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A THREAT-BASED THEATER WAR DAMAGE METHODOLOGY

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Engineers are responsible for repairing or replacing war-damaged sustainment base facilities. Planning for the amounts and kinds of war damage repair is, however, confounded by the vagaries of war. Theater wargames generally ignore damage at rear-area installations, and war damage models typically confine their analysis to direct and collateral facility damage at one installation under one attack. The Engineer Studies Center (ESC) has used various approaches to estimate theater damage in its series of engineer assessments. In its most recent studies, ESC has developed general methodology and a PC-based computer program that extends the capabilities of the installation-level damage models to theater-level analysis. The approach incorporates scenario data and actual threat capability to estimate damage by facility, installation, and time. The primary purpose of ESC's threat-based methodology is to provide engineers a rough, but reproducible and rational, estimate of war damage for planning purposes. The accessibility of the program and the relative immediacy of results enable the user to quickly explore alternative scenarios or hypotheses. This report describes that methodology and the damage model upon which it relies.

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A THREAT-BASED THEATER WAR DAMAGE METHODOLOGY

Prepared by
Engineer Studies Center
U.S. Army Corps of Engineers

June 1991

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ABBREVIATIONS AND ACRONYMS

AAP	Attack Assessment Program
AFCS	Army Facility Component System
AIDA	Air Base Damage Assessment Model
AR	Army Regulation
BBL	barrel
CAA	U.S. Army Concepts Analysis Agency
CEP	circular error probability
CESPG	Civil Engineering Support Plan Generator
COB	collocated operating base
COMMZ	communications zone
COSAGE	Combat Sample Generator
DAMOC	Damage Allocation Model
DOD	Department of Defense
EA	each
ESBAS	Engineer Studies Center Bomber Assessment Study
ESC	Engineer Studies Center
FEBA	forward edge of the battle area
GAL	gallon
GEOLOC	geographical location
HQDA	Headquarters, Department of Defense
JCS	Joint Chiefs of Staff
JEPES	Joint Engineer Planning and Execution System
JOPS	Joint Operation Planning System
KW	kilowatts

MOB	main operating base
MOS	minimum operational strip
NAASP	Naval Air Attack Simulation Program model
NATC	North Atlantic Treaty Organization
NCAF	nuclear capable airfields
OOP	object-oriented programming
PC	personal computer
PMD	postmortem dump
POL	petroleum, oils, and lubricants
RAM	random access memory
SEAC	Simulated Engineer Assessment of the Communications Zone Model
SOF	special operations forces
SPANS	spans
SPETSNAZ	Soviet Special Purpose Forces (SPF)
SSM	surface-to-surface missiles
U.S.	United States
USAF	United States Air Force

EXECUTIVE SUMMARY

In addition to their mission of constructing and maintaining the theater sustainment base, engineers are responsible for repairing or replacing war-damaged facilities. Planning for the expected amount and kinds of repairs, however, is confounded by the vagaries of war. Theater wargames typically ignore rear area installations, much less attempt to estimate what damage might occur over the course of a campaign. Installation-level models, that estimate the effect of individually targeted munitions and the expected resulting direct and collateral facility damage, currently exist. However, such programs are limited to one installation under attack and require too much specificity to be useful at theater-level.

The U.S. Army Engineer Studies Center (ESC) has used various approaches to this problem when performing engineer assessments of the major theaters where U.S. forces might be deployed. In its most recent studies, ESC developed a methodology that objectively addresses theater war damage. Building on the capabilities of the installation-level models, ESC formulated an approach that utilizes the best available intelligence and estimates of enemy capability to project theater damage by facility, installation, and time. This report describes that methodology and provides guidance on how it could be used and implemented elsewhere.

