USE OF MATHEMATICAL TECHNIQUES AND ELECTRONIC DEVICES IN THE DETERMINATION OF REQUIREMENTS

12 December 1950

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RESTRICTED

Mr. Marshall K. Wood, Chief, Planning Research Division and Assistant Director of Program Standards and Cost Control, Deputy Chief of Staff, Comptroller, U. S. Air Force, was born in Washington, D. C., 19 February 1914. He was graduated from the University of Chicago with a B.S. degree in 1935 and has taken graduate work at the University of Washington, 1939 and North Carolina State College, 1941. Prior to his college work, 1930-32, Mr. Wood was a research associate in internal combustion engineering at the National Bureau of Standards. From 1936-1942 he was associated with the U. S. Forest Service on range survey and flood control work. In 1942 he was appointed statistician, Statistical Control Division, Army Air Forces. Under Assistant Secretary Lovett's direction, he developed the first comprehensive Air Force program, "Working Schedule for the 273 Group Program," for which he was awarded "Emblem for Meritorious Civilian Service." From 1944-1948 he has been associated with the Air Comptroller, Office, Program Analysis Division, as program analyst and assistant director of Program Analysis. During this time he developed systematic programming, planning, and scheduling procedures which are now in use by the U. S. Air Force. In 1948 he was promoted to Chief, Planning Research Division and Assistant Director of Program Standards and Cost Control, Deputy Chief of Staff, Comptroller U. S. Air Force, which position he now holds. As part of his duties in this capacity, he initiated and directed project SCOOP, "Scientific Computation of Optimum Programs," which is designed to provide systematic techniques for military program planning, utilizing computers and mathematical techniques. He is also the Air Force member, Munitions Board Committee on Electronic Computers.

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MR. HENKEL: General Holman and gentlemen: In practically all the talks on the determination of requirements this year there is one element that seems to run through all of that. That is the matter of developing more speed in the computation of requirements. The various military services have recognized this weakness and are making studies to overcome it. No doubt one of the most intensive studies is that being done by the Air Force under the guidance of our speaker today. You Air Force officers know this by the term SCOOP--Scientific Computation of Optimum Programs. I might also add that the Logistics Branch of the Office of Naval Research has made a contract with George Washington University for a similar study.

Mr. Wood spoke to us last year, and it was the feeling of the Requirements Branch that he should repeat his talk this year. He is Chief of the Planning Research Division and Assistant Director of Program Standards and Cost Control, under the Deputy Chief of Staff, Comptroller, United States Air Force.

Mr. Wood, it is a pleasure to welcome you back to our platform this year. Gentlemen, I present to you Mr. Wood.

MR. WOOD: Thank you, Mr. Henkel.

General Holman and gentlemen: The first step in determining requirements is to define what it is that we are determining requirements for. This is a comparatively simple job in wartime, relatively speaking at least, when we have a definite job to be done and have only to determine the requirements to carry it out. In peacetime we have a more difficult job, because in peacetime we are not determining the requirements to do a peacetime job; we are determining the requirements to do a wartime job. Furthermore, we don't know exactly what the wartime job is or when we are going to have to do it.

The peacetime program is not an end in itself but must be directed toward creating a position of strength, as Mr. Acheson puts it, which will deter the initiation of aggression by other powers and, which will, concurrently, insure against our defeat if war is forced upon us. In either case, the criterion of the success of the peacetime program is our ability to successfully fight a war if it is forced upon us.

This capability is only partially determined by our peacetime military program. It depends primarily and most directly upon our

ability to produce, in wartime, the trained manpower, organizations, personnel, supplies, and equipment, military and industrial, which are needed to carry out the wartime program. Given a stated requirement to be met in wartime, we would choose to meet as much of this requirement as possible from current production, whether it be the production of supplies and equipment or the production of organizations and the training of personnel. Only that portion of the wartime requirement which cannot be met concurrently during the wartime period need be provided from the peacetime program. This provision in the peacetime program might be in regular units or in Reserve forces, war reserve stocks, industrial reserve equipment, or material stockpiles.

The steps in determining a peacetime program are then as follows: first, to define in terms of war plans, for as many future dates and alternative assumptions as possible, the actions necessary to successfully prosecute the war. These actions, as stated in war plans, are generally limited to a statement of the major combat operations to be carried out. The second step is to translate these combat operations, as specified in each war plan, into a mobilization program, and to determine all the supporting actions necessary to carry out the war plan. The third step would be to determine the extent to which these requirements, as generated by the mobilization program, can be met from current production during the wartime period. (We use "production" in the broad sense here, to include training of personnel, training of units, as well as the production of supplies and equipment.) The fourth step would be the determination of the D-day requirements, which would consist of that portion of the wartime requirements which cannot be met from concurrent production and training during the wartime period. The fifth step would be the determination of the peacetime program itself, that is, the specification of all the actions necessary to get us from our present status to the required D-day status.

Chart 1--Planning, Programming and Budget Cycle, page 19.--This chart illustrates in general the relationships between these various steps. This is drawn in terms of a series of successive sets of plans in different years. There are generally three sets of plans. First, we have a short-range emergency war plan, together with a mobilization program defining the supporting actions necessary to carry out the war plan. Then we have an intermediate-range war plan extending over a longer period and a related mobilization program defining the supporting actions necessary to accomplish it. Finally, there is a long-range war plan, in outline form only, with a statement of some of the major supporting actions necessary to carry it out, principally in the research and development and construction areas. Obviously this long-range plan can be only in fairly general form.

We have, then, a statement of the peacetime program, starting from the initial status, which presumably is consistent with the initial status of the emergency plan, and continuing on to attain the D-day

status of the intermediate-range plan and the long-range plan. The rest of this chart is merely a repetition of the same process in succeeding years. Obviously, we might, and should if we could, have several alternative plans for each time span, and we might have more time spans than the three we have indicated here.

I think everyone is familiar with the first of these steps, that is, the determination of war plans. This is not a phase to which, at the present time, we feel we can apply mathematical techniques or electronic computers. The problems involved are much too complex and difficult to formulate and, in general, our problem has not been a lack of war plans. We have had almost a plethora of them, although perhaps a shortage of accepted and feasible plans.

The second stage is the development of a mobilization program to support the war plan. It involves essentially the same steps as the preparation of a wartime program. The following chart illustrates the steps which were involved in the preparation of an Air Force program in wartime.

Chart 2--Schematic Diagram of Major Steps in Air Force Wartime Program Scheduling, page 20.--It starts from the development of the statement of the war plan itself, from which we make parallel determinations of the deployment of tactical units to combat theaters, and an intelligent estimate as to enemy capabilities to react against our proposed deployment. From these we have to determine the attrition, loss, and retirement rates of aircraft, crews, and other equipment which will stem from the interaction of our deployment of forces with the enemy's forces. From these we can develop schedules of required combat crew and aircraft shipments to theaters. Concurrently, we can determine from the unit deployment the required schedule of activation, training, and movement of units. From the requirements for activation of units we can determine the requirements for crews to go into those units, and from these requirements, plus the requirements for replacement crews as developed earlier, we can determine the combat crew-training program.

I don't think I need to follow this through in detail. There is a fairly long sequence of steps which took us something like seven months in wartime, and which now takes a good deal longer in peacetime with reduced staff and personnel. I believe the last time the Munitions Board asked the three military departments to state their time schedules for the determination of requirements to implement a war plan--essentially the steps illustrated here--each of the three departments said it took over two years to carry out these steps for any given plan.

We don't have any comprehensive analytical procedure now available for accomplishing the third step, that is, the determination of the extent to which wartime requirements can be met from production after

D-day; yet the peacetime program is absolutely dependent upon the accuracy with which this step is accomplished.

Chart 3--Monthly Requirement, Maximum Production, etc., page 21.--This chart illustrates this problem with hypothetical data for a particular item. The broken line gives the month-by-month requirements for the item to meet the requirements of the plan. Because of limitations on the rate at which the production of the item can be expanded, the production, indicated by the line immediately below the broken line is less than requirements. This indicates the maximum production which can be obtained for this item, given the scheduled initial production rate of 96 per month, which was fixed by the peacetime program.

You notice we have a big requirement--6,000 plus on D-day--which is the initial requirement for equipping all units and filling initial pipelines. Of course, many of these will be on hand in the peacetime structure.

