptions influence the results of his decision, and if so, to what extent. Although some conditions are more likely to obtain than others, in many cases it is extremely difficult to estimate the probabilities of occurrence. Comparative estimates of effects under alternative conditions must be made.

There is always uncertainty in estimates of the precise types, quantities, and characteristics of resources available to the enemy. In determining the effects of his use of these resources, it is not enough to take the "most probable" estimate of what they are. The variation in effects with the differing sets of resources of varying probability must be determined. For example, the degree of accomplishment of the BRAVO Objective will certainly be influenced in 1960 by whether or not the Soviets have an operational ICBM. They may have none; they may have 100. It is necessary for us to take both extreme cases into account in estimating the effects of war in 1960.

One other requirement for the air battle analysis involves the operation of chance on enemy plans. Enemy plans do not represent the threat he presents until they have been degraded by chance operational constraints. Chance (or nature) is the first antagonist of war plans. As previously noted, chance enters into air operations in many ways — bombing errors, navigational errors, equipment malfunctions, etc. As a result, the threat presented by a series of plans will always amount to something less (or at least different) than the plans themselves. There is a need, therefore, for one-sided gaming of planned use of resources in order to estimate an actual capability to use these resources without interference from enemy action. This degraded threat may then be used as a base on which a two-sided game can measure the effectiveness of counteraction in reducing the threat.

Description of the Air Battle Model

The Air Battle Model programs a high-speed computing machine to simulate about three days of a two-sided strategic air war. It is completely mechanized in that, after the inputs are fed into it, it works through the air war in great detail, writing up its history as it goes along.

If you think of the Model as a kind of black box which will do our war gaming for us, the inputs fed into it may be viewed as the terms of reference of a problem. These terms of reference must describe what war resources are available to each side, what courses of action each will attempt, and the characteristics and conditions determining the results of interaction. Two different kinds of data are fed in for each problem to be gamed, one representing the quantities, location and status of the offensive and defensive forces of both sides, and the other roughly the strategies (intentions and plans) of both.

For each side the inputs include offensive base information, defense installation characteristics, aircraft lists, target lists, and finally, plans for offensive sorties. In addition, the black box itself has a set of parameters, a constant part of the Model, which define the effectiveness of the defense against bombers, register the aircraft characteristics and support requirements, calculate the weapon effects against resources, and determine the way in which the plans are to be used.

The Model looks at the air battle at certain specified time periods, perhaps every fifteen minutes of real time. It takes a look at the situation at the beginning of the first fifteen minutes and asks what would happen during the next fifteen minutes. It starts looking at one side, say the US side. It looks at all the information characterizing it and computes what would happen in the next fifteen minutes. It then looks at all the information characterizing the SU side and computes what would happen in the same fifteen minute period. It now asks whether the game time has ended. If not, it raises time one fifteen-minute period and starts the cycle over again. This cycle continues until a time predetermined as the last period of interest. The two-sided interaction is simulated in the cyclical process by feeding data on the SU defense installations and targets into the US side and data on the US defense installations and targets into the SU side.

In view of limitations on the amount of rapid-access memory available in a high-speed computer, the Air Battle Model was developed with five major parts — five major operations which together make up the substance of the air battle. Each of these parts is a separate routine on the computer. The computer can therefore use its full memory on each, and can retain all the information necessary to carry out the operations of one particular routine. At the end of a routine, the data stored in the high-speed memory is dumped onto a magnetic tape, and the new data needed for the next routine is "read" into the memory from the tape. Since the Model is two-sided, the routines must all be carried out for both sides in the battle. When all five routines have been carried out for one side, the machine switches over and carries out the same five for the other side for the same time period. The five routines by which the machine simulates the air battle are:

(1) cell handling, (2) attrition, (3) cell forming, (4) targeting, and (5) damage assessment.

A "cell" is a homogenous group of aircraft in flight, belonging to the same type, taking off together, flying at the same speed, carrying the same weapons and the same amount of fuel, having the same fuel consumption rate, etc., and having the same general destination. Planes on the ground at a base, on the other hand, are treated as individuals for the sake of flexibility in simulating ground support operations.

