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LULEJIAN -I THEATER-LEVEL MODEL[1] COMMENTS ON

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SUMMARY:

It is difficult to furnish criticism on a model such as this Theater level Model without:

1) Appearing to criticize the modeler, or
2) Being challenged to do better on the same problem with the same constraints, or
3) Both.

None of these consequences are desired.

The model-makers appear to have done a very workmanlike job, and have introduced several promising developments. The detailed comments appearing below may be principally negative; this is because of concentration on the points where the model may be improved.

The principal difficulty is that the model-makers were set an impossible task. There is no way in which several levels of analysis of such a complex problem as theater military operations can be usefully combined in a single computerized model. When the attempt is made, we will always get the following deficiencies (which pertain to this model):

1) One aspect of the problem (in this case Air Operations) gets detailed treatment incommensurate with that of other equally important aspects (Ground Combat, Logistics, etc.).

[1] WSEG Report 259, The Lulejian-I Theater-Level Model (U), Vol. II: Model Logic& Equations (U). October 1974

2) The model has zero visibility - so many detailed calculations are done that it is impossible to determine the fundamental "drivers" producing various outputs. This defect may be amplified if the labor and expense of single runs prohibit extensive experimentation with parametric inputs.

3) Output variations are critically dependent on numerous input factors - primarily the "Kill Potentials" of various weapon systems in various situations - which are unavailable without very detailed examination in lower-level models. Even after such examination, these inputs would be subject to large uncertainties, and should be varied (preferably one at a time) between upper and lower bounds which have been established by a combination of analysis and informed professional judgment (2^N variations for N critical inputs).

4) At several points within the model, calculations which have been performed in considerable detail are effectively negated by an averaging process forced by computer limitations.

5) Although the model attempts to analyze opposing strategies, its utility in this regard is severely diluted by the proportional assignments made in execution. E.G. - escort aircraft are assigned in proportion to the number of strike aircraft without reference to the importance of the strike.

If this model were used only by people intimately familiar with its structure and conscious of its defects, and if the output were available only to decision-makers who will listen carefully to caveats and apply independent professional judgment to the conclusions drawn from that output, the model in its present form could be useful.[2] In any other circumstances it is more likely to be harmful.

The remedy suggested is to try again, but to start by scoping a manageable problem. A "top-level" theater model which treats the interactions of a limited set of theater components is needed. It should probably operate on some "rate" basis rather than by discrete time-sequenced or event-sequenced steps. It should accept input aggregated (with uncertainty bounds) from the results of lower-level models (which in turn must depend on still lower-level models.

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2 The model is not useful, however, to examine the impact of a specific weapon system which varies only in detail from other alternative systems.

1.0 PURPOSE OF THE MODEL:

The Abstract states (in part) - "The model may be used as a planning tool for assessing the net combat capability of theater forces and for evaluating force structure alternatives". The Introduction includes the phrase - "--- allows determination of approximately enforceable outcomes". One may infer from Exhibit I-1 that the assessments and evaluations will use as a primary measurement "Area gained and attrition suffered".

COMMENT:

"Area gained and attrition suffered" differs only in form from the Anatomy of Combat concept of "Combat Potential", which is defined as " the ability to take or hold terrain and to inflict damage". The Anatomy of Combat approach combines the two results by "Directive Variables", but these are admittedly imprecise and arguable, and in any case the same could be done with the Lulejian output.

The model will perhaps be a useful tool for evaluating gross force structure alternatives - force fractions assigned to the major subdivisions (Logistics, Air, Ground) and first-level subdivisions thereof. However, it must be borne in mind that the results are dependent on a very large number of detailed inputs, assumption, and algorithms connecting these. It would seem advisable initially to conduct exhaustive sensitivity studies to determine what input changes materially affect the output. Such a process would add to model visibility and to user's capability intelligently to use the output.

As to the other purposes - "assess combat capability" and "determine ---- outcomes" - one must be more pessimistic. Both statements <u>might</u> imply use of the model to <u>predict</u> the outcome of some postulated conflict. No model presently conceivable can make any such predictions, unless the ratio of opposing strengths is so large that it is folly for the weaker side to fight at all. Otherwise the outcome of the conflict will be determined by factors not covered in the Lulejian Model - e.g., motivation, generalship, the initiative.