The line starting at 6,000 and curving downward illustrates the cumulative deficits which result from the differences between the requirements line and the availability line. We see that this deficit gets worse and worse until about D-day plus 27 months, when it reaches a figure of some 16,000. If, then, we go into a war with this initial production rate we must be prepared on D-day, in our peacetime structure, to have the additional 16,000 items stockpiled some place if we are to meet the war-plan requirements. Of course, if the initial production rate were greater, the expansion could be more rapid and the deficits would be less.

The same kind of picture could be drawn for aircraft, aircraft engines, or a variety of other items. We have also made similar studies for aviation petroleum which show essentially the same kind of picture.

We have this same kind of relationship to work out as we go through the program, to determine what our peacetime program must provide, and what our D-day status must be, in each major item for which there is some sort of limitation on the rate at which the production can be expanded. This includes a wide variety of items. In many cases, as, for instance, the training of pilots, it would be obvious that our peacetime pilot training program would have and could have no relationship to our peacetime operating program, but instead must be directed primarily toward providing, either in the regular forces or in the civilian components, this "stockpile" of personnel. A similar situation exists for other major types of personnel and equipment.

So far as I am aware, this type of relationship has not, until very recently, been a controlling consideration in the development of peacetime programs in any of the three departments. I am illustrating this to point out the logical dependence of peacetime programs on

wartime requirements and the independence of peacetime procurement programs of the requirements for support of peacetime programs in many areas.

The preceding discussion has covered essentially the third and fourth steps, the determination of the extent to which requirements can be met from concurrent production in wartime, and the deficit between wartime requirements and concurrent production capabilities which generates the peacetime requirement. The determination of the peacetime program then becomes the final step--the job of getting from our current status to the required D-day position.

Chart 4--Schematic Relationship of War Plans and Current Program, page 22.--This chart illustrates schemically the dependence of the current program on the various war plans. The emergency war plan provides no guidance for the peacetime program, but is instead actually a derivative of it. It should be an expression of what can be done with the existing status. The program in most areas should be directed toward meeting the required D-day status of an intermediate-range war plan, with a D-day something like four years from the present, because of the necessary time lags involved in actually planning the peacetime program and carrying it out through the program-budget cycle. Major areas in construction and research and development would be related in part to an intermediate-range plan, but more directly to a long-range plan because of the long lead times involved.

Chart 1--Planning, Programming and Budget Cycle, page 19.--This chart illustrates a possible schedule for fitting together these various steps and points out some of the reasons why we have to pin the peacetime program to an intermediate-range plan with a D-day something like four years hence. This chart allows six months for the preparation of the war plans and their translation into a mobilization program and a statement of the required D-day position (a job which the departments now say takes two years or more).

Following this, three months are allowed for the development of a detailed peacetime program to attain that D-day status. (This is a job which now requires, I think, much more than three months in any of the three departments.) However, this task must be completed by about this date in order to provide approximately three months for the development of the budget estimates, for their review by the departmental budget advisory committees, the Joint Chiefs of Staff's program and budget advisers, and the Office of the Secretary of Defense, so as to meet the statutory date for submission to Congress on the fifteenth of September. Review by the Bureau of the Budget takes from 15 September until the first of the year, and congressional action takes six months after that, which brings it up to the beginning of the fiscal year for which the funds are appropriated.

During this next fiscal year the appropriated funds are obligated, but, because of lead time, our operational capabilities are not materially affected until the following year. Therefore these plans which we started in July of 1948 relate primarily to the creation of a combat capability in 1952.

It is obvious this is not the way things are presently being done, because the capability doesn't exist to do the job this fast. This is a somewhat "idealized" cycle in order to get it into the four-year time span.

It is thus apparent that peacetime programs have necessarily been developed largely independent of explicit strategic guidance except for the composition of the combat forces themselves. There has not been time nor capability to explicitly relate peacetime procurement and logistic programs to war-plan requirements.

About three years ago, in an attempt to overcome some of these difficulties, we set up, in the Air Force, a Planning Research Division of the Comptroller's office, with the idea that, through the use of modern techniques of numerical analysis and the use of high-speed electronic computers, we might be able to short-cut these operations to reduce this time span and thereby make it possible to explicitly relate our peacetime requirements to war plans, wartime programs, and the requirements stemming from them.

We hope to do this through the development of what we call a mathematical model of operations. This mathematical model attempts to define quantitatively the interrelationships between all of the different activities in which the Air Force engages. It consists basically of a series of equations, each of which prescribes equality between the requirements for and the resources of a particular item in a particular time period. The variables in each equation are the activities which use, produce, or consume a particular item; and the items may be combat sorties, trained military organizations, personnel, air fields, aircraft, vehicles, supplies and equipment of various sorts. The coefficients in the equations are the amounts of each item required (or produced) as a result of a unit operation of a particular activity for one time period. There will be one equation for each item or group of items being programmed, for each time period in this program. To compute a program, we must solve this system of equations for as many time periods as we wish the program to cover. We felt that if we could successfully formulate these relationships, we could greatly reduce the time span in this process through the use of high-speed electronic computers.

We haven't as yet succeeded in getting into practical operation any of the several electronic computers which have been built and are being built for this purpose. We have managed, however, to come pretty

close to completing the formulation of the basic equations defining the Air Force structure, the interrelationships of Air Force activities, and at least a first approximation to the planning factor coefficients which go into these equations.

To try to get some feel for the operation of this system, we have started with existing punched card equipment and are now computing wartime programs using this system on an experimental basis. Using this system, we are now able to compute essentially a complete mobilization program to support a war plan in three to four months, as compared with the roughly two years required to do a comparable job by normal staff procedures. We believe that by the end of the current year, when we get the "bugs" out of the electronic computers, we will be able to cut this time down by a factor of at least ten, and perhaps much more.

Chart 5--Example of Coefficients Used in Mechanized Program Computations Activity: Heavy Bomb Wing Combat Operations, page 23.--This chart illustrates basically what the formulation of this mathematical model is and how it works. It starts with a statement of the basic planning factors and interrelationships between the activities. This chart is a very simplified picture of one activity and its requirements, the activity being heavy bomb wing combat operations. Its output, the reason for its existence, is to produce heavy bomb "wing-months." It produces heavy bomb "wing-months" at the rate of one per month over a time interval from the time of initiation of the activity to one month later. These heavy bomb "wing-months" are tied, in any real plan, to specified sortie and attrition rates. These in turn are derived from detailed analysis of the requirements to accomplish the objectives of a plan, in terms of sorties at particular ranges and against particular types of target systems with particular bomb loadings.

In order to produce this one unit of output, which is produced continuously as a flow over this one-month time interval, we must have various other items available. The first thing we need is the bomb wing itself, which is an aggregate of all the personnel and equipment in the Table of Organization and Equipment with the exception of the aircraft. We have handled the aircraft separately for a variety of reasons. We need to have this bomb wing in place as an instantaneous requirement at the beginning of the month in which we are going to operate. At the end of this month it becomes an output, for operations in a subsequent month.

We also need thirty aircraft to carry out the operation, again as an instantaneous requirement at the beginning of the time period; and these become available at the end of the time period for operations in a subsequent time period. Both the bomb wing and the aircraft are in effect capital equipment of the activity.

In addition we need a flow of six aircraft per month over the one-month interval for attrition replacements. Similarly, we need a flow of five combat crews per month for attrition replacements, and another flow of five combat crews per month for replacements of retirements over the interval from three to four months later, anticipating the period when the crews who flew sorties in the first month will have completed their combat tour. (All of these figures are illustrative, not actual.)

Seven months later we get a production of fifteen retired combat crews as an output of this activity. This represents the time at which the initial crews of this unit will have completed their combat tour. We started flowing in replacements for retirements at an earlier date in order to avoid the problem of having to replace all of the crews in the unit at one time. This replacement flow will provide a temporary overstrength prior to the period when the initial crews will be retired. Similarly, we get a flow of two and a fraction crews per month per wing for the period from seven to eight months after the start of operations, and some more from ten to eleven months, representing the retirement replacements for the first attrition replacement crews and the first retirement replacement crews, respectively.

