TSAR and TSARINA: SIMULATION MODELS FOR ASSESSING FORCE GENERATION AND LOGISTICS SUPPORT IN A COMBAT ENVIRONMENT

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ABSTRACT

The objectives of this paper are to provide an overview of the TSAR and TSARINA simulation models, and to illustrate their application. These models were developed to provide a method to assess how airbase attacks would affect the capability of airbases to generate effective combat sorties, and to evaluate how a wide range of airbase improvement options could increase the combat capability of airbases during wartime. TSAR simulates the complex interdependencies between the diverse kinds of support resources needed by a modern military organization to sustain combat, and as such has also been successfully applied to assessments of the readiness and sustainability of other kinds of military organizations. Following a description of model highlights, the application of these models is illustrated with some results from a recent analysis.

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1. BACKGROUND

In the event of conflict in Central Europe, U.S. plans call for massive air operations to be conducted from a limited set of large, semi-autonomous airfields located in Western Germany and the Benelux countries, with additional aircraft to be based in the UK. Each base is equipped to provide most necessary organizational maintenance and some battle damage repair, as well as much of the intermediate maintenance (parts repair). Over the years, airbase growth has paralleled the growth in aircraft sophistication, and U.S. airbases are now complex conglomerates of maintenance specialists, fragile test and repair facilities, and extensive supply and fuel storage facilities.

In recent years there has also been a dramatic improvement in Warsaw Pact offensive air capabilities that threatens to seriously jeopardize NATO's strategic dependence on air support at the outset of a conventional war in Europe. Air power must not only withstand this new challenge of air attacks during the opening phase of any large scale conventional war, but must simultaneously be capable of supporting NATO ground forces in countering the massive ground operations expected by the Warsaw Pact.

These well-recognized problems have led to NATO plans for generating high sortie rates ("surges") during the opening days of the conflict and to programs intended to "toughen" the airbases and to improve their active defenses. But despite the accomplishments of the past, many difficulties still exist and a wide range of possible improvements are under consideration to help mitigate various weaknesses and vulnerabilities. The diversity of these possibilities is suggested in Fig. 1.

- SELECTIVE HARDENING and/or DISPERSAL OF FACILITIES
- IMPROVED RRR, MORE SURFACES, and/or REDUCED REQUIREMENTS
- INCREASED WAR RESERVE MATERIAL
- MANPOWER POLICIES
- REPLACEMENT POLICIES FOR COMBAT LOSSES
- REVISED MAINTENANCE POLICIES
- IMPROVED BATTLE DAMAGE REPAIR CAPABILITIES
- IMPROVED INTRA-THEATER TRANSPORTATION
- IMPROVED THEATER RESOURCE VISIBILITY AND MANAGEMENT

Fig. 1--Options for Enhancing Wartime Sortie Generation

In light of the fiscal implications of this disparate set of improvement options, it was apparent that a method was needed that could be used to compare their individual and joint contributions to a force's combat capabilities. Unfortunately no analytic tools, or simulations, existed that would permit detailed examinations of the impact of likely air attacks. To do that it would be essential not only to analyze all the on-base activities that affect sortie generation at a sufficient level of detail to capture the dependencies among the numerous specialized types of resources, but also to be able to include the benefits that might be expected from improved theater management of available resources. It is for those reasons that the TSAR/TSARINA simulation models have been developed.

2. INTRODUCTION

The only constraints on the continuous recycling of aircraft in wartime are the requirements for adequate launching surfaces, the availability of aircrews, munitions and fuel, and the necessary maintenance to permit the aircraft to fly militarily useful sorties. Of these constraints the last is the most complicated since it involves complex interdependencies among a variety of resources. Without maintenance constraints, estimation of an airbase's sortie potential would be relatively straightforward and would require little or no complex analysis. But if these maintenance constraints are to be analyzed under the impact of (1) a "surge" flight program, (2) extensive aircraft battle damage, and (3) the highly irregular patterns of damage to essential base facilities that would be experienced during airbase attacks, it is important that the analysis procedure include sufficient detail so that the critical effects of these factors can be captured. Unless these possibilities for bottlenecks, as well as the emergency procedures that could be adopted, are acknowledged, the likely behavior of an airbase during wartime operations could hardly hope to be represented.

TSAR and TSARINA are Monte Carlo models designed for these kinds of examinations. TSARINA [1] simulates user-specified air attacks, and estimates the losses and damage to various classes of resources and to key facilities. TSAR [2,3] simulates the activities at each of a set of interdependent airbases, that are supported by shipments from the United States and by intra-theater transportation, communication and resource management systems. The nature of the TSAR/TSARINA simulations and their interactions are suggested in Figure 2.