This limitation on predicting outcomes is not particularly onerous, since a prediction would be of no practical use in the military budgeting and force structuring process. Force levels adequate to "guarantee" victory over various "threats" are always to high for peacetime budgets. The only practical question is that of the choice among competing alternative systems and force structures.

The model should not be used for purposes other than those for which it was designed (reduced by the above to evaluating gross force structure alternative, after sensitivity investigations). In time it may have utility for interplaying the results of different lower-level models. This possibility is briefly discussed (on pp. IV-63, Vol. II). The "bench-marking" experiment model (in conjunction with others) for evaluation of competing systems.

1.1 INTRODUCTION

Exhibit I-1, considered in conjunction with the other detailed charts in Vol. II, shows a distinct orientation to Air Force problems. The Navy is not represented, except to the extent it may assist in Air Force missions. The Logistics and Ground Force models are not structured for any detailed study of the internal problems of these forces, though they may serve to picture the gross interaction of these forces with the Air Force.

This accent on Air Force considerations makes the "optimizations" , other than those on composition and utilization of the Air Force, very questionable.

The remainder of the introduction simply describes the gross information flows within the model. The processing seems appropriate; detailed comments on inputs, assumption and algorithms are deferred to following paragraphs.

2.0 GROUND COMBAT ASSESSMENT MODEL (Section IV)

2.1 OVERVIEW (A)

It is dubious that this model adequately fulfills the second of its two "fundamental objectives". It is at too high a level of aggregation, and omits too many functions, to reflect ground force component contributions and interactions. If it does not properly reflect ground force interactions, it probably does not properly assess the impact of air units on these interactions.

The reason for this deficiency is quite clearly explained in the first paragraph (on pp. IV-2). To make the model serve its primary purpose and still run within reasonable bounds of time and expense, it was necessary to use a very simplified representation of the ground interactions. Since the model appears to be efficiently constructed, it is probable that little improvement can be made in this framework. What is needed are separate models of Ground, Air, Logistics, etc., which provide outputs which can be manipulated in some "top-level" unified force model.

The "concept" of "trading space for survivability" is a definite improvement on the more common pure attrition model. Time needs to be added however; combat outcomes depend on relative assets and their efficient employment in space and time (plus of course "human factors", which qualify the worth of the assets).

It seems probable (See pp. IV-3) that the worth of maneuver is down-played, since the maneuver units "search for" opposing units and close in order to maximize fire effectiveness. Preferred tactics are to find the opposing units, fix them with minimum force, and then maneuver to negate the contribution of those fixed units to the battle outcome.

In fact, it should normally be the defender who "searches" for the attacker in order to prevent him from penetrating through the defensive line or into the protected territory.

The conduct of the attacker and of the defender built into the model establishes one pair of opposing "doctrines". Flexibility of opposing doctrines could be built in by use of the Anatomy of Combat developed concept of directive variables, though such a move should probably be accompanied by a separation into several models operating at various "levels".

It appears that the model is actually aggregated at the level of four types of Ground Force Battalions, and five generic types of elements - 1) Air Defense Sites, 2) Aircraft, 3) Helicopters, 4) Transport Vehicles, and 5) Supply Installations. Since there are numerous variants within these generic types, and most of the possible pairs of aggregated units can interact, there are a very large number of interactions to be defined and calculated. The model has great "breadth". Additional types of aggregated units would add up to N interactions for the $(N + 1^{st})$ type. Since the model is already very large, it is likely that any change should be made by the previously-mentioned division into separate models, rather than by additions.

2.2 AGGREGATION OF FORCE ELEMENTS (Para. C, pp. IV-8)

The "effectiveness coefficients" for the various elements are obviously very critical inputs, since they will ultimately determine casualties and FEBA movement. They appear quite analogous to "firepower scores". It is not clear from the text whether the effectiveness coefficient for a given element varies with the terrain, weather, and composition of opposing force. All these factors do condition effectiveness, but it may be infeasible to introduce these complexities into a model at this level.