We need, similarly, a flow of what we have here called "flying hours." This is a shorthand notation for an aggregate of all the supporting aircraft supplies and equipment. What we are actually furnishing are maintenance supplies and equipment for the operation, measured in terms of flying hours, as a measure of the activity of the unit. The unit of this "item" is the number of hours flown; this is converted by another activity later into the individual items of supplies and equipment, which are needed.

We need also a flow of technical personnel for replacements of attrition on the ground personnel. This again is an aggregate comprising a very large number of military occupational specialties, with very small figures in each one.

Finally, we need bombs, 1,200 tons per month, as a flow over the one-month period for consumption. We have a capital requirement of a two-month supply of bombs on hand at the beginning of the period as a stock level, which still remains as an output availability at the end of the period.

These are the basic building blocks of the mathematical model. They define the relationships between each activity and all of the other activities which support it.

Chart 6--Example of Coefficients Used in Mechanized Program Computations Activity: Heavy Bomb Combat Crew Training, page 24.--This is a similar picture of heavy bomb crew training activity. I don't think we need to go over this in detail. It has much the same

characteristics as the previous chart. Its output is trained combat crews instead of sorties or wing-months. Its inputs are pilots (for students and instructors), navigators (bombardiers for students and instructors), flexible gunners, aircraft, and flying hours, which again are a measure of the supply requirements to support the activity. This chart illustrates schematically the interrelationships of the activities in our mathematical model. It is analogous to the chart we discussed earlier, Schematic Diagram of Major Steps in Air Force Wartime Program Scheduling.

Chart 7--Sample of Relationships Used in SCOOP Computations, page 25.--We start with a specification of combat operations which corresponds to the war plan in the staff procedure. The amounts of the combat operations activity are specified by the war plan. Its coefficients down the column represent its requirements for supporting supplies, equipment, and personnel. They are the same kinds of coefficients which I showed you on the preceding two charts. On this chart we merely employed a plus or a plus and a minus to indicate the existence of a coefficient of like sign in a particular cell. If we had a larger chart, we could show the actual numbers, as we did on the previous charts, illustrating the derivatives of the coefficients.

This chart is drawn purely to indicate general relationships. Each of the columns represents a group of coefficients of the type that you saw on the preceding two charts. By multiplying the amounts of combat operations activity by its coefficients in the first column, we determine then its requirement for combat wings, combat crews, aircraft, ammunition, fuel, serviceable engines, maintenance of spare parts, bombs, and bases, and the availability, indicated by a minus sign, of retired combat crews and unserviceable engines.

Since there is no other activity except combat operations which uses combat wings, this defines our requirements for the activity of shipping combat wings from the zone of the interior to combat areas. It also defines our requirements for shipping combat crews, aircraft, ammunition, fuel, serviceable engines, and maintenance spare parts. All these other activities are completely determined when we have specified the combat operations, since these items are used only by the combat operations and the activities exist for the purpose of satisfying the requirements of the combat operations for these items.

Down to this point all of the activities are completely determined by the basic equations, which state that we can only use what we produce. If we are going to use the amounts which are required by the combat operations, we must then produce them by comparable levels of supporting activities.

When we have defined these, however, we have also defined our requirements for a number of other items. You can see that this

activity of shipping combat wings to overseas theaters generated a requirement for combat wings in the zone of the interior.

These are satisfied then by the activities of combat wing training and combat crew training. These in turn define our requirements for rated personnel (flying personnel), which in turn define our requirements for shipping rated personnel other than crews--that is individuals --to combat crew training.

Each time we add a line on the chart, we define the requirements for one or more additional activities, which in turn define the requirements for additional items, which in turn define the requirements for additional activities. Thus we can proceed down the chart to the determination of our requirements for flying training graduates, nonrated personnel, technical training graduates, aircraft ammunition, and fuel, and finally their requirements against supporting industry.

It is possible to make wide variations in the types of detail with which we consider the mathematical model. The next chart illustrates a little more in detail some of the activities and items involved in the determination of heavy or medium bomb aircraft requirements.

Chart 8--Interrelationships Among Activities Affecting Requirements for Heavy or Medium Bomb Type Aircraft, page 26.--This is a section essentially of the last chart, blown up into more detail. This still represents a great simplification of what we are actually using. The actual model that we employ for computation is in much more detail than is described here.

We have, then, complete latitude in the formulation of a model, in the level of detail at which we consider activities and items, depending upon the amount of time spent on it, the amount of detail desired in the answers, and, of course, the amount of detail in our basic planning factors and coefficients.

You will notice that this model, as it stands, gives a completely defined answer merely by a straight-forward computation, once the war plan has been stated. Actually, we know that we do in fact have many alternative ways of doing things, that there is more than one way to do everything, and that in fact we must consider many alternatives. We have made only a beginning at introducing some of these alternatives into our planning model. Actually, any wide-scale introduction of considerations of alternatives involves a very great increase in the computing requirement, which we cannot handle until we get the large-scale electronic computers that we hope to have working by midsummer. We have, however, introduced into this model some elements of choice between alternatives. We can do this where we can state a priority between two different activities and where the choice is conditioned by the availability of resources. We have been able to incorporate

into our mathematical model an allocation procedure for allocating the available resources of aircraft of a given type (such as medium bombers) to particular activities by type, model, and series. Thus, if we have two models of medium bombers, B-29 and B-50, we can compute, on the basis of a statement of priorities given by the operations staff, how many should go in each time period to each particular activity.

Given such a statement of requirements on the part of the three military departments, consistent with the limitations on production capacity for major military end items such as pilots and aircraft, we still have to determine the over-all feasibility of the program. This involves the determination of essential civilian requirements and the analysis of the adequacy of productive capacity and critical materials availability to meet total military and essential civilian requirements. This requires a different kind of procedure. It has seemed to us that the interindustry relations or input-output technique, developed some years ago by Professor Leontief of Harvard, could be adapted for this purpose. To accomplish this, the Air Force has sponsored and supported extensive research and development of this technique in order to provide a planning model for the supporting industrial economy. This model is essentially parallel in its formulation, to the Air Force planning model which we have been developing for internal program planning.

This interindustry relations technique provides a model of the supporting industrial economy, classified into industry groups which are analogous to the activities used in our Air Force planning model. Given the statement of total requirements against these industries (which would come out as one of the end products of the computation of the military requirements plus essential civilian requirements), we can then determine in exactly the same fashion the requirements of each of these industries from all of the other industries from which they purchase their components and materials. Thus we can go back up stepwise through the entire supporting economy, determining successively the levels of production of each industry required to support the stated output levels of the industries producing final end items or final demand.

If we are able to state the capacity limitations of these industries, the purchase requirements for creation of new capacity, and perhaps, also, limitations on the rate at which capacity can be expanded, we can determine the particular combination of initial production levels of each industry, and initial quantities of products of each industry which are needed on D-day in order to permit or create the capability for carrying out the desired program.

I think I had better cut this short at this point and leave the rest of the time for discussion.

QUESTION: I would like to raise the question whether this technique you describe has actually been used in practice. For example, before Congress is the second deficiency bill for fiscal year 1951, I understand, which has recently been calculated on some such basis. Was this technique that you described used at all in deriving the requirements which subsequently were used in the budgetary estimates?

MR. WOOD: There are several different answers to different parts of that question. Let us take the last part first. On the supplemental estimates, the whole technique as I have outlined it here was not used, although some subsidiary parts of the estimates were based on SCOOP techniques. These SCOOP techniques (which I didn't describe here in detail) provide a method for building up aggregates of supply requirements in dollar terms as a function of the size of the program. These are techniques which we developed some three years ago for use at Air Materiel Command to provide for quick preparation of budget estimates. These techniques were used for preparation of that portion of the budget estimate which related to supplies and equipment and permitted us to reduce the time necessary for the computation of requirements for these individual items of supplies and equipment to a matter of a few days, instead of the six to eight months formerly required.

The bulk of the estimate in terms of dollar value stems from principal items such as aircraft, engines, and personnel, which are explicity computed on the basis of particular program schedules. SCOOP techniques were not used for these portions of the program and budget estimates. The big time-consuming job has been the computation of requirements for supplies and equipment. This we have reduced to a matter of a few days' computation with our SCOOP techniques. These techniques have been in use for about two years for the preparation of both regular budget estimates and quick revisions thereof.