An important objective in the original design formulation was to achieve a sufficiently high speed of operation so that the

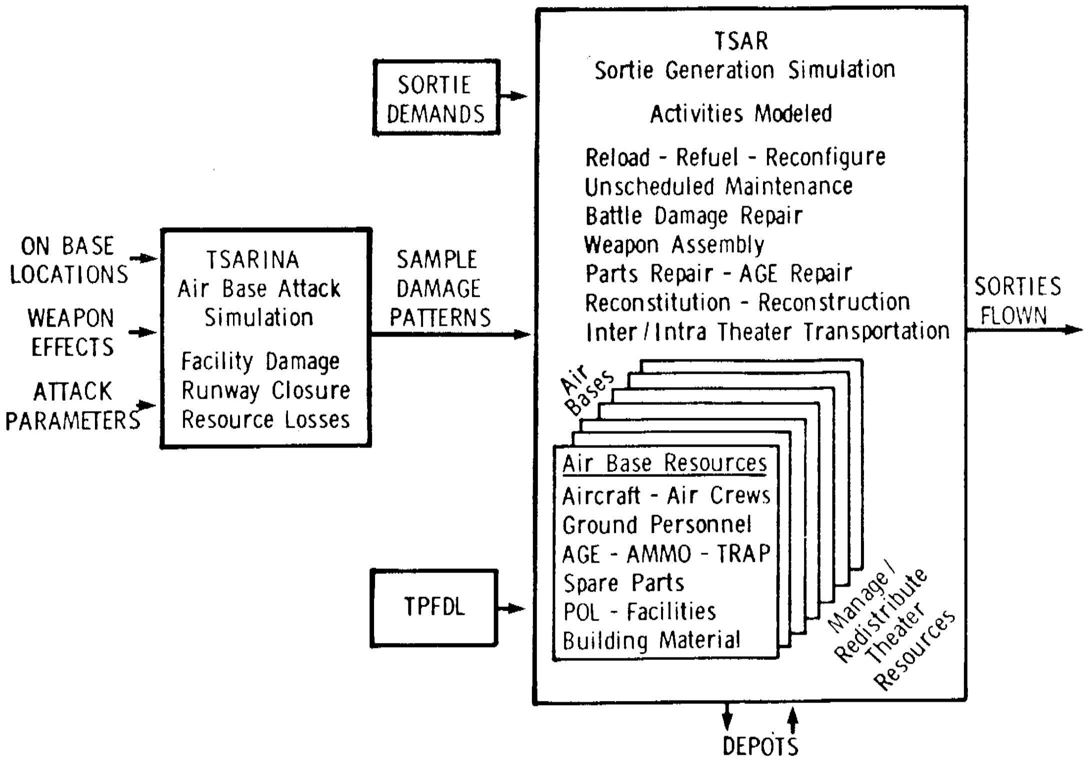

Fig. 2--TSAR-TSARINA -- For Analyzing Sortie Improvement Initiatives

extensive sequence of runs so frequently necessary in research and analysis would be economically practical. Adaptation of existing airbase maintenance models (e.g., LCOM [4,5] , SAMSOM [6]) was rejected for several reasons, including the extent of the modifications that would have been required and the prohibitive costs that would be associated with their use for problems of the size that were contemplated. The resultant, custom-designed programs achieve a substantially higher speed by virtue of more efficient processing, and by taking advantage of the recent dramatic increases in the size of the core storage of modern computers.

3. TSARINA - A DAMAGE ASSESSMENT MODEL FOR COMPLEX TARGETS

TSARINA is a special version of the AIDA (AIrbase Damage Assessment) model [7] and was developed to provide damage data for TSAR. TSARINA accepts detailed descriptions of the size, location, and vulnerability of various airbase facilities, as well as detailed specifications of enemy attacks and weapons effectiveness factors. In addition, the on-base location of resources (e.g. personnel, munitions, aircraft spare parts, etc.)

can be readily associated with various targets (structures/facilities), and different MAEs (mean areas of effectiveness) and/or Pks (kill probabilities) can be defined for the different resources.

TSARINA permits damage assessments of attacks on an airbase complex (or other complex) composed of up to 500 individual targets (buildings, taxiways, etc.), and 1000 packets of specific types of resources. The targets may be grouped into 20 different vulnerability categories, and many different types of personnel, equipment, munitions, spare parts, TRAP*, and building materials can be distinguished. The attacks may involve as many as 50 weapon-delivery passes and 10 types of weapons. General purpose bombs, precision-guided munitions, as well as dispensers for submunitions with controlled impact patterns can be accommodated.

TSARINA determines the actual impact points by Monte Carlo procedures--random selections from the appropriate error distributions. Weapons that impact within a specified distance of each target are classed as hits, and estimates of the damage to the structures and to the various classes of support resources are assessed using either a standard "cookie-cutter" weapon-effects approximation, or a novel two-level "cookie-cutter". Provisions are included that permit the weapon effectiveness factors to be defined differently for direct hits and for near misses.

For each trial computation of an attack, TSARINA determines the fraction of each target covered by the circular damage patterns, and the results include estimates of the overall damage to each target and to all resource classes that are collocated with that target. In addition, the TSARINA output includes an estimate of the total percentage of each type of resource that was damaged at its various storage locations. These data are formatted for immediate processing by TSAR without the need for any manual intervention.

TSARINA also tests to see if operations are possible from runways and other surfaces that are of sufficient size for emergency flight operations. To do this, up to five surfaces are searched to find if there is an undamaged area of the prescribed minimum size. This area may either be rectangular, or rectangular with a superimposed triangular clear area needed for cable clearance when using a mobile aircraft arresting barrier.