Routine 1 — Cell Handling

The Cell Handling Routine is concerned with in-flight plans given each cell. The in-flight plan tells the machine what route a group of planes is to take, what the choice of flight altitude and speed is to be, and what the planes are to do along that route. It gives the coordinates of a point along the proposed cell route and specifies the operation (*subroutine* in Model terminology) to be executed at that point. There are twelve of these subroutines simulating aircraft operations, any or all of which may be used. They are:

1. *The land-at-a-base subroutine.* This provides for landing the cell at a specific base, if the base is operational. If it is not operational, there are two alternative in-flight plans giving the choice between flying on to another base or landing in an area.
2. *The land-in-an-area subroutine.* This provides for landing the cell at the best equipped base in an area of specified size.
3. *The splash subroutine.* This means either a crash landing or that all the aircraft in a cell have been destroyed so that the cell itself no longer exists.
4. *The refuel subroutine.* This specifies the procedures, waiting time, and further instructions to be followed when either a bomber cell or a tanker cell reaches an aerial refueling point.
5. *The dogleg subroutine.* This provides for a change in direction or mode of operation of a cell. The latter may be a change in altitude or speed, for example.
6. *The rendezvous subroutine.* This allows, where feasible, simultaneous penetration of enemy defenses by several cells.

7. *The target assignment subroutine.* This sets up a procedure to simulate specific selection of a target for each bomber.
8. *The branchpoint subroutine.* This permits several cells to use the same in-flight plan up to a branch point and then to separate, each taking one of two exit routes according to a prearranged system.
9. *The target point subroutine.* This simulates bomb drop at bomb release line, recording the number of bombs dropped in a target area.
10. *The intelligence communication point subroutine.* This simulates communication of intelligence to friendly forces concerning whether or not a target has been bombed and concerning potential targets.
11. *The orbiting for evacuation subroutine.* This provides for keeping a cell of planes which have been evacuated from a base under threat of enemy attack in an orbit pattern in the vicinity of the base. The original take-off to evacuate a base is automatic if evacuation is desired.
12. *The decoy release subroutine.* This provides that at some specified point aircraft in a cell may release decoys.

Routine 2 — Attrition

The attrition routine is concerned with the loss of bombers to local defenses (surface-to-air missiles) and area defenses (fighter interceptors), taking into account the effects of electronic countermeasures (ECM) and of radar. In beginning the attrition routine the machine makes a check to find a list of bomber cells and defense sites close enough to each other so that there is a chance of interaction between them. Then for each possible interaction it determines whether defensive plans and resources available would result in an offensive-defensive duel. If a duel would result, the probability of bomber and fighter kills is determined. The number of planes shot down is then calculated on the basis of the kill probabilities.

In interactions with local defense missiles, the machine takes into account the number of missiles directed against each plane and the ECM characteristics of the plane in computing aircraft kill probabilities. Then it determines how many planes have been shot down by matching random numbers for each plane against the kill probability (the Monte Carlo method), and revises the cell records accordingly. If a plane is shot down while carrying a bomb and there is a probability that the bomb will go off, the computer uses the Monte Carlo method again to determine whether the bomb explodes and computes a chance location for the bomb to fall in.

The term area defense is used to describe the operation of fighter aircraft assisted by radar. Three operating modes are distinguished for each radar type: search, broadcast control, and close control. In search, the defensive aircraft operate with no guidance from the radar other than the information that offensive aircraft are in the area. At intermediate ranges, broadcast control is furnished the fighters. This means that they are given the position of the offensive aircraft but are not vectored to their targets. At close ranges the fighters may be given close control, that is vectored to their targets. These three modes of operation are introduced explicitly in the Model as three levels of probability of killing a bomber.

The close control capacity of a radar is given as a specific number of close control channels and a specific number of fighters that can be controlled by each channel. So far as possible, each fighter cell is given a channel of close control. However, if there are not enough close control channels to go around, the superior fighters are given the available control channels and the rest are sent up on broadcast control. On the basis of the amount of control, the type of fighters and bombers, the ratio of fighters to bombers, and the amount and type of ECM (which serves to reduce the control) present, the computer makes a Monte Carlo determination of how many bombers and fighters are shot down. If there is a chance that the weapon aboard a shot-down bomber may explode, the Monte Carlo method is applied to determine whether there is actually a ground zero and what its location will be.