The reason the whole technique has not been used is that, so far as we can see, the use of the technique depends upon an explicit definition of the objectives of the program. As I tried to illustrate earlier, we can't see any way to compute requirements for a peacetime program until we have defined what that peacetime program is to accomplish Thus, we can't determine our peacetime pilot training program in terms of our peacetime group structure. It has little or no relation to it. It must proceed at a rate many times greater than is necessary to supply our peacetime establishment, in order to create the necessary reserve of personnel to meet wartime requirements.

The same thing is true, as we see it, for most major items of equipment; for aircraft, for engines, and for a variety of major component So far as I am aware, this last blitz budget recomputation was not tied to any explicit determination of wartime requirements, but, rather, was tied to an expansion of the peacetime structure without any clear definition of what this structure was to accomplish. Until we have defined our basic objectives, we can't determine our requirements.

The technique, however, has been used and is being used in toto for the determination of wartime requirements for the Munitions Board. The Munitions Board directed on 25 May 1950 that each of the three military departments compute in detail its wartime requirements for carrying out the wartime programs implicit in the JCS interim guidance.

Our SCOOP techniques were used for developing the operational programs to carry out the JCS interim guidance and for a substantial part of the individual item requirements for supplies and equipment to carry out the operational programs. Our techniques were not developed to a point permitting the computation of all item requirements, but part of the work was done by conventional methods at Air Materiel Command. The major part of the work was done by using these techniques. We haven't yet, however, bridged the gap completely between the statement of the wartime requirements and its translation into peacetime requirements.

QUESTION: Mr. Wood, I understood that you took these cards of coefficients and simply transcribed them onto a mechanical tape for entry into your computer. I would like to have you confirm that that is the technique; and, if so, what is the limit on the number of coefficients that you can put in a computer of feasible size?

MR. WOOD: At present we are using punched-card equipment. Coefficients are contained on punched-cards of the conventional type, with which you are all familiar. When we get the large-scale electronic computer working, we will be transcribing from punched cards on to either magnetic wire or magnetic tape, or both. We have both types of equipment under development. There is no limit to the number of coefficients you can put in, because you can use as many reels of wire or tape as you wish.

In terms of our present computing procedure, with the punched-card equipment, we have something upward of a million coefficients that are involved in a complete computation of the mobilization program. This is overtime, however. The actual basic coefficients from which the coefficients overtime are generated is a much smaller number, possibly 25,000. I don't know that I can give you a precise figure on that.

QUESTION: I don't want to ask you a technical question, but I am concerned about the time cycle. My impression is that it takes us two years to complete the requirements cycle, forgetting the procurement lead time, and that we must be utilizing the ordinary, soon to be out-moded electrical accounting machines to the fullest extent. If it takes us two years now with the very best equipment we have, perhaps the utilization and the perfection of the electronic computers may be our only hope of shortening this cycle. Is that correct?

MR. WOOD: Most of the two years that it takes us to compute requirements by our present methods is devoted to the development of

the operating program upon which the supply requirements are based. This is not mechanized with punched cards, accounting equipment, or any other kind of mechanical equipment except for the SCOOP operation, which I have been describing. As I indicated, we can cut this time down very greatly through the utilization of presently available punched-card equipment. In connection with this Munitions Board job, we have been through the complete development of an Air Force wartime operational program from the JCS interim guidance in a matter of two to three months. Except for this, no use is being made of mechanical techniques for the determination of the operating program, the troop program, and all the other things which go with it. This is the major time-consuming area. I think the first place where we can save is by mechanizing that area. The computation of item requirements has been mechanized but that is the tail end of the operation. The big bottleneck is ahead of that.

QUESTION: How much time does that last part take after you get your plan all set and you go into the individual departments?

MR. WOOD: I don't know that I can give you good figures for present techniques in all three departments, but I would say it is a little under a year. It is hard to make a clean break, because the various tasks overlap. Some parts of it take more than a year and some less. Some of the operational plan gets done in less than a year and some takes more. I think more than half of that two-year period is devoted to the preparation of the operational plans and programs which are prerequisite to the determination of supply and equipment requirements.

GENERAL HOLMAN: It seems to me in the computation of requirements for an all-out mobilization, where your quantities are changing rapidly, with new factors coming in and new equipment, that a lot of this labor requiring the two-year cycle is due to having too much attention paid to the quantitative requirements, the numbers of end items that you are going to need for particular programs. Then, as soon as a new assumption is brought in, all that work has to be done over to get quantitatively the exact number of end items.

Now, instead of looking at this thing and saying what you will need a year from now, what you will need two years from now, what you will need after we have been in operation three years, why shouldn't we think more in terms of rates--that is, factory A produces in terms of 500 units per month. Factory B, on the same thing, can give you 300 units per month. That is practically immediately. Factory C will build up in 18 months. It will not give you very much before that, but it will be up to 3,000 units per month by then. I would like to ask the question as to how much attention is given to a concept such as that, where, for our mobilization requirements, we quit thinking in terms of precise cumulative end item figures and think in terms of rates of production projected over a period of time.

MR. WOOD: These, I take it, would be rates of production, not for an individual item, but for a whole group of items, or a class of items?

GENERAL HOLMAN: Any way you want it.

MR. WOOD: This is exactly what we are trying to do in the application of the interindustry technique. We are trying to develop requirements not for individual end items, but for whole groups of items, which, in terms of the capability of the supporting economy, will be measured in terms of dollar-value aggregates against an industry. We will then measure the capability of that industry to produce this whole group or aggregate of items rather than to try to measure each item individually. I think implicit in your statement is the idea that, even though the equipment changes rapidly, these aggregates perhaps will not change nearly so rapidly; that there will be internal changes in the items within the aggregate but not so much change in the aggregate itself.

GENERAL HOLMAN: No. My protest is against addition. You have many hundreds of columns of figures that must be added. At the end of four months we will have a certain number, but your basis for requirements has changed by that time.

Now, if you could work out a system that would say, well, you have tanks coming in on the fifteenth month at the rate of 100 per month, on the eighteenth month you will have 200 per month; then, when you begin to change the requirements, the organizations that are going to be used in the particular operation, instead of needing 1,000 tanks per unit, will need 1,500. You are thinking in terms of rates of production, and at the industrial end that is much easier. You can have factory A planned to where their schedule calls for 500 of a unit a month.

Then the decision comes to build up. You may want to bring in another company with 300, or another at 800, or you may get Company A to double its production to 1,000. If we think in terms of rates, we can do that. But if we think in terms of the quantities of end items that are needed at a particular time under a great many assumptions, when those assumptions change, you have to recompute it over again, and it looks as if you are wasting a lot of time.

MR. WOOD: This implies, I guess, a more or less continuous model, handling these requirements as continuous variables rather than as discrete quantities, as we have done here. We have considered that. The difficulty encountered was the fact that we can't, in any event, meet all of our requirements from current production; we have to accumulate the cumulative deficit in numbers between our requirements and our production, and set that back into the pre-D-day period as a stockpiling requirement.

This is not in terms of a rate but in terms of a quantity. It has to be. There are very few items for which we can satisfy all of our wartime requirements completely from current production. There is always some kind of cumulative deficit which has to be backed up into the pre-D-day period, and this has to be added up numerically as a production objective or a stockpiling objective for the peacetime program.

QUESTION: How much of an organization and staff will be required, and how difficult is it going to be to keep all these basic data up to date that you throw in these machines?

MR. WOOD: Well, it is a job, and a sizable one. I think in general it is going to be less work to keep it up to date than it is to develop it initially from scratch, which we have largely accomplished.

I have, I guess, a staff of 15 or 18 people solely devoted to the development of factors which go into this model. Everything which has been developed has immediately been found useful by the staff in its current planning operations by conventional techniques. We have published a several hundred-page manual of planning factors, which has been very widely used throughout the Air Force. We have been having to practically double its printing each six months, as we have revised it, in order to satisfy the demand.

The factors which we need for this purpose are no different from the factors which we need for ordinary planning operations, but which nobody ever had time to develop. I think the only hope of keeping them up to date is, of course, through decentralizing a major part of the work to the operating agencies involved. We haven't developed by any means all of the factors. We have tried in every case to get other staff agencies or the major commands to do the factor-development work, but we have indicated the areas in which factors were needed and the kinds of relationships that had to be considered.