TSARINA may be used either as a special-purpose model in support of the TSAR simulation, or as a general-purpose damage

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*Tanks, racks, adaptors, and pylons

assessment model. When used with TSAR, multiple trials of a multi-base airbase-attack campaign can be evaluated with TSARINA and used directly with TSAR.

4. TSAR -- A THEATER-LEVEL SORTIE GENERATION SIMULATION MODEL

4.1 General

The classes of resources that are treated in TSAR include aircraft, aircrews, ground personnel, support equipment, aircraft parts, aircraft shelters, munitions, TRAP, fuel, building materials, and a variety of airbase facilities. Many different types of each resource class may be distinguished. On-equipment maintenance tasks, parts and equipment repair jobs, munitions assembly, and facility repair tasks are simulated for each of several airbases. Asset accounting for each of the eleven classes of resources, and for each type within each class, permits assessment of a broad range of policy options that could improve the efficiency of resource utilization on a theater-wide basis.

TSAR is readily adaptable to problems across a broad range of complexity. When specific features are not needed for the examination of a particular issue, they simply need not be used. Thus, TSAR permits one to represent either a single base, a set of independent airbases, or a set of interdependent airbases, without any adjustment or modification of the program. Similarly, the user may not wish to examine the effects of airbase attacks, or may wish to ignore the possible restraints imposed by shortages of aircrews, shelters, ground personnel, support equipment, aircraft parts, munitions, TRAP and/or fuel. TSAR adapts automatically to all such problem representations. And although the present discussion focuses on aircraft, TSAR is also in use on a Rand study of Army readiness, in which tanks and other army vehicles successfully fill "aircraft" roles without modification of the TSAR code.

4.2 Airbase Activities

In TSAR, specified numbers of aircraft of various types can be assigned to each airbase. The aircraft of a given type at any airbase may be supported by a common pool of personnel and equipment, or the aircraft may be organized into two or three sub-groups (squadrons) each supported by its own set of resources. The aircraft are launched on sorties in response to a set of user-supplied sortie demands, differentiated by base, aircraft type, mission type and priority. Flights may be scheduled, or scrambled on demand using aircraft that have been placed on alert.

When an aircraft is lost on a combat mission, a replacement may be requested and it will be received after a stipulated delay. When aircraft that are not lost return, they may be damaged, they may still have munitions, and they may have several unscheduled maintenance task requirements. The basic input data that govern the probabilities with which unscheduled maintenance tasks are demanded are derived from the large data bases developed by the Air Force (and other agencies) for the LCOM model.

The user is given substantial flexibility in defining the rules by which aircraft maintenance tasks are to be processed. He may permit the activities of certain groups of shops to proceed simultaneously, and may require that the activities of several such groups of shops proceed in a specified order. He also may control these prescriptions for simultaneous and sequential operations, separately for each aircraft type at each base. Figure 3 illustrates how ground operations might be organized to ready an aircraft for flight. In this example the three tasks in parallel--load guns, shelter aircraft, and check--can all be commenced after hung munitions have been dealt with and battle damage has been repaired. And when these tasks are complete, the four tasks shown in parallel can all begin, given that the required resources are available. These features permit alternative maintenance operating doctrine to be simulated and to be examined for their influence on sortie generation capabilities. Work speed-up and other procedures to shorten on-equipment, pre-flight and off-equipment activities also may be specified.

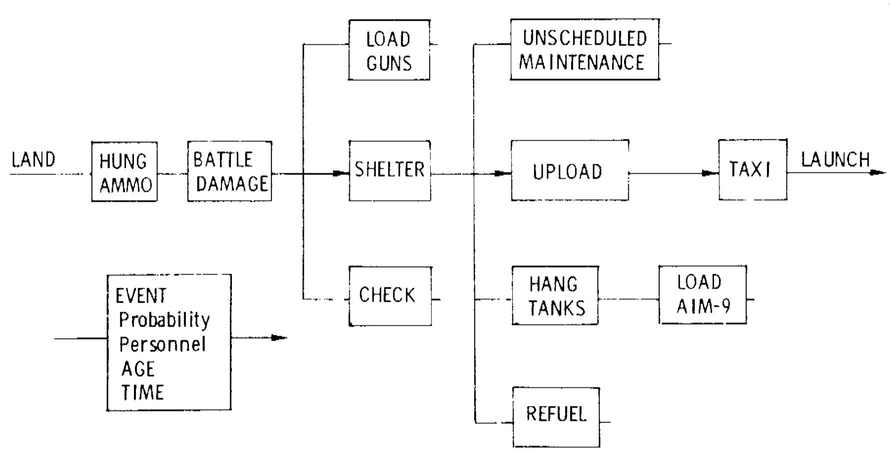

Fig. 3--Simulated Sortie Generation Procedures

Each on-equipment maintenance task may require a team composed of one or two types of maintenance specialists, specialized equipment, a spare part, and a specified amount of time; each unscheduled maintenance task is either a single set of such requirements, or it may be a network of tasks, each with its own demands. When resources are limited, those aircraft most likely to be readied first are given priority.