Much of the methodology is embodied in a computer program that ESC developed--the Damage Allocation Model (DAMOC). The program was designed to run on any PC-compatible microcomputer. It is written in TURBO PASCAL 5.5, a computer language which supports object-oriented programming (OOP). This software engineering approach is receiving much attention in computer circles, especially in the areas of modeling and simulations. ESC was able to combine its past experience using OOP with PASCAL's features to construct an efficient and extensible model. The resulting design of DAMOC proved to be a great advantage during implementation, especially when making changes and improvements to the model. Because of relatively few object-based operational models in use, software designers might find DAMOC to be of interest apart from its functional representations.

Overall, the accessibility of the system, the separation of facility damage and targeting, and the relative ease of use enable the user to utilize varying amounts of available information to estimate damage and to quickly explore alternative scenarios or hypotheses.

ESC encourages prospective users to request a copy of a distribution diskette that contains DAMOC, test data, and sample files. Such inquiries should be made directly to the Office of the Director, U.S. Army Engineer Studies Center, Casey Building 2594, Fort Belvoir, Virginia 22060-5583; phone number (703) 355-2373.

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I. INTRODUCTION

1. **PURPOSE.** This report describes a methodology developed by the U.S. Army Engineer Studies Center (ESC) to assess theater war damage to facilities. It documents the data, design, and operation of a threat-based process to generate expected facility-level war damage at installations across a theater. In addition, it documents a damage allocation model that ESC developed as a major component of the process.

2. **BACKGROUND.** One of the more difficult aspects of war planning is assessing facility damage--what was damaged, what must be repaired, and how does it affect mission accomplishment. An air base that is fully functional may not require additional facilities to support its units. But if that base is attacked, engineers will be needed to repair runways, erect petroleum, oil, and lubricant (POL) storage, or restore operational and maintenance facilities.

a. Over the years considerable effort has been expended trying to estimate these requirements. Some models have gone to great lengths in simulating an attack and recording the damage (direct and collateral) by using explicit facility and munitions characteristics. The U.S. Air Force (USAF), in conjunction with the RAND Corporation, has developed several air base attack models: AIDA[1] and TSARINA[2]. These RAND models explored issues such as optimal attack strategy and effect on sortie generation capability. The Attack Assessment Program[3] (AAP) is another installation damage model. It is used as a front-end for damage input to the Civil Engineer Support Plan Generator (CESPG),[4] the Department of Defense's (DOD) approved engineer support model. More recently, the Navy has adapted the AAP to run on any IBM-compatible personal computer. The common trait of all these models, however, is that they tend to deal with a single installation and the effect damage has on operational capability. There is no easy way for analysts to extrapolate from individual installation damage to theater requirements.

b. ESC's interest, however, was broader and twofold--to estimate war damage for the entire theater and campaign, and to derive the resulting engineer workload. Since the mid-1970s, ESC has conducted many studies[5] that examine wartime engineer support across the entire communications zone (echelons above corps) and use different approaches. The CESPG can accept

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[1] D. E. Emerson, *AIDA: An Air Base Damage Assessment Model*, R-1872-PR (The Rand Corporation, September 1976).

[2] D. E. Emerson and Louis H. Wegner, *TSARINA--A Computer Model for Assessing Conventional and Chemical Attacks on Air Bases*, N-2244-AF (The RAND Corporation, August 1985).

[3] Attack Assessment Program (AAP), CCTC, Computer Systems Manual, CSM UM 267-81 (1 March 1981).

[4] *Joint Operation Planning System (JOPS)--Civil Engineering Support Plan Generator (CESPG) User's Manual, Computer System Manual CSM UM 122-86* (1 April 1986).

[5] - *Bomb Damage to Critical U.S. Facilities in Europe* (ESC, May 1981).
- *Engineer Assessment, Korea: Communications Zone Analysis* (ESC, August 1987).
- *Soviet Air and Unconventional Warfare Damage, Southwest Asia* (ESC, September 1987).
- *Joint Operational Assessment, Engineer Requirements, European Southern Region* (ESC, February 1991).

direct or indirect repair tasks, but does no damage or threat calculations. When and where the damage occurs must be done off line. The Simulated Engineer Assessment of the Communications Zone Model (SEAC)[6] incorporated threat-based damage into an engineer workload model. While this general model incorporated both the calculation of damage at the facility-ordnance level and the engineer capability to repair it, it still required off-line target specification. ESC still needed a better means to generate war damage--one that would avoid the need to explicitly represent every facility in theater, and at the same time, would tie damage to threat capability.