Routine 3 — Cell Forming

The cell forming routine incorporates the planner's decisions as to how operations are to get under way. These decisions are put into the computer in the form of initiating plans, instructions to the machine to form cells at some time with some number of planes of a particular type carrying specified weapons. Instead of asking a particular number of planes from a particular base to go to some particular place at a particular time, the input chooses an "initiating point" at which planes for a cell are to gather. The initiating point may be any convenient point on the route to the cell's destination. The initiating plan specifies a time interval, rather than a particular time, at which the cell is to be formed, and specifies a maximum and minimum, rather than a particular number, of planes for the cell. Planes are to be drawn from any base within a given radius rather than from a specific base, with the limitation that they must be drawn from a particular unit — roughly a wing.

If there are enough planes available and if it is time for a plane or cell to take off, the machine automatically writes what is called an implementing plan to get the planes to the initiating point. Each time a plane becomes available, the implementing plan sends it off to the initiating point. If now is not the time for the first plane to take off but the plan is feasible, the machine waits and tries it again in the next time period. Sooner or later, when conditions are right and the time comes for the first plane to take off, the implementing plan will be written and the cell formed.

Another aspect of the cell forming routine is concerned with aircraft maintenance on the bases. The computer, as part of its record-keeping function, maintains what is called a base list. The base list gives for each base the number of runways, the maximum length of usable runway, the amount of above-ground fuel, the amount of below-ground fuel, the number of hydrants, the number of maintenance slots available, and the number of different types of weapons in the weapons stockpile. Treating each plane on an individual basis, the machine determines whether it needs maintenance, bombs, or fuel, and furnishes them if they are available. It calculates the time needed to perform these operations which keep the aircraft out of action. Airbase inventories of fuel and bombs are reduced accordingly.

Routine 4 — Targeting

The major product of the targeting routine is a list of ground zeros for each weapon reaching bomb release line. These ground zeros are obtained by taking into account the radius of probable error for each of the types of aircraft and the mode of delivery for each weapon reaching target point. By the Monte

Carlo method a precise point of burst is obtained for each weapon. The targeting routine also takes into account the possibility of a gross navigational error. A determination is made by the Monte Carlo method as to whether there has been such an error, and if so a random target is selected for the bomb release point.

Routine 5 — Damage

The damage routine calculates the effect of bombing on military installations. It considers nuclear weapon effects in two categories, blast and radioactive fallout. Different blast effects are used for air burst and ground burst. The effect of fallout is to make installations inoperative while it is above a certain tolerance level. Blast damage is calculated for each installation close enough to a ground zero to be affected. Each type of air defense installation has an appropriate kill radius measured from the ground zero. If the installation is within the kill radius it is destroyed.

Offensive bomber bases are treated in more detail. Each of them has a geometrical array of points which represent existing runways, parkways for planes, maintenance facilities, above-ground fuel storage, hydrants, and bomb storage sites. When a weapon explodes in the vicinity of a bomber base, the amount of damage to the various facilities and to the planes which may be located at those facilities is determined on the basis of the appropriate kill radius, and the status of the base is revised accordingly.

Application of the Air Battle Model to Air Targeting

Assuming that a war situation has been set up as needed for model runs, how would the runs be made, what products would result, and how would the outputs be used? How can resulting estimates be applied to targeting problems? We know that war gaming will only provide an idea of how things might go in a war under certain assumed conditions rather than provide an estimate of how the war will actually go. Results will be only comparative among themselves — that is, we will be able to say that one type of attack is probably better than a second under certain conditions, whereas the second may have better effects under different conditions.

The results will not be indicative of how war will go for at least two reasons: first, because we know that our inputs are of tenuous validity, and second, because certain result-determining conditions must be assumed and will never be explicitly analyzable. This is to say that the detailed results of single runs will rarely be meaningful; results can only be significant after consistent occurrence in many runs. For example, loss of all facilities at Thule Air Force Base during the first few hours of war becomes useful information only when it can be shown that it occurs most of the time under chance variations and under a variety of Soviet strike plans.