I think we can keep them up to date with a not unreasonable staff. I don't know what it may be. It may be twice our present staff in the factor-development area or perhaps even more, but it is a fairly small cost, I think, in relation to the benefit that we get from it, not only in terms of our centralized management operation, but in terms of making better information available to people in the field for local planning operations.

MR. HENKEL: Mr. Wood, do you know whether the Army and Navy are following any of these techniques in developing their requirements?

MR. WOOD: So far as I know, nothing in the Army has gone beyond the talking stage. The Navy has, as you mentioned earlier, a contract with George Washington University for research in this general area.

So far as I know, they haven't yet gotten down to the stage of actually putting numbers on paper either.

I have some doubt as to whether the job of planning factor-development can be done successfully on a contract basis. It seems to me that it is a job which is an integral part of normal staff operations, which will have to be done, in large part, by in-service personnel. This group at George Washington certainly is making progress on the formulation of the problem, and is, I think, getting ready to do some work on actual development of numbers. They may have actually accomplished some already. I am not sure.

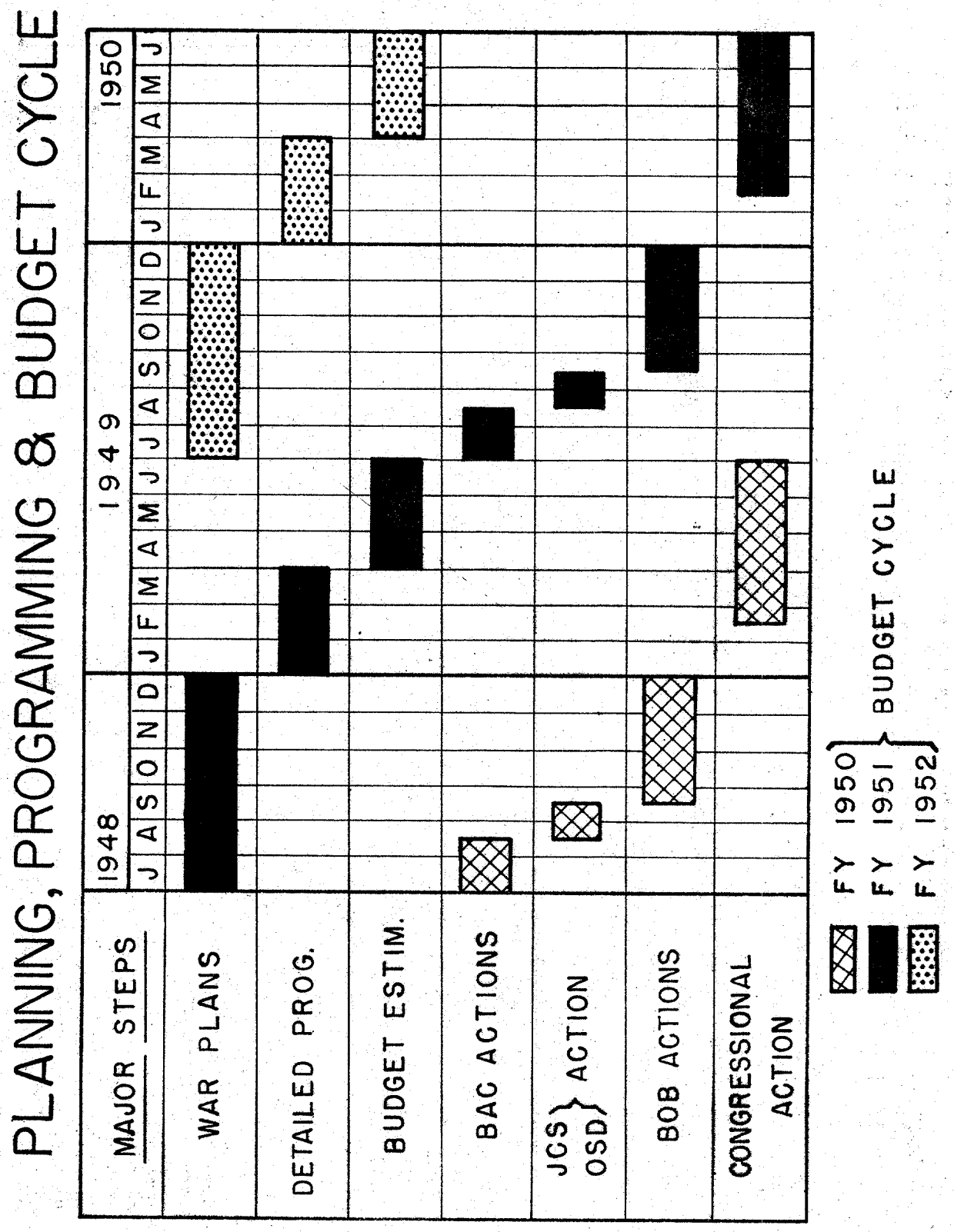
QUESTION: Would you comment on the relative difficulty in the three services from the factor point of view? You have in the Air Force a rather concentrated effort with respect to aircraft and all it takes for them. In the other services you have more diversified activities. Do you think that presents any particularly difficult problem with respect to other departments?

MR. WOOD: Yes. I think that is a very good point. I think there is no question but that the job is much easier in the Air Force than it would be in the Army, and considerably easier in the Army than it would be in the Navy. There is a relatively less complex operation, as you say, more centralized, more directed toward a single objective. Of course, in the Air Force we have the additional advantage of a relatively clean-cut, well-centralized organizational structure, which gets around many of the problems inherent in the Army technical service and the Navy bureau structure--so that, both from the technical point of view and from the administrative point of view, I think the job is clearly a much easier one in the Air Force than in either the Army or the Navy. I don't think, however, that the job is an insurmountable one in the case of the Army and Navy, though it certainly is tougher.

MR. HENKEL: Mr. Wood, on behalf of the Commandant and the College I thank you for a most interesting talk.

(21 June 1951--350)S.