2.3 BATTALIONS ON LINE (Para. D, pp. IV-10)

A literal reading of the text here seems to indicate that FEBA movement is a function of the fraction of forces committed by each side, rather than the ratio of opposing forces. E.G., the table at the bottom of pp. IV-17 seems to indicate that if the attacker reduces forces by about 70% and the defender increases by 75%, FEBA movement will increase from zero to maximum rate. Previous discussion in the text has made it clear that this is not the intent - the change in assignment is the result, rather than the cause, of FEBA movement - but the mechanics are unclear.

An old military adage is "reinforce success, not failure". This would imply that an attacker uses his reserves to exploit a breakthrough, and defender uses his primarily for counter-attack. To the extent this is actually feasible on the battlefield, it would produce a reversal of the tactics incorporated in this model.

2.4 NUMBER OF BATTALIONS IN "CONTACT" (Para. E, pp. IV-18)

It is unclear why random search equations are used. Coordination among searching battalions should prevent duplicative searches, and intelligence input should even further reduce the area which must be searched in detail. In addition, specialized reconnaissance elements should make the rate of search much higher than the rate of movement of any battalion.

It has previously been stated (top of pp. IV-19) that force contact is a mutual event. Equations (15), (16), and (17) (pp. IV-24) seem redundant if this is the case.

It is recognized that FEBA progress will be dependent on the strength of opposition after the time spent in search has been accounted for. However, if f_{ts} (Bottom of pp. IV-20) is large, the procedure may distort results. A strong force might simply sweep through the area, with minor detachments to deal with pockets of resistance. Model results should be critically examined to see whether they can reflect this phenomenon.

It appears probable that the model-builders have adopted these methods to avoid assessment by means of "fire power scores", The attempt is certainly meritorious, and these lines of investigation should be pursued and added to. However, at this stage it is dubious that results should be considered indicative of combat outcomes to be expected, even on the average.

2.5 FORCES LOCATED (Para. F, pp. IV-25)

The Poisson approximation for probability of location is reasonable, though assignment of credible values to ρ, π, and Ω is likely to be difficult.

There seems to be an inherent assumption that the knowledge acquired by each element is immediately polled as knowledge of the unit. This is dependent, of course, on intelligence processing and communication capability, which is not modeled.

2.6 EFFECTIVENESS OF FIRE FROM SUPPORT UNITS (Para. G, pp. IV-33)

The principle of barrage fire is correct; however, the barrage sizes seem too large. It is suggested that platoon target size barrages would be nearer to field practice.

2.7 LOSSES INCURRED DURING COMBAT (Para. H, pp. IV-41)

The procedure for calculating infantry casualties seems sound; it should be interesting to compare the resultant casualties with historic experience.

Effects of weapon overlap should not be completely "random" (Bottom pp. IV-45). Tactical fire direction allocates targets to weapons and thus distributes fire more or less well, dependent on command and communications.

It is not completely clear (See pp. IV-52, 53) whether the helicopter stand-off range is measured from the FEBA . If not, they should be subject to surprise attack from unlocated AAA. The approach used may under-estimate the vulnerability of helicopters in intense combat situations.

2.8 FEBA MOVEMENT AND SOLUTION METHOD (Para. I)

The solution method (See pp. IV-59) finally makes FEBA progress a function of <u>average</u> separation distances, of specified "resolve", of opposing force ratio, and of composition. It would seem reasonable to simplify input to the model by expressing this functional relation directly, and examining the effect of parametric variations thereto. The preceding detail could then be used (and perhaps other relationships added) for the sort of studies at lower level touched upon on pp. IV-63.

2.9 BATTLEFIELD INTERDICTION (Para. J)

The write-up is insufficient to establish just how the suppression potentials (η) are calculated. This is of course the key input for any evaluation of the worth of "battlefield interdiction".

2.10 MODIFYING FACTORS (Para. K)

These modifications appear capable of fixing up some of the cases in which the basic equations would lead to unrealistic results. The calculations on "APC Occupancy Preference" may be excessive detail for what is actually a rather "broad brush" treatment of ground combat.

3.0 LOGISTICS AND INTERDICTION MODEL (Section II)

3.1 GENERAL (pp. II-1)

To introduce port allocation problems into this model is perhaps an unnecessary complicating factor. There are many other factors influencing model results, and it will be quite a task to assess their impact.

3.2 VEHICLES EMERGING FROM THE NETWORK (Para. A)

In the equation at top of pp. II-6, V_{OUT} is obviously limited to $C_N Z$ in all cases (not as stated in the discussion.