If a required part is not available, (1) the broken one that is removed may be repaired on base, (2) the appropriate part may be cannibalized, (3) a part may be obtained from another base, or (4) the part may be ordered from a central source within the theater. When a part cannot be repaired on base it may be sent to a neighboring base or to a centralized facility in the theater. When parts cannot be repaired within the theater, a replacement may be requested from a depot in the United States. Often the parts removed from an aircraft are what are called line replaceable units (LRUs) that contain several subordinate components known as shop replaceable units, or SRUs. Repair of both indenture levels may be simulated. Furthermore LRUs may be "cross-canned" to obtain an SRU to repair one of two LRUs, if the LRUs require different SRUs.

The failure and repair of support equipment also may be simulated, and the special "partial-mission-capable" characteristics of modern AIS (avionics intermediate shop) test equipments may be represented. In addition, the manpower intensive munitions assembly tasks may be simulated. When this is done, munitions demands are projected periodically to define which types of munitions need to be assembled. Such jobs may require both personnel and equipment, much like other tasks in TSAR.

TSAR may be used to simulate the effects of damage due to airbase attacks with conventional munitions using the damage estimates generated by TSARINA, as described above. When aircraft or facilities are damaged or destroyed by air attack, some portion of the personnel, equipment, and parts present at these locations because of the then ongoing tasks also may be lost. Aircraft are kept in aircraft shelters when sufficient shelters are available, but it may be required that the shelter doors are open when certain shop operations are underway at the time of airbase attack; different loss rates are applied in each case. Aircraft in excess of those that may be placed in the shelters sustain still another loss rate. After TSAR has decremented the various resources to the extent implied by the damage data, the surviving personnel are reorganized into night and day shifts. Replacement resources may be ordered for whatever losses are sustained. After a user-stipulated delay to roughly account for the disruptive effects of the attack that are not simulated (e.g., fires, broken utility lines, and impassable roads), the surviving maintenance personnel resume their activities to the extent that the surviving support resources permit, unless their facility is required and has been damaged.

After an airbase attack, civil engineering personnel, equipment and building materials may be allocated, according to a priority system, to commence the required repairs on runways and taxiways and to begin reconstruction of the damaged facilities. Operation of the facilities is resumed when they once again are functional.

4.3 Theater-Level Activities

The theater-wide management of the various resources is supported by a user-specified scheduled transportation system that may be subjected to delays, cancellations and losses. TSAR also permits the user to represent a theater-wide reporting system that can be used to provide the central authority with periodic status reports from the several operating bases; these reports may be delayed, incomplete or lost.

When these transportation and communication systems are coupled with a set of rules for distributing and redistributing resources among the operating bases, various concepts of theater resource management may be represented and examined in the context of realistic transportation and communication imperfections. In its current formulation TSAR already includes certain alternatives for the theater management rules and has been designed in a fashion that will permit additions or modifications to be readily accommodated.

Daily estimates may be prepared of each base's capabilities for generating different kinds of sorties with different types of aircraft. These estimates can be used to provide the basis for various aircraft management decisions. One application is in selecting which base is to be "fraged" with sorties for which no base has been specified. These data can also be used to support assignment decisions when aircraft must be diverted in flight, and to redistribute aircraft among airbases to improve the balance between flight requirements and support capabilities.

The options currently available for theater-wide management of aircraft and spare parts are suggested in Figs. 4 and 5, respectively.