[6] *Simulated Engineer Assessment of the Communications Zone Model (SEAC), Documentation and Users Manual* (ESC, June 1988).

II. METHODOLOGY

3. **APPROACH.** ESC's objective was to develop a reasonable and reproducible, threat-based system to estimate facility damage across a theater. The system that evolved was very similar to the hierarchical structure espoused in AR 5-11[7]. That regulation established an objective that components in the Army's combat model hierarchy would be able to interface. One means to accomplish this could be to use ". . . libraries of previous results from those components . . . ."[8] While the Army still awaits seamless interconnections, the linking of models of different resolution is routinely done.

a. To conduct theater analysis, the U.S. Army Concepts Analysis Agency (CAA) first uses the Combat Sample Generator (COSAGE), a stochastic division-level model, to construct a library of battle results. These "killer/victim scoreboards" record the average attrition results of replicating simulations of different posture and force structures. The scoreboards are then used by CAA's deterministic theater models as data-points in a result n-space from which new outcomes are interpolated.

b. ESC followed a similar two-phased approach. A detailed installation-level damage model is used to generate a library of attack results (damage profiles). The library is then one input to the deterministic theater damage assessment model along with scenario specific information regarding threat capability and targets. **Figure 1** portrays this methodology.

4. **DAMAGE PROFILE DEVELOPMENT.** Initially, ESC intended to use one of the installation-level models to calculate damage at each target and to aggregate the results by time and location. From available models, ESC selected the PC-based Naval Air Attack Simulation Program (NAASP)[9]. This is a stochastic model which replicates proposed attacks many times to produce an expected level of damage. However, the user must provide a laydown of installation facilities and various attributes of the contemplated attack, some of which require additional off-line calculations. ESC's attempt to use the NAASP for each installation target in a theater proved easier in concept than in practice. The problems, however, might have been fortuitous. Modifications made to ESC's initial approach resulted in a method that more equitably treats threat capability with blast and fragmentation effects. The lynchpin was the development of damage profiles.

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[7] *Army Model Improvement Program, AR 5-11* (HQDA, August 1981).

[8] Ibid., page 1-4.

[9] J. Ferritto and K. Hager, *User's Guide for Conventional Weapons Effects Survivability Computer Programs*, UG-0012 (Naval Civil Engineering Laboratory, February 1988).