The concept of a fixed C_N for a transport network has produced many ridiculous results in Interdiction studies. Perhaps a more realistic concept is that τ goes up with increasing congestion. What really happens when a network is overloaded is that more vehicles get through - but with less efficiency and greater vulnerability per vehicle.

3.3 AIR INTERDICTION (Para. C, pp. II-10)

The recognition that bridges do not absolutely control network capacity is most encouraging.

As in the case of infantry battalion search, it is probable that coordination among aircraft prevents the search for vehicles from being absolutely random (pp. II-11).

The proportional assignment of vehicle kill (pp. II-12) prevents consideration of selective interdiction (e.g., fuel-carrying vehicles to hamper armor progress).

3.4 EFFECT OF SUPPLY AVAILABILITY TO GROUND COMBAT FORCES (Para. E, pp. II-17)

The assumption that ground fore combat capability is directly proportional to supply allocation is no doubt very influential on the assessed worth of air interdiction. It is suggested that at least one other functional dependence of capability on supply rate be examined to determine model sensitivity.

4.0 <u>GROUND FORCE ALLOCATION LOGIC</u> (Section V)

4.1 BATTALIONS BECOMING "FOUGHT OUT" (Para. A)

The procedures described in this section are an attempt to model one facet of "Human Factors". The data that are given and the assumptions that are made are probably as good as any other that could be put forward. However, many other aspects of Human Performance are omitted - e.g.; Leadership, Individual Motivation, State of Training - and thus the "prediction" of fought-out status is incomplete.

Human performance is quite unpredictable, and also very highly variable. It is probably more determinative of the outcome of conflict than relative strength and equipment. it is also the factor which makes "prediction" of combat outcomes literally impossible.

However:

1) A partial modeling of "Human Factors" makes the process less visible and more difficult to understand, thus detracting from utility.

2) A total modeling of "Human Factors" is beyond the state-of-the-art, and would make the model impossibly cumbersome.

3) If the model actually included flexible strategy, which it does not, "fought-out " battalions might be worth considering. As it is , they are just a needless complexity.

The detailed calculations have the effect of making tank battalions more durable than infantry battalions. This will probably bias the model in favor of "tank-heavy" mixes.

4.2 ALLOCATION OF REPLACEMENTS (Para. B, pp. V-12)

It seems that since "resolve" is based on survival of original members of on-line battalions, the model is likely to favor a unit replacement policy over individual replacement policy.

4.3 "FOUGHT-OUT" BATTALIONS ENTERING RESERVE (Para. C, pp. V-14)

The "user-specified" values for t_r , $P_{S_{eff}}$, and b will be very influential in determining combat outcome, especially if they are allowed to vary by side, national participant, and type of battalion. This option assigns better fighting quality to some battalions than to others. If used, the assumptions should be very clearly presented for use in evaluating the output. If not used, the whole procedure merely has the effect of increasing the advantage of the stronger side.

4.4 SELECTION OF POSTURES (Para. D, pp. V-16)
ALLOCATION OF RESERVE BATTALIONS (Para. E, pp. V-21)

These sections are a very interesting attempt to introduce concepts of maneuver into the model. It will probably be useful to vary the user inputs (initial posture, RESFRO, and RESPL) quite widely and determine the effect on overall outcome. It would be useful to allow more user decision after the first day, but this development might have to be implemented in a separate model of ground combat (due to present size of the model).

5.0 TACTICAL AIR MODEL (Section III)

5.1 RESOURCES AND ALLOCATIONS (Para. B.1, pp. III-1)

The proportional allocations of suppression, escort, and defense aircraft (pp. III-3)preclude investigation of two rather important facets of strategy:

1) Concentration of support and strike elements against a selected area of defense installations, and

2) Coordination of defense aircraft with defending SAM's and AAA.

5.2 TACTICAL AIR MODEL STRUCTURE (Para. B.2, pp. III-4)

Exhibit III-2 entitled Tactical Air Model Flow Diagram (pp. III-7) needs more explanation of terms (e.g.: What is an "Air Defense Engagement"?)

5.3 CAPABILITY FACTORS (Para. C-1)

The write-up clearly states that the "Capability Factor" for aircraft (sorties) is directly proportional to the fraction available of required supplies. The same statement is not made for air defense artillery (ADA) installations, though it can perhaps be inferred.