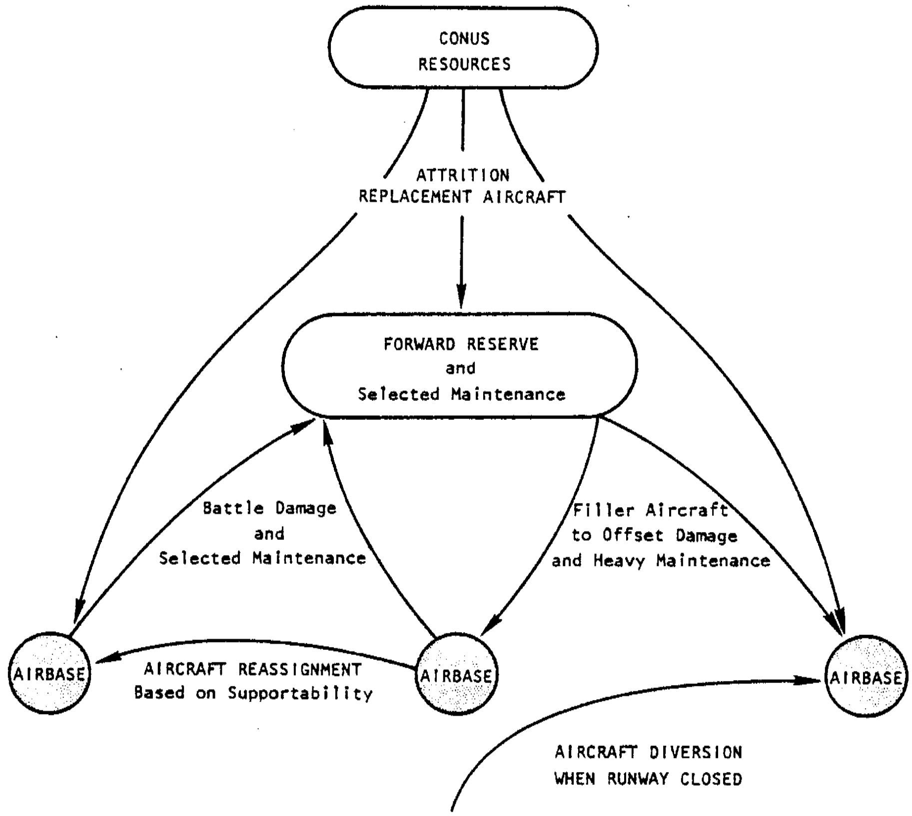

Fig. 4--Aircraft Management Options

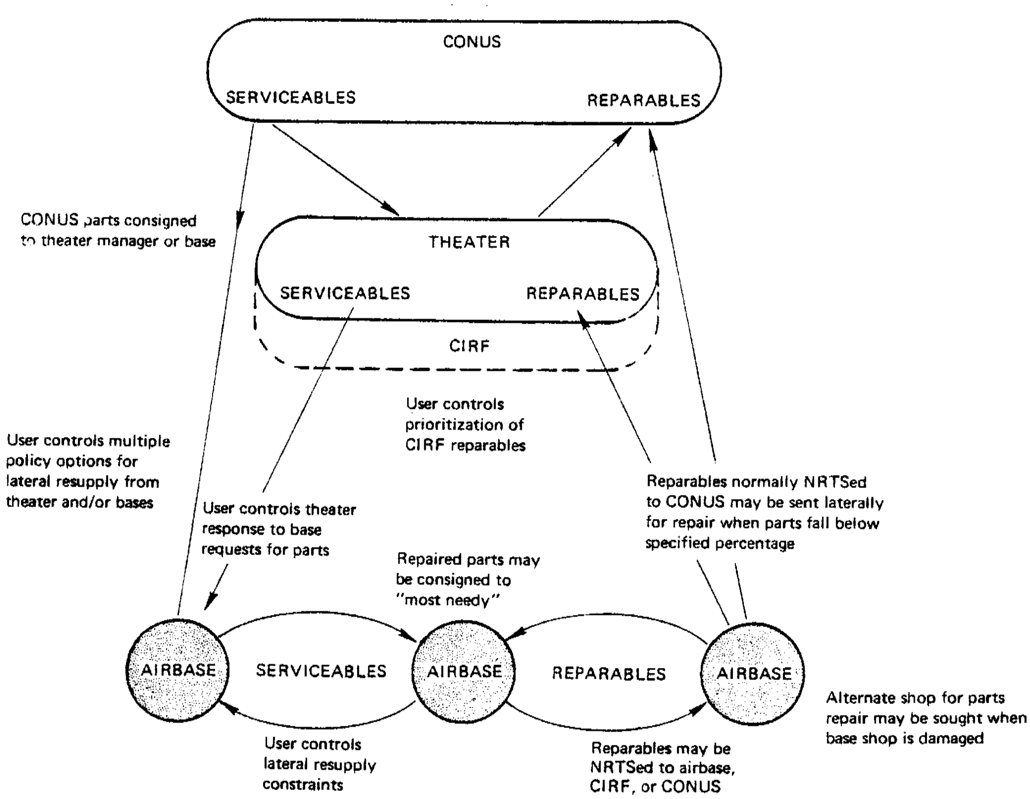

Fig. 5--Theater Management Options for Spares

In addition to simulating a set of airbases, the user also may specify the existence of a centralized theater distribution center and/or a centralized theater repair facility at which some or all intermediate maintenance is conducted. The centralized distribution facility can receive spare parts from the United States and either retain them until demanded by a base, or transship (some or all) to the base with the earliest projected requirement. The theater management features may also be used to direct the lateral shipment of parts and other resources from one base to another. The repair facility, sometimes referred to as a CIRF, is assigned maintenance personnel, equipment, and spare parts (LRUs and SRUs). Parts are shipped to and from the CIRF from the operating bases and are processed in the manner prescribed by the user's choice of which theater management rules are to govern these operations. Parts repair priorities can be based on existing and projected demands and on the relative essentiality of parts for the various missions. Shipment priorities are related to the current and projected demands, on-base reparables, and enroute serviceables. When central stocks are insufficient to meet a base's demand, another base can be directed to ship the required part, if both the requesting base and the donor base meet certain conditions relative to the importance of the demand and the availability of stock.

4.4 Output Statistics

Normal outputs include the number of sorties flown, the maintenance tasks accomplished, shop performance statistics, and resource constraint statistics. One optional feature enables the user to observe the daily activity of 24 aircraft in detail. Data may be displayed on a daily, trial, or multiple trial basis. While the output options that are provided permit the user to examine a substantial portion of the more relevant results, all possible outputs certainly are not available. Custom additions can and should be readily included by users as the need arises.