Conversely, aggregate measurements of effects will be of greatest significance for any one set of inputs. The status, eight hours after initiation of US operations, of the 25 key Soviet staging bases for attack on the US will be more meaningful than the status of the Anadyr airfield. Because aggregate measurements will be of such significance, the Air Battle Model has been programmed to provide certain of them for each time period. First, aircraft counters for each time period record the number of aircraft killed on base, the number killed by abort, the number killed by local defenses, the number killed by area defenses, the total number killed in flight, and the number arriving over enemy territory. Second, installation counters record the number of bomber bases killed (inoperative because of damage), the number of surface-to-air missile sites killed, the number of radars killed, the number of bomber bases out from radiation, and the number of radars out from radiation. Third, a counter of ground zeros records the number of offensive weapons exploding each time period. Fourth, new cell counters record the number of cells and the number of bomber and tanker aircraft taking off each time period.

A typical use of these counts might be to indicate the effect of different degrees of warning, different intervals of time between the start of aggression by one side and the awareness of it by the other side. This problem is set up with the resources and plans of both sides fixed, leaving as the only variable the interval between the times the two sides start to implement their plans. Playing through the problem several times with the warning time set at different values will show the effect of warning on the number of aircraft killed, on the number of cells formed, on the status of installations, and on the number of weapons delivered by each side.

These aggregate counts provide indications of how the war is going and to what extent the air battle objective is accomplished in each period. Much more detailed information is needed, however, for analysis of why things are going as they are. For this purpose other measurements are now programmed for the output of Air Battle Model runs. Whenever a cell reaches initiating point or performs an in-flight plan, information on the nature of the cell and what it is doing is recorded. A ground zero list by time period notes the unit number, cell number, bomb size, and location of each ground zero during the course of the game. Various presentations of these data would permit large-scale analysis of the air battle in any significant area or group of areas of the northern hemisphere. It would show by area and by time, for example, the level and type of air activity, the build-up of enemy aircraft within the area, the attrition of incoming enemy aircraft by defenses in the area, the weapons delivered by enemy bombing and the explosion of weapons shot down, the effects of enemy flights and bombing on the planned operational schedule of friendly forces in the area, and the effects of enemy bombing on offensive and defensive facilities.

One of the major problems of the Air Battle Model lies in the vast quantities of data it generates concerning the history of a war. Selection and presentation of only a small portion of possible outputs is required for practical use. Careful review of many study problems over a long period of time will be required to provide assurance that most of the pertinent available measurements are saved and recorded in usable form. Manual review of even those outputs described above would be too time-consuming for practical use, and mechanized presentation procedures are now under development. The comparison of the outputs of different runs is also expected to be time-consuming. A methodology for such comparisons, aimed towards mechanization, is now under development. Similarly, the results of many runs will need aggregation for purposes of hand analysis, since the computer can grind out results (e.g., ground zero patterns) much more rapidly than they can be reviewed.

With the preceding background in mind, let us examine the kind of Model runs that will be needed. Remember that the basic purpose will be to estimate the degree of accomplishment of the air battle objective achieved by our selection of targets and target systems, and the major subpurpose to estimate the influence of a planning decision or a group of planning decisions on the outcome of a battle for air supremacy and survival. And bear particularly in mind that our confidence is high only in the *comparative* results of war gaming.

There are four broad types of Model runs required for these purposes. First, one-sided runs with all input data constant will indicate the operational limitations on each side's plans and segregate the offensive and defensive problems faced by each side. These runs will show the unopposed capabilities for each side, providing a basis for estimating in later runs the extent to which the other side can interfere with these capabilities. Second, one-sided and two-sided runs with all input data constant will determine the chance variations both in the unopposed execution of plans and in the interaction of forces of the two sides. Third, runs with variations in one or more input parameters will determine the sensitivity of results to a range of values for assumptions and low-confidence estimates. Fourth, runs with basically different sets of inputs will compare significantly different strategies and force availabilities.