This assumption is probably better for aircraft than for ground forces, though it does not reflect the declining "payoff" of added sorties (assuming command is adequate to assign the more profitable missions first).

It is probably a rather bad assumption for ADA, since under-supplied sites are more vulnerable to saturation by multiple penetrations (perhaps using decoys) and to early exhaustion of available missiles. As recommended earlier for ground forces (See Para. 3.4 above), some alternative assumption as to the ratio of "Capability" to supply for ADA should probably be investigated.

5.4. AREA DEPLOYED ADA BATTALIONS (Para. E, pp. III-17)

5.4.1 Fly-By Suppression (pp. III-17)

This factor is treated as though suppression aircraft are blanketing the whole "air region", while the attack aircraft are concentrating in certain corridors (it would seem the two should be coordinated). However this detail is probably unimportant because the averaging procedures used obliterate the effect of most of the particularized input.

5.4.2 Aircraft Attrition To Area-Deployed ADA Battalions (pp. III-19)

The total SAM kill potential against penetrating aircraft is assessed as a product of "Capability" and density factors and the following inputs:

SMFPS	Average number of SAM's fired per site at aircraft
SPT	Average SAM site tracking probability
SPK	Average SAM probability of kill

None of these inputs can be furnished with any great degree of confidence, even after long and detailed analysis of SAM performance, or, alternatively, from statistical examination of past experience.

It is quite useless to machine somebody's guess as to proper input values; it will be even worse if "conclusions" are then drawn as to appropriate mixes.

The detailed input should be replaced by some simpler formulation (e.g., average attrition as a function of SAM density). This would avoid any inference that the SAM problem has been studied in detail, while still permitting consideration of a parameter named SAM influence on the overall conflict.

5.5 AIR BATTLE (Para. F, pp. III-28)

On pp. III-29, the concept of combining operational characteristics into a "national" aircraft is rejected. It has, however, really been used in calculating aircraft vulnerability to SAM's.

The results of the air battle are fundamentally dependent on "Engagement Potential" and "Kill Potential", which vary for each pair of dueling aircraft. As in the case of SAM performance input (see above) these inputs will be very difficult to substantiate.

The statement (top of pp. III-35) that "defense aircraft will not be allocated optimally against the penetrating aircraft but more likely will be distributed in proportion to the numbers of each type of aircraft penetrating" is questionable. Command will not be perfect, but is unlikely to be no better than random, which is the situation presented in the model.

The equations used to determine kill results (Equations 31 and 32 on pp. III-33) also assume random or "average" pairing; so they exhibit an advantage of superior numbers, but not optimum tactical use thereof.

5.6 SUB-ALLOCATION OF AIRCRAFT TO TARGETS (Para. G, pp. III-42)

The interdiction aircraft are sub-allocated according to the amount of supplies that can be destroyed (or denied) by attack on each class of target (bridges, vehicles, or depots) (See pp. III-43). Thus, both strategy and results are heavily dependent on the "Kill Potentials" of aircraft versus these targets, which form an input to the Logistics Model.

Results from both Korea and Vietnam should have demonstrated by now that fractional denial of supply "requirements" across the board and over an extended period does no particular good. Interdiction efforts must be very timely and concentrated for some specific objective. This model offers no method which will assist in the study of interdiction and its effect on ground operations.

5.7 SUPPRESSION OF ADA BATTALIONS (Para. H)

As in most previous Sections, the results obtained here are highly dependent on input factors such as are displayed in Exhibit III-4 entitled "Example Of Attrition To Suppression Aircraft And Suppression Of ADA Battalions In Combat Area (pp. III-61). Aircraft 1 is presented as quite lethal and relatively invulnerable. If 100 of these aircraft are devoted to suppression of 30 SAM sites, one might expect a high level of suppression, say about $\left[1-(1-0.15)^{100/30}\right]$ (neglecting the trivial aircraft attrition of 0.01) or 0.42. To this is added whatever is attained by the much less effective Aircraft 2.

The essence of the calculation is merely that shown above, and since the other manipulations do not truly represent strategy, their effect is easily submerged in the uncertainty of these prime inputs.