4.5 Validation

The aircraft representation used during much of TSAR's development was based on an LCOM input data deck for the F-4E, obtained from TAC headquarters at Langley AFB. Validation of single-base operations has been limited to comparisons of TSAR results with LCOM results, and with an exercise at Hahn Airbase; although these comparisons have not been under sufficiently controlled conditions to constitute formal validation, the results have been quite similar. For multiple-base operations, validation has been limited to checking model output against projected results for many hundreds of test runs.

4.6 Technical

TSAR was written in FORTRAN IV and was recently converted to ANSI FORTRAN 1977. The only feature not supported by ANSI FORTRAN 1977 is the widespread TSAR usage of packed half-word integers for data storage (a feature available on IBM machines); for those systems that do not permit half-words to be addressed, data storage requirements (in words) will be nearly doubled.

Currently TSAR consists of some 132 subroutines and functions with a total of 236 entry locations; the source code consists of somewhat more than 34,000 card images, exclusive of the Common statements. Core storage for the executable statements is approximately 520K bytes (8 bits) on an IBM 370/3032 when only the input-related subroutines are overlaid. The additional core required for data storage is indicated in Fig. 6 for a current configuration; firm limits imposed by the program architecture are also indicated.

A crude, but serviceable, rule of thumb for TSAR's computational efficiency can be expressed in terms of sorties simulated per CPU minute. Although such a measure naturally varies with the complexity of the representation, the level of

Bases	8 (63)
AC Types	3 (9)
Aircraft	400
Aircrews	800
Missions/AC	4 (5)

Resource Types	
Personnel	200 (320)
Equipment	100 (100)
Munitions	25 (100)
TRAP	25 (100)
LRUs, SRUs	1000 (3200)
Shelters	1 per base

Procedures	
On Equipment Tasks	1500 (5000)
Part Repair	1000 (5000)
Damage Data	2000
CONUS Cargo	2500
IntraTheater Cargo	2500
Equipment Repairs	100 (5000)

Tasks & Queues	
Ongoing	1000
Parts	250
Waiting	2000
Interrupted	400
Deferred	4000
Parts Delay	1500

COMPUTER DATA

SPACE: Instructions 520 K (400 - 600) Bytes
Storage 550 K (100-1000+) Bytes
Total 1100 K (500-2000+) Bytes

SPEED: 1000-6000 Sorties/CPU Min

Fig. 6--TSAR Dimensions and Storage Requirements
Current (Max)

theater activity, and the extent of the on-base shortages, a majority of our analyses have run at 2000 to 3000 sorties per CPU minute on an IBM 370/3032. Cases that involve heavy damage and extensive shortages have dropped to as low as 1000 to 1500 sorties/ CPU minute, and the examinations of Army readiness regularly attain 6000 sorties/CPU minute.

5. APPLICATIONS

TSAR and TSARINA have been used in several studies at Rand and have recently been acquired by several USAF organizations: the new Airbase Survivability Office at Eglin AFB, the Logistics Management Center at Gunter AFB, the Aerospace Medical Research Laboratory at Wright-Patterson AFB, and by Studies and Analysis at Hqs. USAF. The Rand studies have included an analysis [8] that helped to evaluate the impact of the Air Force proposal for an EDS (European Distribution System), and a study [9] to quantify the effect of alternative resource levels on the readiness and sustainability of combined arms brigades.

In another recent analysis, we examined the (simulated) wartime activities of three Air Force units in the West Germany--72 F-4Es at a main operating base (MOB) and two 24 F-4E squadrons that are to be deployed to collocated operating bases (COBs) when NATO forces are mobilized. Each base was resourced with the personnel, equipment, and spare parts normal for such bases; the lateral resupply and repair of spare parts was supported by a transportation system that provided daily deliveries. Although the results are, of course, specific to this set of bases and resources, these bases are a reasonably representative slice of the theater. For the first week of the war these units were directed to "surge" at rates of approximately two-and-a-half sorties per day. Aircraft were to be flown in groups of four (two minimum), during five 60-90 minute launch windows over a 14-hour flying day. These requirements were held constant throughout the analysis presented here.

If we assume, as is frequently done, that losses will be instantly replaced, and that damaged aircraft will not affect sortie production, these objectives are largely fulfilled, as shown in Fig. 7. The upper line indicates the total numbers of sorties that the three bases might expect to achieve under these conditions. Although not representative of actual wartime operations, this performance is used as a reference case for the other results.