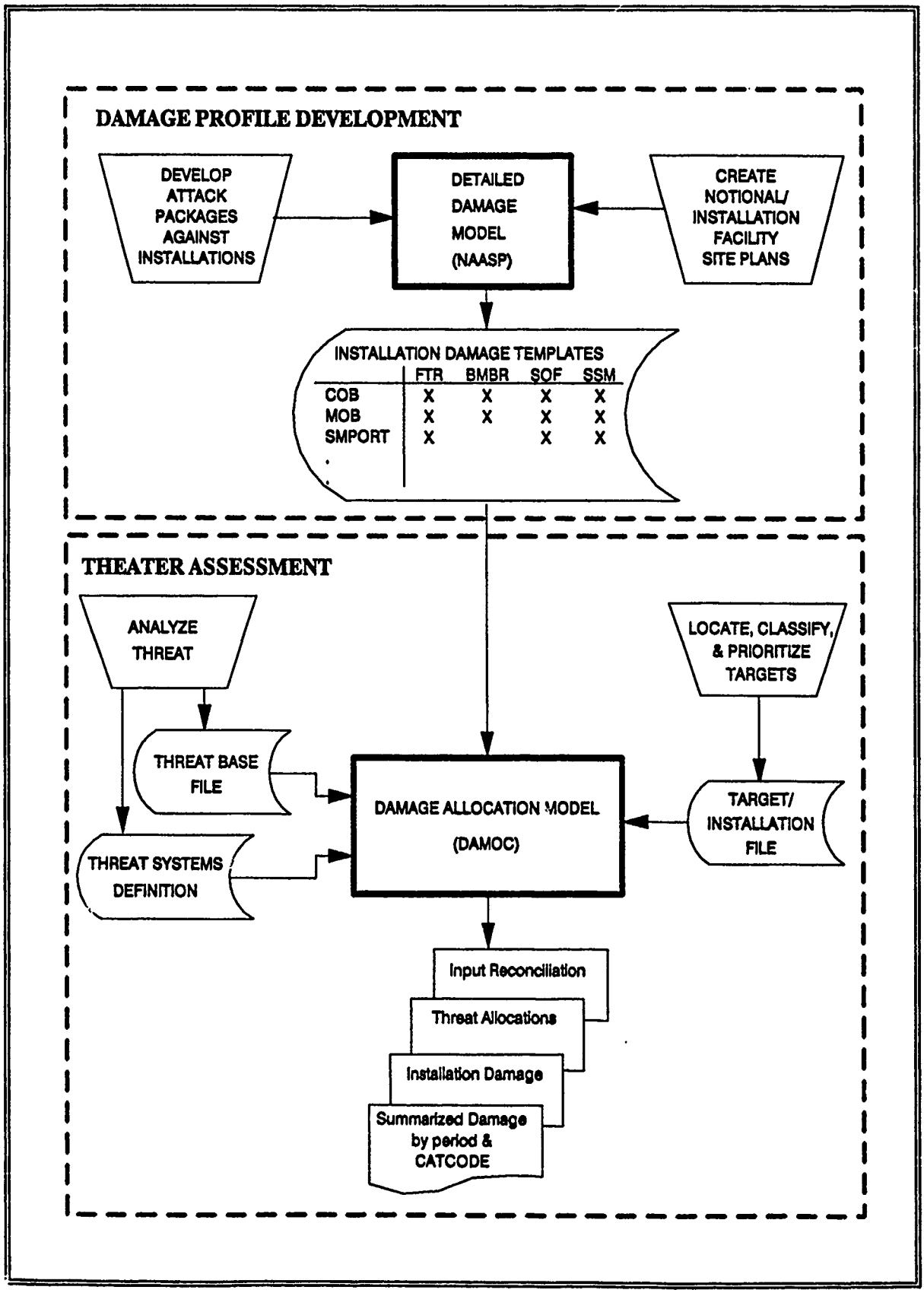

Figure 1. WAR DAMAGE METHODOLOGY CHART

a. **Notional Installations.** ESC initially planned to use the NAASP with data digitized from actual installation site plans. Each installation target within a theater would be attacked, and facility damage recorded. This ambitious approach quickly became unrealistic in execution.

(1) A variety of problems arose: installation site plans often were not available (especially for non-U.S. targets); even when site plans were available, scaling problems frustrated accurate digitization; frequently the category (e.g., construction standard, building usage) of facilities within an installation could not be established; and the time to complete one target precluded individual NAASP runs. There were also mechanical difficulties associated with converting installation data into the NAASP's digitized format. It was no easy matter to ensure that the data was formatted correctly. When an installation was digitized, numerous NAASP runs were required to refine data input until it was correct and until the program executed as intended.

(2) Based on the general unavailability of installation information and inaccuracies within the available data, ESC analysts resorted to notional installations as a way to ensure complete and consistent input data. After reviewing the classes of installation targets encountered in a theater on which information was available, patterns of typical facilities at installations of similar function were constructed; e.g., air bases have runways and communication facilities; ports have piers and storage. These were used as surrogates for actual site plans in the NAASP. The expected damage was subsequently used for all attacks against targets of the particular notional installation class. Development of the notional installations guaranteed that critical facilities were always considered and solved the building type and use problems that were encountered when interpreting real installation site plans.