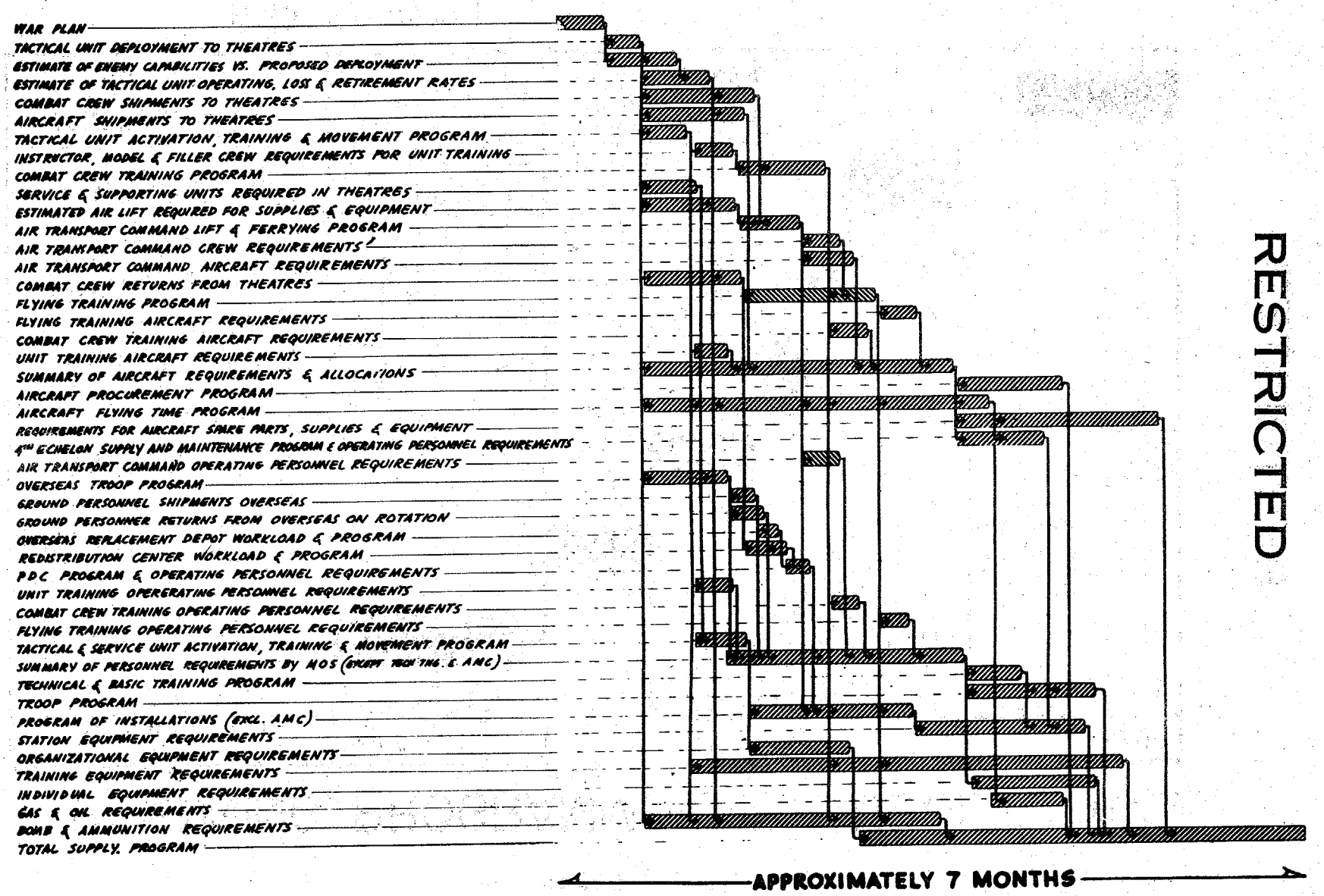
Chart 1


PLANNING, PROGRAMMING & BUDGET CYCLE
MAJOR STEPS
1948
1949
1950
J A S O N D J F M A M J J A S O N D J F M A M J
WAR PLANS
DETAILED PROG.
BUDGET ESTIM.
BAC ACTIONS
JCS
OSD
ACTION
BOB ACTIONS
CONGRESSIONAL ACTION
FY 1950
FY 1951
FY 1952
BUDGET CYCLE

RESTRICTED

Chart 2

SCHEMATIC DIAGRAM OF MAJOR STEPS IN AIR FORCE WARTIME PROGRAM SCHEDULING



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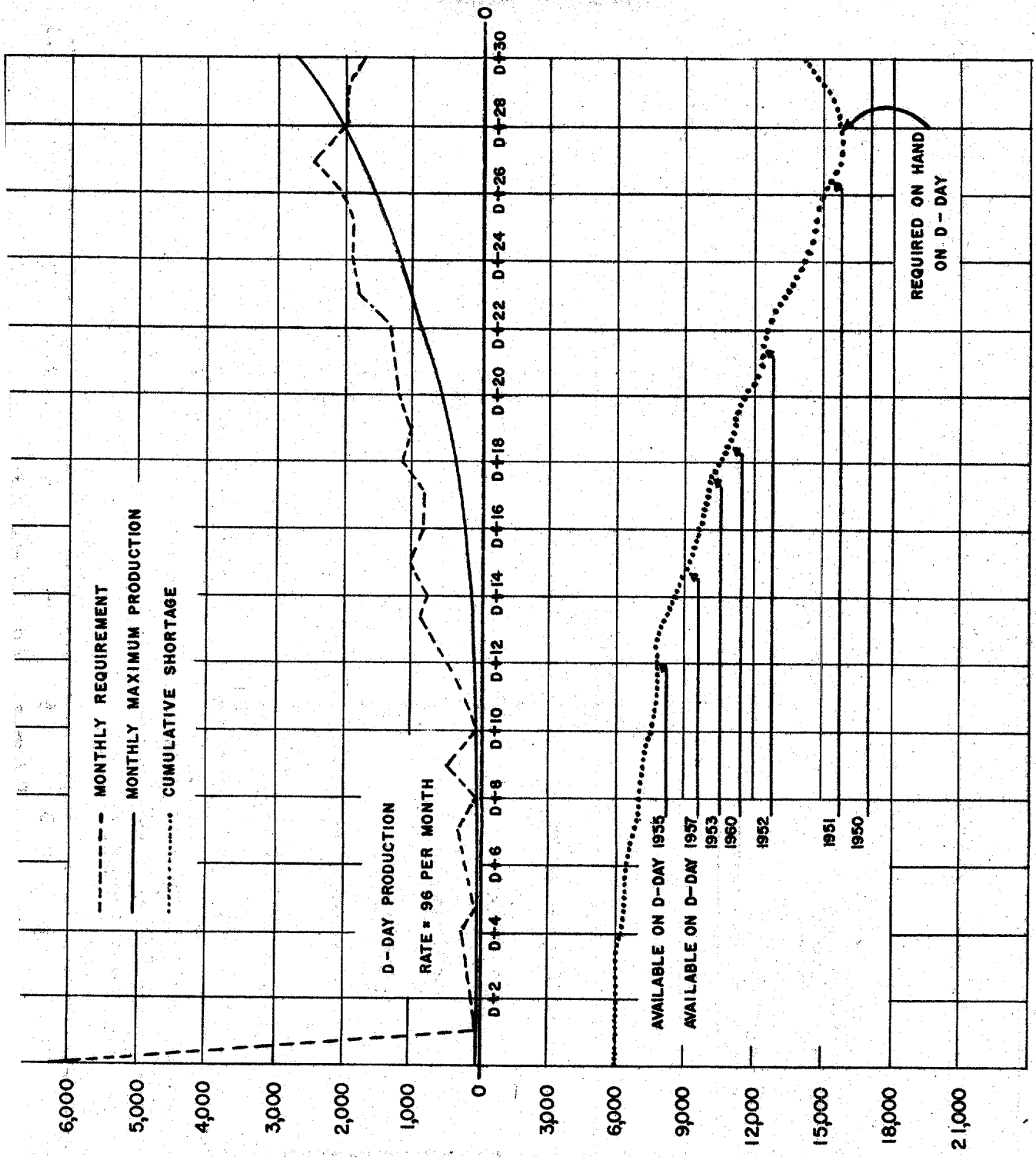
MONTHLY REQUIREMENT
MONTHLY MAXIMUM PRODUCTION
CUMULATIVE SHORTAGE
D-DAY PRODUCTION
RATE = 96 PER MONTH
AVAILABLE ON D-DAY 1955
AVAILABLE ON D-DAY 1957
1953
1960
1952
1951
1950
REQUIRED ON HAND ON D-DAY
D+2
D+4
D+6
D+8
D+10
D+12
D+14
D+16
D+18
D+20
D+22
D+24
D+26
D+28
D+30
0
6,000
5,000
4,000
3,000
2,000
1,000
0
3,000
6,000
9,000
12,000
15,000
18,000
21,000