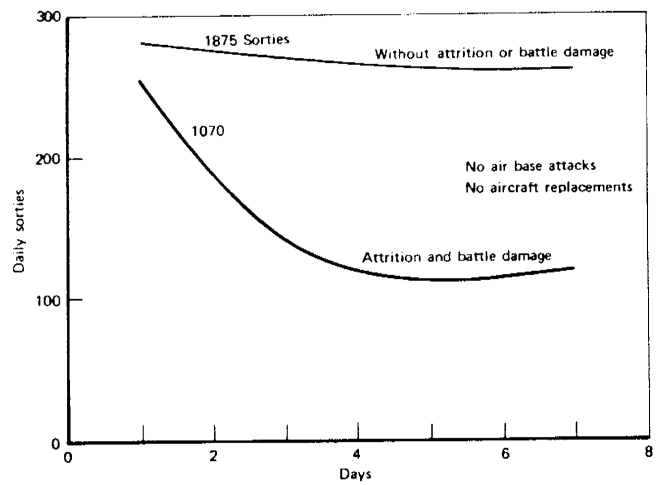

Fig. 7--Effects of Attrition and Battle Damage on Sortie Generation

We next examined the same scenario, as it might actually develop during the first week in wartime, if replacements for lost and badly damaged aircraft could not be made available within that time. We assumed that the attrition rates for flight operations would drop off as a function of time, and would average just under three percent per sortie during the first week. We also assumed that the damage-to-kill ratio would be that that was experienced in the South-East Asian (SEA) theater, and that the manpower requirements for battle damage repair could also be based on SEA experiences. As the lower line in Fig. 7 indicates there would be a very substantial reduction in the sorties under these circumstances.

In Fig. 8 we have assumed, first, that 72 aircraft will be available as replacements within about two-and-one-half days of a loss. Performance is improved, but still falls far short of the reference case, as shown by the next to lowest curve. Fig. 8 also indicates the incremental improvement that might be achieved by having additional ABDR (aircraft battle damage repair) specialists available on D-day (in addition to the replacement aircraft). If, as presumed here, attrition and battle damage are highest at the beginning of the conflict, it is essential that battle damage specialists be in place by D-day. But even when these specialists are in place at the beginning of the conflict, there is still a substantial sortie shortfall during the critical first week. Thus even in the absence of air attack, it seems questionable that the planners' objectives of a "surge" can be

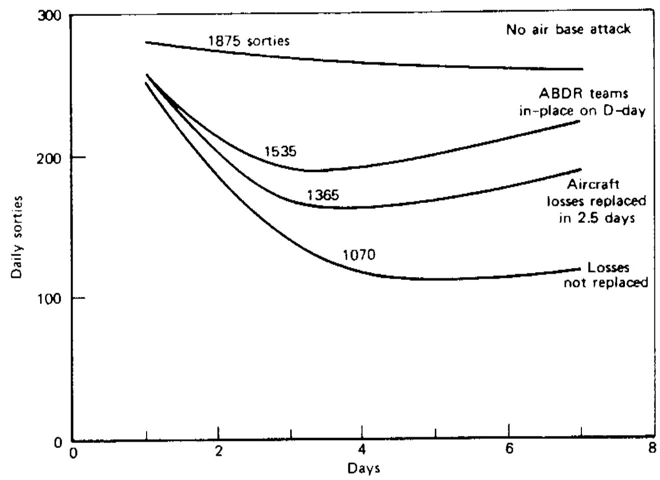

Fig. 8--Reducing Effects of Attrition and Battle Damage: Aircraft Replacement and Extra ABDR Personnel

attained because of the difficulty of maintaining a full complement of combat capable aircraft at the forward operating bases.

And what of air attack? Despite long-term Air Force efforts to obtain the funds needed to shelter all aircraft planned for deployment to the Central Region in Europe, Congress has strongly resisted the necessary expenditures. Based on the programs that are currently funded, only about 60 percent of the USAF aircraft expected to be in NATO's Central Region after a week of mobilization can be sheltered. No shelters will be available for USAF aircraft on some of the COBs where early deployment is planned, and very few of the support facilities have any special protection.

In our analyses of air attacks we assumed that one of the two COBs does not have shelters, but that the aircraft would be well dispersed on base. Furthermore we assumed the same types of construction and the same locations for the support facilities, as for those that actually exist at three bases in West Germany. The attack levels examined are those that these three bases might expect if the Warsaw Pact were to initiate hostilities with an air campaign that stressed attacks on NATO's air assets, as it is frequently presumed that they would. The attacks consisted of third-generation fighter-bombers and medium bombers delivering conventional munitions; the attacks are repeated, at reduced strength, every couple of days during the first week. Chemical attacks and attacks with surface-to-surface missiles have not been considered.

The air attacks we examined presumed that the enemy would concentrate on the aircraft shelter areas and on the concentrations of maintenance and support facilities. Our earlier analyses examined runways, as well as the shelter areas, as possible enemy targets, and both types of attack would seriously affect aircraft operations; our present focus derives in part from the fact that many actions are already underway in the Air Force to counter the threat of runway attacks.

If lost aircraft are not replaced, and additional ABDR personnel are not in place at D-day, the sorties that might be expected to be generated in the face of these hypothetical Warsaw Pact airbase attacks are shown by the lowest line in Fig. 9. Only about one-third as many sorties are achieved, as in our reference case. The irregular generation profile is in part due to the assumption that unscheduled maintenance is disrupted for six hours after heavy air attack; only ready aircraft are launched and ongoing weapon loading and aircraft fueling tasks completed during this period. The attacks destroy or damage over 50 aircraft, as well as substantial numbers of maintenance specialists, critical support equipment, and spare parts. In addition many parts repair facilities are damaged.