This section treats "suppression" as a level of damage sufficient to prevent operation of the site for one day, and "destruction" as damage sufficient to permanently prevent operation. There is no treatment of the type of "suppression" in which the site abstains from firing due to the threat of the suppression aircraft and waits for a more favorable opportunity..

5.8. AIR INTERDICTION OF ENEMY AIR BASES (Para. J, pp. III-64)

Although sub-paragraph 1 lists some other potential targets, the air-base attack is modeled as an attack against aircraft on the ground, with the added possibility that shelters may be destroyed, with or without airplanes contained therein.

It is difficult to understand how shelters can be treated as an area target. Presumably they are employed for <u>cover</u> as well as concealment; and a weapon adequate for penetration will be very expensive for random application to a suspect area.

Once again, the crux of the calculation is in two input factors - TKP and TKPS - the "Kill Potentials" against aircraft in the open and in shelters, respectively . Of course, the entire purpose of airfield attack is to prevent the aircraft from operating, and they are therefore the most attractive target. At the same time, they are the base's primary resource and therefore will be protected as thoroughly as possible. It is somewhat dubious that effort expended on destroying aircraft in shelters will pay off as well as similar effort in interceptors, SAM defenses, or attacks on air-base operating and maintenance facilities. The whole question needs detailed study. However this "top-level" model probably should accept an input describing a probability of air-base shut-down for periods which may be a function of the strike aircraft penetrating to target.

6.0 <u>RESOURCE ALLOCATION ALGORITHM</u> (Section VI)

It is quite difficult to determine from this explanation exactly what procedures are incorporated into the model. As an example, "strategies chosen by the players" gives the impression that a Blue player and Red player interact continuously with the computer at each move. Other sections of Volume III give a quite different impression.

6.1 MULTI-MOVE GAMES (Para. B, pp. VI-1)

The game theoretic approach is interesting and useful, especially for the study of command (strategy) matters. However, it should be recognized that in actuality the game matrix is neither "two-person" nor "zero-sum".

The creators of this model have discovered that it is impossible, within any acceptable expenditure of computer resources, to solve for "optimum" allocation of the air resources entered into the game. This merely illustrates that complexity of military problems which has led to a chain of command. The true situation is one of decision matrices at each command center or element in the military structure. Only rarely will we have a situation of one Blue decision-maker against one Red decision-maker.

The "games" are not zero-sum because of differing objectives of the opposed players; for any pair of opposing strategies both may "win" or both may "lose", and a "win" by one will not necessarily have the same numeric value as a "loss" by the other.

The decision matrix being evaluated in this model is that of the Theater Air Force Commander. Payoffs are apparently in terms of movement of the FEBA. This would be a zero-sum game only if movement of the FEBA is of equal importance to both sides, and if attainment of some terrain objective terminates the conflict. Otherwise the conservation of resources for future operation must be a consideration.

6.2 APPROXIMATE ITERATIVE SOLUTION METHODS (Para. D)

If, as in the text, V_{k-1} "is approximated by playing the game through to the end using strategies which have been previously 'optimized' ", and to begin the optimization process one needs to estimate "good strategies" then how is one to determine how closely V_{k-1} has been approximated? In other words, how much does the approximation of V_{k-1} depend on the optimization of strategies and how much does the optimization of strategies depend on the "estimation of good strategies"?

It seems probable that the algorithms described bias the "optimization" in favor of the "good strategies" originally selected. Radically different strategies are unlikely to be discovered.

This is not necessarily unrealistic - the "fog of war" usually dictates a step-by-step decision process guided by strategies found useful in the past.

6.3 SOLUTION OF ONE-MOVE GAMES (Para. E)

It is not stated how $V_k(x)$ is selected (it may be an average of $V_k^{(1)}(x)$ and $V_k^{(2)}(x)$).

The search procedure described probably has a bias in favor of continuation of the initially chosen strategy. Again, this is not unrealistic; it is quite difficult, because of communication delays, to radically change plans after execution has started.

6.4 MIXED STRATEGY SOLUTIONS (Para. F, pp. VI-11)

It might be profitable to employ these methods in the following manner:

1) Limit available strategies to just a few (3 or 4) of the 18 listed.

2) Determine a mixed strategy for this set.

3) Check to see whether this is represented in the set not used.

4) Repeat.