RESTRICTED

Chart 4

SCHEMATIC RELATIONSHIP OF WAR PLANS AND CURRENT PROGRAM

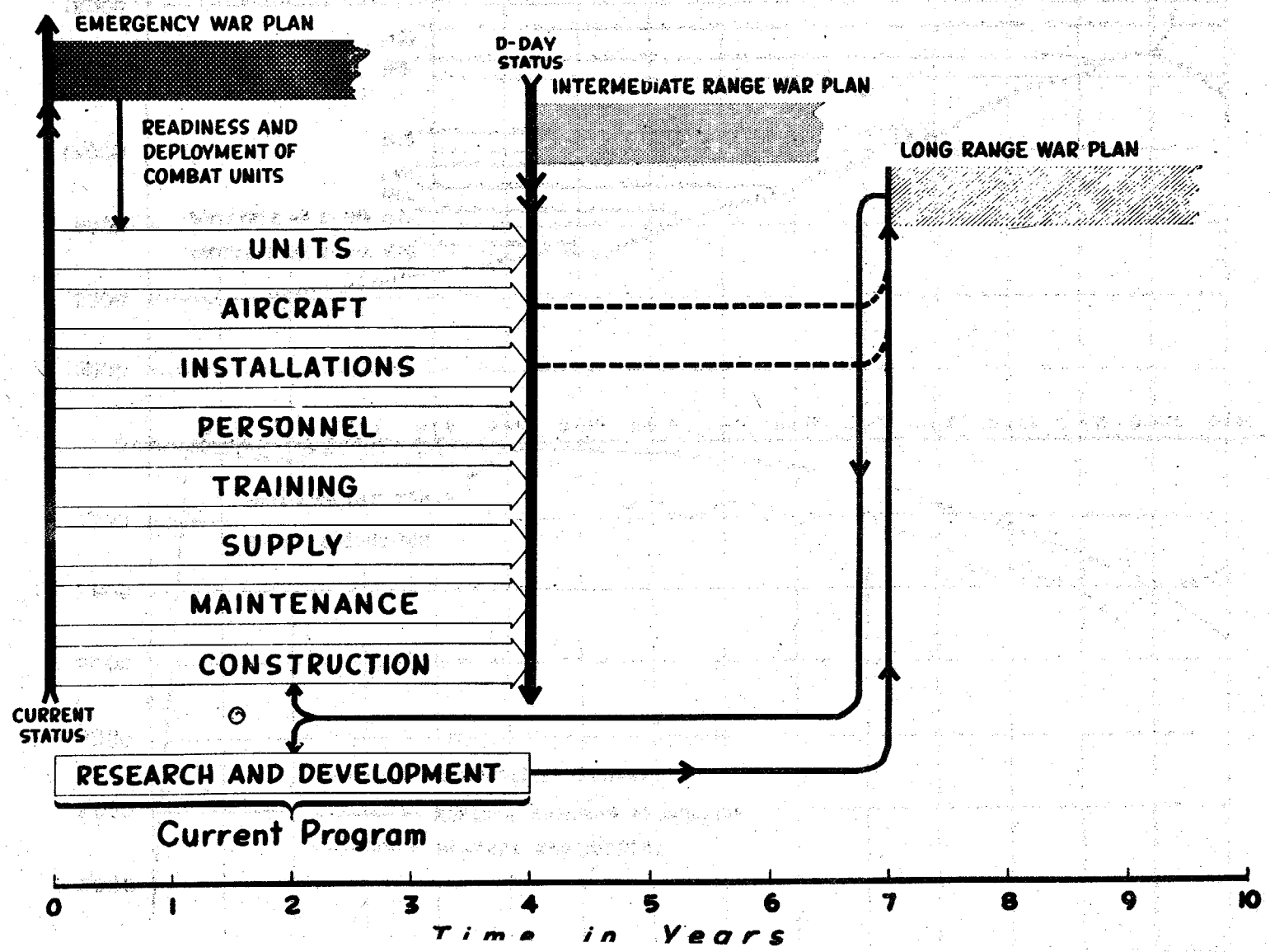

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Chart 5

EXAMPLE OF COEFFICIENTS USED IN MECHANIZED PROGRAM COMPUTATIONS

ACTIVITY: HEAVY BOMB COMBAT CREW TRAINING

ITEM	COEFFICIENT		MONTHS AFTER INITIATION THAT REQUIREMENT FOR ITEM		USE OF ITEM
	AMOUNT PER UNIT OF ACTIVITY	TYPE	BEGINS	ENDS	
HEAVY BOMB COMBAT CREW	-1.00	INSTANTANEOUS	4		*REPLACEMENT CREW*
HEAVY BOMB PILOTS	+0.80	INSTANTANEOUS	0	4	*INSTRUCTOR*
MEDIUM BOMB PILOTS	+3.08	INSTANTANEOUS	0		*CREW MEMBER*
	-.02 *	FLOW	0	4	*WASHED OUT CREW MEMBER*
NAVIGATOR - BOMBARDIERS	+0.80	INSTANTANEOUS	0	4	*INSTRUCTOR*
	+4.08	INSTANTANEOUS	0		*CREW MEMBER*
	-0.02 *	FLOW	0	4	*WASHED OUT CREW MEMBER*
FLEXIBLE GUNNERS	+2.20	INSTANTANEOUS	0	4	*INSTRUCTOR*
	+6.12	INSTANTANEOUS	0		*CREW MEMBER*
	-0.03 *	FLOW	0	4	*WASHED OUT CREW MEMBER*
HEAVY BOMB AIRCRAFT	+0.40	INSTANTANEOUS	0	4	*CAPITAL*
HEAVY BOMB AIRCRAFT FLYING HOURS *(1000's)*	+0.04 *	FLOW	0	4	*CONSUMPTION*

* *THIS COEFFICIENT IS APPLICABLE FOR EACH MONTH FOR THE FOUR MONTHS INDICATED.*

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Chart 6

EXAMPLE OF COEFFICIENTS USED IN MECHANIZED PROGRAM COMPUTATIONS

ACTIVITY: HEAVY BOMB WING COMBAT OPERATIONS

ITEM	COEFFICIENT		MONTHS AFTER INITIATION THAT REQUIREMENT FOR ITEM		USE OF ITEM
	AMOUNT PER UNIT OF ACTIVITY	TYPE	BEGINS	ENDS	
HEAVY BOMB "WING MONTH"	−1.00	FLOW	0	1	*COMBAT OPERATIONS*
HEAVY BOMB WING	+1.00	INST.	0	1	*CAPITAL*
HEAVY BOMB AIRCRAFT	+ 30.00	INST.	0	1	*CAPITAL*
	+ 6.00	FLOW	0	1	*ATTRITION REPLACEMENT*
HEAVY BOMB COMBAT CREWS	+ 5.00	FLOW	0	1	*ATTRITION REPLACEMENT*
	+ 5.00	FLOW	3	4	*RETIREMENT REPLACEMENT*
"RETIRED" HEAVY BOMB COMBAT CREWS	−15.30	INST.	7		*NON-COMBAT DUTY*
	−2.13	FLOW	7	8	*NON-COMBAT DUTY*
	−2.13	FLOW	10	11	*NON-COMBAT DUTY*
HEAVY BOMB AIRCRAFT FLYING HOURS *(1000's)*	+ 3.60	FLOW	0	1	*CONSUMPTION*
HEAVY BOMB WING "TECH. PERSONNEL MONTH"	+ 1.00	FLOW	0	1	*CONSUMPTION*
BOMBS (THOUSANDS OF TONS)	+ 1.20	FLOW	0	1	*CONSUMPTION*
	+2.40	INST.	0	1	*STOCK LEVEL*