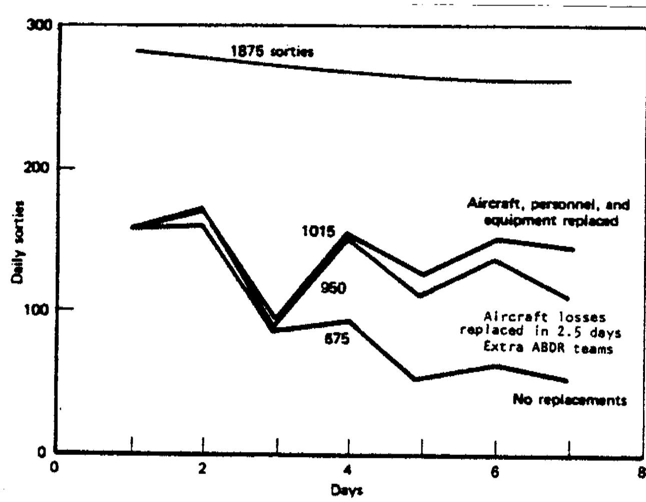

Fig. 9--Reducing Effects of Airbase Attacks: Aircraft Personnel, and Equipment Replacement

If we now presume that replacement aircraft are available within two-and-one-half days, and that extra battle damage specialists are in place when the conflict begins, the force still is unable to achieve more than about 50 percent of the sorties flown in the reference case, as the next to the lowest line in Fig. 9 indicates. Some sorties are prevented by the unpredictable losses among maintenance equipment and personnel; when these are also replaced within two-and-one-half days of their loss, performance is improved somewhat as is also shown in Fig. 9, but not very much. The critical problem is airframes. There are discouragingly small numbers of aircraft available to respond to the demand for sorties, despite the introduction of substantial numbers of replacement aircraft.

Furthermore there has been serious damage to many of the backshop facilities that will have to be rebuilt or replaced before reparable spare parts can be processed in order to sustain even these limited numbers of sorties. And these problems will be further compounded by the heavy losses that were sustained on some trials to the stocks of serviceable spare parts, and to munitions and fuel.

What else can be done to improve matters? More rapid aircraft replacement, more effectively protected facilities, larger numbers of personnel, equipment, spares, etc.--all of these obviously would help. But without a means of assessing the impact that airbase attacks will have on sortie generation, there is limited motivation to consider such changes to existing plans, and without those same means there are few credible approaches to assessing how possible changes would improve combat capability. But with the assessments that can be generated with TSAR/TSARINA simulations we believe that decisionmakers will be increasingly motivated to make changes that will improve matters, and that they will have a better basis for deciding which of widely disparate options that are available should be chosen.

6. CONCLUSIONS

TSAR and TSARINA have been designed to provide a variety of potential users with an analytic structure within which a rich variety of potential improvements for theater airbases may be tested in a common context. New passive defenses, new maintenance doctrine, modified manning levels, increased stock levels for parts and equipment, etc., as well as a variety of concepts for improved theater-wide resource management--all of these can be examined with TSAR/TSARINA within a common context in terms of their ultimate impact on the system's capabilities for generating sorties.

ACKNOWLEDGMENTS

The development of TSAR demanded uninterrupted concentration over an extended period. My debts to the Air Force and Rand management are obvious; not so obvious are the debts owed a most understanding family. Among my colleagues at Rand, I would particularly like to acknowledge Lou Wegner and Mike Poindexter for their many suggestions regarding various programming problems, and Milt Kamins and Major John Halliday for their ideas that have been incorporated into the model logic, and for their careful work in generating essential data bases.

REFERENCES

1. Emerson, D. E. (1980), TSARINA--User's Guide to a Computer Model for Damage Assessment of Complex Airbase Targets, N-1460-AF, The Rand Corporation, Santa Monica, CA.
2. Emerson, D. E., An Introduction to the TSAR Simulation Program: Model Features and Logic, R-2584-AF, The Rand Corporation, Santa Monica, CA.
3. Emerson, D. E., (1982), TSAR's User's Manual, Vol. I, II, and III; N-1820-AF, N-1821-AF, and N-1822-AF; The Rand Corporation, Santa Monica, CA.
4. Drake, W. W. (1974), Logistics Composite Model Users Reference Guide Update, AFLC/ADDR Report 74-1, Systems Requirements and Control Division (ADDR), Office of DCS/Data Automation, Headquarters, Air Force Logistics Command, Wright-Patterson Air Force Base, OH.
5. Fisher, Capt. R. R., W. W. Drake, J. J. Delfausse, A. J. Clark, and A. L. Buchanan (1968), The Logistics Composite Model: An Overall View, RM-5544-PR, The Rand Corporation, Santa Monica, CA.
6. Smith, T. C., G. D. Brown, P. A. Mason, R. Moulenbelt, and H. J. Shukiar (1967), A User's Manual for SAMSOM II: The Support Availability Multi-System Operations Model, RM-4923-PR, The Rand Corporation, Santa Monica, CA.
7. Emerson, D. E. (1976), AIDA: An Airbase Damage Assessment Model, R-1872-PR, The Rand Corporation, Santa Monica, CA.
8. Shishko, R, and R. M. Paulson, (1981), Relating Resources to the Readiness and Sustainability of Combined Arms Units, R-2769-MRAL, The Rand Corporation, Santa Monica, CA.

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