(3) Development of the notional installations guaranteed that critical facilities would not be overlooked. It also solved the building type and use problems encountered when interpreting real property inventories and installation site plans. The advantages of using uniform templates for targeted installations out-weighed the probably illusory advantages of using actual site laydowns, especially when plans existed for only a small portion of the targets. Ultimately, facility laydowns were defined for 27 different notional installations.[10]

(4) The assumption that notional installations can be used throughout the theater raises an even broader possibility--if a notional installation is representative of the class of theater targets with similar functions, can this same notional design be used for similar targets in other

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[10] ESC-defined notional installation classes for a Southern European scenario:

Main Operating Bases
Telecommunication Sites (fixed)
Telecommunication Sites (field)
Large Ports
Small Ports
NATO Pipeline
Ammunition Depot (fixed)
Ammunition Depot (field)
Electric Power (fixed)
Electric Power (field)
Bridge (highway)
Bridge (railroad)
Railroad Lines
Water Storage
Collocated Operating Bases
Field Camps
Hawk Sites
Large POL Installation
Small POL Installation
Tactical POL Facility
Storage Depot (fixed)
Storage Depot (field)
Highway (4-lane)
Highway (2-lane)
Tunnel (highway)
Tunnel (railroad)
Switching Yard

theaters? To a great degree, one would expect that a Southwest Asian air base would have an inventory of core facilities very similar to an air base in North America. In fact, this commonality is the underlying basis for the facility component planning systems found in each of the services. If some or all notional installations can be used across theaters, the benefit is obvious--it obviates the need to develop a completely new set of notional installations, attack packages, and damage profiles.[11] The library of profiles could then be used when a quick reaction answer forecloses any possibility of running NAASP-like analysis of actual installation attacks.

b. **Attack Packages.** Deciding on how much and what type of threat capability should be used against a target is not automatic. What level of damage is required? What threat assets are necessary to achieve that damage? The NAASP looks only at the characteristics (amount, accuracy, target point, etc.) of the ordnance and affected facilities to measure damage. The targeteer must, therefore, first determine what assets are available to cause damage.

(1) ESC defined four types of threat attack systems: fighter-bombers, bombers, special operations forces (SOF), and surface-to-surface missiles (SSM). These types then had to be defined in terms that could be used by the NAASP. The packages were engineered in reverse. First, the facilities to be attacked and the amount of damage to be achieved were specified. Then, to achieve the desired level of damage, the size and conduct of the attack was developed by trial and error means. These levels might be considered thresholds where a point of diminishing return for additional sorties has been reached (it is primarily characteristic of fighter or bomber attacks). SOF and SSM attacks were never presumed to destroy enough facilities at larger installations. (NOTE: Air, SOF, and SSM thresholds are separate. Meeting the bomber sortie saturation level will not foreclose either SSM or SOF attacks against that installation. It would, however, cutoff any additional fighter attacks.)

(2) To simplify the process, ESC standardized on an air sortie that delivered two FAB 250s. Package requirements were measured in terms of these "standard sorties." Fighter and bomber assets were similarly measured by the "standard sorties" they would provide. Thus, one SU 24 Fencer variant (external load $\leq$ 24,000 lbs) might be rated 3 times greater than an SU 22 Fitter (external load $\leq$ 7,000 lbs).

c. **Damage Profiles.** A damage profile is comprised of facilities damaged when a defined threat package attacks a specific installation. The profile defines which, and to what extent, facilities are damaged on an installation. NAASP results provide a list of facilities, amounts, and expected damage percentages, hits, and critical craters. To this information ESC adds the size of threat packages that induced the damage and the JCS category codes[12] for the various facilities. The threat size, facility information, and attack results comprise a damage profile. Profiles must be developed for each threat type, notional (or real) installation combination for which damage is to be considered in the scenario. (The user may choose not to construct profiles for unlikely uses--e.g., an SSM, with a large circular error probability (CEP), against a small highway tunnel portal.) These profiles make up the library used for theater damage assessments.