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Chart 7

SAMPLE OF RELATIONSHIPS USED IN SCOOP COMPUTATIONS

ITEM \ ACTIVITY	COMBAT OPERATIONS	SHIPPING FROM ZI TO COMBAT AREA: COMBAT WINGS	COMBAT CREWS	AIRCRAFT	AMMUNITION & FUEL	SERVICEABLE ENGINES	MAINTENANCE SPARE PARTS	PAY, SUBSISTENCE, ETC.	CONSTRUCTING BASES FOR COMBAT	RETURN COMBAT CREWS	UNSERVICEABLE ENGINES	SHIPPING BACK TO ZI: COMBAT WINGS	COMBAT CREWS	SHIPPING COMBAT CREW TRAINING TO COMBAT TRAINING	RETURN TRAINING OF PERSONNEL	SHIPPING NON-RATED PERSONNEL TO TRAINING	TECHNICAL TRAINING OF PERSONNEL	SHIPPING SUPPLIES TO TRAINING: AIRCRAFT	AMMUNITION & FUEL	SERVICEABLE ENGINES	MAINTENANCE SPARE PARTS	PAY, SUBSISTENCE, ETC.	CONSTRUCTING TRAINING BASES	SHIPPING UNSERVICEABLE ENGINES TO DEPOT	SERVICEABLE ENGINES AT DEPOT	SPARE ENGINES	PROCURING: AIRCRAFT	AMMUNITION & FUEL	MAINTENANCE SPARE PARTS	PAY, SUBSISTENCE, ETC.	PROVIDING APPROPRIATIONS FOR: AIRCRAFT	AMMUNITION & FUEL	MAINTENANCE SPARE PARTS	PAY, SUBSISTENCE, ETC.	PURCHASING FROM: AIRCRAFT INDUSTRY	PETROLEUM INDUSTRY	CHEMICAL INDUSTRY	FOOD PROCESSING INDUSTRY
COMBAT: COMBAT WINGS	+ −		−																																				
COMBAT: COMBAT CREWS	+			−																																			
COMBAT: AIRCRAFT	+ −				−																																		
COMBAT: AMMUNITION & FUEL	+ −					−																																	
COMBAT: SERVICEABLE ENGINES	+ −						−																																
COMBAT: MAINTENANCE SPARE PARTS	+ −							−																															
COMBAT: PAY, SUBSISTENCE, ETC.	+ −								−																														
COMBAT: BASES	+ −									−																													
COMBAT: RETIRED COMBAT CREWS	−										+																												
COMBAT: UNSERVICEABLE ENGINES	−											+																											
ZONE OF INTERIOR SUPPORT: COMBAT WINGS		+											−																										
ZONE OF INTERIOR SUPPORT: COMBAT CREWS			+											−																									
ZONE OF INTERIOR SUPPORT: RATED PERSONNEL												+ −	+ −		−																								
ZONE OF INTERIOR SUPPORT: FLYING TRAINING GRADUATES										−				+		−																							
ZONE OF INTERIOR SUPPORT: NON-RATED PERSONNEL												+ −	+ −		+ −		−																						
ZONE OF INTERIOR SUPPORT: TECHNICAL TRAINING GRADUATES																	+		−																				
ZONE OF INTERIOR SUPPORT: AIRCRAFT												+ −	+ −		+ −					−																			
ZONE OF INTERIOR SUPPORT: AMMUNITION & FUEL												+ −	+ −		+ −						−																		
ZONE OF INTERIOR SUPPORT: SERVICEABLE ENGINES												+ −	+ −		+ −							−																	
ZONE OF INTERIOR SUPPORT: MAINTENANCE SPARE PARTS												+ −	+ −		+ −			+ −					−																	
ZONE OF INTERIOR SUPPORT: PAY, SUBSISTENCE, ETC.												+ −	+ −		+ −			+ −						−																
ZONE OF INTERIOR SUPPORT: TRAINING BASES												+ −	+ −		+ −			+ −							−															
ZONE OF INTERIOR SUPPORT: UNSERVICEABLE ENGINES													−		−											+														
AIR FORCE END ITEMS: UNSERVICEABLE ENGINES AT DEPOT												−															+													
AIR FORCE END ITEMS: SERVICEABLE ENGINES AT DEPOT						+														+								−		−									
AIR FORCE END ITEMS: AIRCRAFT				+													+													−									
AIR FORCE END ITEMS: AMMUNITION & FUEL					+													+											−										
AIR FORCE END ITEMS: MAINTENANCE SPARE PARTS							+														+									−									
AIR FORCE END ITEMS: PAY, SUBSISTENCE, ETC.								+														+									−								
BUDGET: AIRCRAFT APPROPRIATION																										+	+					−							
BUDGET: SPECIAL PROCUREMENT APPROPRIATION																												+					−						
BUDGET: MAINTENANCE & OPERATION APPROPRIATION																												+	+					−					
BUDGET: MILITARY PERSONNEL APPROPRIATION																														+					−				
INDUSTRIAL IMPACT: AIRCRAFT INDUSTRY OUTPUT																										+	+		+							−			
INDUSTRIAL IMPACT: PETROLEUM INDUSTRY OUTPUT																												+									−		
INDUSTRIAL IMPACT: CHEMICAL INDUSTRY OUTPUT																												+										−	
INDUSTRIAL IMPACT: FOOD PROCESSING INDUSTRY OUTPUT																														+									−

RESTRICTED

Chart 8

INTERRELATIONSHIPS AMONG ACTIVITIES AFFECTING REQUIREMENTS FOR HVY. OR MED. BOMB TYPE AIRCRAFT

	COMBAT OPERATIONS								SHIPPING FROM NON-COMBAT AREAS TO COMBAT AREAS														SHIPPING BACK		OTU & CCTS TRAINING								SHIPPING TO NON-COMBAT AREAS		TRAINING		SHIPPING TO NON-COMBAT AREAS		PROVIDING AVAILABILITY OF		
	HEAVY BOMB	MED BOMB	LIGHT BOMB	STRAT. RCN	TANKER	RESCUE	HEAVY BOMB WINGS	MEDIUM BOMB WINGS	LIGHT BOMB WINGS	STRAT RCN WINGS	4-ENGINE PILOTS	FLEXIBLE GUNNERS	HV BOMB REPL. CREWS	MED BOMB REPL. CREWS	LT. BOMB REPL. CREWS	STRAT RCN REPL. CREWS	HEAVY BOMB ACFT.	MEDIUM BOMB ACFT.	STRAT RCN. ACFT.	TANKER ACFT.	RETD. 4-ENG. PILOTS	RETD. FLEX. GUNNERS	HEAVY BOMB OTU	MEDIUM BOMB OTU	LIGHT BOMB OTU	STRAT RCN. OTU	HEAVY BOMB CCTS	MEDIUM BOMB CCTS	LIGHT BOMB CCTS	STRAT RCN CCTS	4-ENGINE PILOTS	FLEXIBLE GUNNERS	4-ENGINE PILOTS	FLEXIBLE GUNNERS	HEAVY BOMB ACFT.	MEDIUM BOMB ACFT.	STRAT RCN ACFT.	HEAVY BOMB ACFT.	MEDIUM BOMB ACFT.	STRAT RCN ACFT.	TANKER ACFT.
HEAVY BOMB WINGS IN COMBAT AREAS	+-						-																																		
MEDIUM BOMB WINGS IN COMBAT AREAS		+-						-																																	
LIGHT BOMB WINGS IN COMBAT AREAS			+-						-																																
STRAT. RCN. WINGS IN COMBAT AREAS				+-						-																															
4-ENGINE PILOTS IN COMBAT AREAS	+	+		+	+-	+-					-																														
FLEXIBLE GUNNERS IN COMBAT AREAS			+		+-							-																													
HEAVY BOMB REPLACEMENT CREWS IN COMBAT AREAS	+												-																												
MEDIUM BOMB REPLACEMENT CREWS IN COMBAT AREAS		+												-																											
LIGHT BOMB REPLACEMENT CREWS IN COMBAT AREAS			+												-																										
STRAT RCN REPLACEMENT CREWS IN COMBAT AREAS				+												-																									
HEAVY BOMB AIRCRAFT IN COMBAT AREAS	+-																-																								
MEDIUM BOMB AIRCRAFT IN COMBAT AREAS		+-				+-												-																							
STRAT RCN AIRCRAFT IN COMBAT AREAS				+-															-																						
TANKER AIRCRAFT IN COMBAT AREAS					+-															-																					
RETIRED 4-ENGINE PILOTS FROM COMBAT AREAS	+	+		+	+	+															-																				
RETIRED FLEXIBLE GUNNERS FROM COMBAT AREAS	+	+	+	+	+																	-																			
HEAVY BOMB WINGS NOT IN COMBAT AREAS							+																-																		
MEDIUM BOMB WINGS NOT IN COMBAT AREAS								+																-																	
LIGHT BOMB WINGS NOT IN COMBAT AREAS									+																-																
STRAT RCN WINGS NOT IN COMBAT AREAS										+																-															
HEAVY BOMB REPLACEMENT CREWS NOT IN COMBAT AREAS													+														-														
MEDIUM BOMB REPLACEMENT CREWS NOT IN COMBAT AREAS														+														-													
LIGHT BOMB REPLACEMENT CREWS NOT IN COMBAT AREAS															+														-												
STRAT RCN REPLACEMENT CREWS NOT IN COMBAT AREAS																+														-											
4-ENGINE PILOTS NOT IN COMBAT AREAS											+											+	+		+	+	+		+	-											
FLEXIBLE GUNNERS NOT IN COMBAT AREAS												+										+	+	+	+	+	+	+	+		-										
4-ENGINE PILOT GRADUATES																				-										+		-									
FLEXIBLE GUNNER GRADUATES																					-										-		-								
HEAVY BOMB AIRCRAFT NOT IN COMBAT AREAS																						+-			+-							+-	+-	-							
MEDIUM BOMB AIRCRAFT NOT IN COMBAT AREAS																							+-			+-	+-								-						
STRAT RCN AIRCRAFT NOT IN COMBAT AREAS																	+																			-					
HEAVY BOMB AIRCRAFT TACTICALLY AVAILABLE																		+																	+		-				
MEDIUM BOMB AIRCRAFT TACTICALLY AVAILABLE																			+																	+		-			
STRAT RCN AIRCRAFT TACTICALLY AVAILABLE																				+																			-		
TANKER AIRCRAFT TACTICALLY AVAILABLE																					+																			-	

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