In refinement of the first type of run, a great deal can be learned about an air battle through a series of runs of one problem with fixed inputs except for the use by one side or the other of its offensive or defensive capabilities, or both. There are seven meaningful combinations of these conditions. In the first two cases only the offensive capabilities of one side are represented, with no defense or offense by the other. Such runs measure the maximum effectiveness of that side's given operational plans. Case three is a full scale two-sided run, in which both offensive and defensive capabilities of both sides interact. By comparison with cases one and two it measures the extent to which the offense-defense and defense-offense interaction reduces the maximum effectiveness of each side's plans. In the fourth and fifth cases the offense of one side is pitted only against the defense of the other. These measure the maximum effectiveness of each side in the absence of offensive effort by the other, and comparison with the full scale two-sided run (case three) gives a measure of the extent to which the offense of one side reduces the effectiveness of the other's offense. In cases six and seven one side only does not defend; the results may be compared with case three to see to what extent the defense reduces the effectiveness of an attacker.

Before we can compare the influence of different decisions on the outcome of an air battle, we need runs of the second broad type to determine the influence of chance on the outcome for each decision. We know that a specific attack against a specific target system may have a wide variety of possible effects, depending upon precisely which aircraft get through to which targets and when, and which aircraft bomb accurately and which inaccurately or with gross error. Information will be required as to the effect of such chance distributions on many of the basic outputs. Since the Air Battle Model employs Monte Carlo techniques to simulate chance events, a series of runs should be made on each set of inputs with different sequences of random numbers to obtain different chance results. All other conditions should be held constant. Statistical analyses of the distribution of the chance variation in results will determine the spread which may be expected with one set of input conditions and indicate how much confidence one can have in a particular outcome.

The third type of run analyzes problems with variable basic conditions. The effects of any particular planning decision must be reviewed under varying basic assumptions and conditions. These analyses will generally not require revision of basic terms of reference or input sets, but will be effected by changing one parameter value at a time; values higher and lower than "best estimate" values will be used for the parameter under study. These parameter variation runs will show the effect on the outcome of the battle of variations in the speed of bombers, effectiveness of use of radar and ECM, bombing accuracies, time of year and time of day of starting hostilities, reaction time after warning, weapon yields, aircraft evacuation policy for bases under attack, personnel evacuation policy for bases under radiation hazards, and many other factors.

Study of parameter variation effects combined with analysis of the effects of chance will require many runs. Fortunately, it is possible with the Air Battle Model to rerun problems with the same random number sequences for the simulated chance events. It is possible, therefore, after determining which sequences of random numbers yield for example very lucky, medium and very unlucky results on a problem, to use these same sequences again to obtain the lucky, medium, and unlucky results of a parameter variation for the same problem.

The results of parameter variation runs, incidentally, offer a tremendous feedback for establishment of intelligence collection and analysis requirements. They indicate the sensitive conditions and inputs on which estimating capabilities should be concentrated. If ECM effectiveness has a significant influence on the effects of the air battle, then priority efforts should probably be devoted to the study of enemy ECM capabilities. Conversely, if a plus or minus 30 percent variation in the speed of bombers has little or no influence on the outcome of the air battle, then attempts to refine estimates of bomber speeds should be given lower priority. Similarly, the runs indicate the sensitive operational considerations which are the key terms of reference in planning estimates.

The fourth type of runs will be required for analysis of "big picture" problems. These require basically different sets of inputs. Variant data reflecting capabilities at short, intermediate, and long range must be used. Several different enemy courses of action should be examined for each time period, and at least one countering US course of action for each. Several US target systems and target system priorities coupled with differing US strategies based on varying amounts of warning should also be studied. Some of the other plan revision factors important in this study are weapon constraints (such as non-use of surface-burst thermonuclear weapons in certain areas of the world), US weapon deployment at initiation of hostilities (in the Zone of the Interior only, or also overseas), delivery force sizes for both US and SU, delivery force structures (including missile-bomber mixes), and Soviet offensive aircraft deployment (at peacetime bases in one case and also at advance bases in another). The formulation of input sets for such studies will take a long time, and our ability to perform these studies in the future will depend upon the programmed development of such input sets.

The Air Battle Model is designed to evaluate the operational and logistic factors bearing on the identification and analysis of a target system for our strike forces. The specification of such a target system, with full assurance that we have the right targets and the right weapons on them at the right time under varying operational conditions, exceeds the capabilities of the best analysts and planners. Human minds cannot keep the thousands of facts and relationships under analytical control and see them as they affect the whole problem. For these reasons we have been pressing the development of this mechanized analytical technique. The Air Battle Model appears to offer the best solution now available to some of the important problems air targeting must solve.