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[11] There is no inherent obstacle to combining notional and real installation targets in a theater analysis. If good site plans exist for particular installations and time to make individualized NAASP runs is available, one should take advantage of the opportunity. The attacks against actual installations simply become damage profile templates for which only one target entry will correspond.

[12] *Department of Defense Facility Classes and Construction Categories, DOD Instruction 4165.3* (24 October 1978).

5. **THEATER ASSESSMENT.** As described in the introduction, installation-level damage models have long been available. The previously missing piece of the puzzle was the ability to go beyond installation damage models and estimate damage for the entire theater for the entire campaign. ESC's Damage Allocation Model (DAMOC) provides a solution. DAMOC is an allocation model more than a damage model because it distributes threat assets among theater targets according to defined priorities and constraints. Damage is calculated by referencing the appropriate entry in the profile library. The calculations already made in the detailed damage model are not repeated. Theater damage thus becomes a function of how threat assets can be allocated against identified targets. By focusing on available enemy capability, ESC has achieved a threat-based approach to theater damage (as opposed to the sometimes-used worst-case approach which assumes that all targets are hit). The allocation models' threat handling offers many tangible features that, up to now, have not been linked to a damage model in one trig system.

a. **Threat Sortie Manipulation.** Through the manipulation of both global and local asset-specific factors that influence sortie generation, the user can exercise a great deal of control over allocations. Specific characteristics of different threat assets must be defined, and bases or launch sites for threat assets must be identified. The ability to move assets from one base to another permits the user to tailor redeployments within, into, or out of the theater. This enables evaluation of different targeting strategies, or alignment of sorties, with estimates from more sophisticated air models. Ideally, threat sortie information should be based to some degree on the results of a high resolution air simulation. For example, in one application of its damage methodology, ESC was able to incorporate sortie and attrition results achieved by CAA.[13]

b. **Ranging.** Geographic coordinates must be entered for both targets and threat bases. The model calculates the distances between base and target to determine if target is within range of threat assets at the base.

c. **Suppression.** Attacking an air base with a full fighter package will achieve an expected level of damage. While this might render the base inoperative for a while, the possibility exists that if the "critical craters" are fixed, a minimum operational strip would be available. In recognition of this, the allocation model can be directed to attack the runway surface periodically to suppress air base operations.

d. **Data Driven.** Both the NAASP and DAMOC are data driven. The entire process, from preparing NAASP input to defining target installations, is user defined. In other words, there should be no reason why either the damage or allocation programs would have to be changed and recompiled under normal circumstances. Consequently there is no compelling need to understand how either of the models (particularly ESC's allocation model) accomplish their tasks internally. However, if a damage model other than the NAASP were used, this might not be true.

e. **User-defined Summaries.** The objective of the damage methodology is to provide expected facility damage. There are available reports on damage information at the facility (JCS category code [CATCODE]) level for each installation and on summarized damage information for specific time periods across the theater.

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[13] *Engineer Studies Center Bomber Assessment Study (ESBAS)*, CAA-MR-90-47 (U.S. Army Concepts Analysis Agency, September 1990). The study relied on the COMO Integrated Air Defense Model to provide the Corps of Engineers the number of enemy bombers that can reach air bases. This information was then used to generate emergency war damage repair requirements.

f. **PC-Based.** One of the advantages of ESC's approach is that it can all be done on a PC-compatible microcomputer. To further maximize program execution capability, most input in the allocation model is saved in dynamically allocated memory locations, rather than fixed arrays. The accessibility and general capability of the methodology facilitates use. It also increases the likelihood of experimentation and alternative evaluations. The ubiquitous PCs also guarantee portability.

6. **ASSUMPTIONS.** Despite our best intelligence gathering efforts, when war starts no one can predict how an enemy will choose to attack U.S. and allied bases. Munitions effects can be modeled with great accuracy if we know the aim point and the proximate facilities. But how confident can one be that the munitions get to the target, or that the target has even been selected by the enemy. The situation is analogous to the Heisenberg Uncertainty Principle--the greater our quest for accuracy, the greater our associated error. With that in mind, ESC made several assumptions in confecting its methodology.

a. **Threat Assignment.** It is conceivable that intelligence means might obtain enemy attack plans prior to hostilities and know exact targeting information. But once that attack begins, attrition, maintenance, counterattacks, mission success, forward edge of battle area (FEBA) movement, etc. make it difficult to estimate what would happen in the following days, much less predict events weeks or months later. ESC concluded that it is impossible to predict these events with any certainty. The best compromise is to adopt a consistent and reproducible method that can be manipulated easily to examine different assignment schemes.

b. **Sortie Equivalence.** The damage model used by FSC to assess installation level damage did not concern itself with how munitions got to a target--its needs were for munitions attributes (fuzing, aiming errors, etc.), not the performance specifications of the delivery platform. To reduce complexity and situations for evaluation, ESC standardized using one conventional munition.[14] This meant that only one fighter bomber configuration needed to be defined. That definition would be in terms of the number of those munitions it could carry. For example, suppose the nominal weapon pattern/load is 4 standard bombs. If a SU-24 Fencer carries 4 bombs and a MIG-27 Flogger carries 6, then each Fencer contributes 1 standard sortie, while each Flogger is worth 1.5 for sortie capability purposes.

c. **Allocation Rules.** Deciding how many attacks should be made against a target is a function of several factors: type of installation, type and amount of facilities, number of available attackers, amount of damage from prior attacks, and the priority of the target. ESC adopted a straight-forward rule that considered these factors during targeting. ESC assumed that it was better to apply reasonable criteria consistently, than to try to intuit the thoughts of threat planners. As a compromise, ESC settled on defining attack packages whose expected results would

[14] The Soviet FAB-250 General Purpose Bomb with instantaneous fuze. See *Red-on-Blue Manual (Effectiveness Estimates for Soviet/Warsaw Pact Nonnuclear Munitions)(U)*, 61 JTCG/ME-77-15 (Rev. 1, 1 October 1982, Change 2--30 April 1986).

achieve the desired level of damage. Allocation was made according to target priority. ESC assumed a simple, preemptive priority rule: the value of a target installation corresponded to its relative location in the theater target list.[15] For example, the third target in the list would be attacked, if possible, before the fourth.

d. **Proportionality.** ESC associates a certain number of threat assets with a desired level of damage. Once sufficient threat assets are directed against a target, the model will look to target installations of lower priority. Frequently, available sorties will fall short of required attack levels. Rather than use an "all or nothing" strategy, ESC's methodology allocates what it has available. In the damage model, attacks are directed against specific facilities. If only half of the required number of sorties are allocated, then one would expect that only half of the targeted facilities will be hit. Since ESC does not know which half of the facilities were hit, damage and hits to facilities are prorated according to the proportion of sorties actually sent and the amount needed for the desired level of damage.

[15] The user should be aware that there is no attempt to optimize sortie allocation with regard to coverage. Like targets, threat assets are allocated sequentially. The program does not look at all assets to find the ones whose range comes closest to the distance to the current target. Therefore, the user should list threat assets in the THREAT file according to range--shorter range assets at the beginning, longer range at the end.

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III. APPLICATION

7. **INPUT.** The two-step damage process (explicit installation damage, theater allocation) raises the need for two sets of input. The user should refer to the NAASP documentation (or to appropriate references if another damage model is used) for its input requirements to produce the damage profiles. DAMOC data requirements are briefly described below. More definitive descriptions appear in Annex A.

a. **Threat Assets.** Threat data drives the allocation model. Nothing happens unless attacks can be made. The most important threat asset data element is its type. The attack packages derived from the NAASP use four threat types: fighters, bombers, SOF, and SSM. Threat assets are the actual systems derived from intelligence and planning sources for which a type must be designated. In addition to the type, a user can define up to three theater movements, as well as performance, attrition, and availability data for each threat asset. Distinctions are drawn among different rates for different types; therefore, the user is advised to consult the associated descriptions found in Annex A.

b. **Threat Bases.** To facilitate management of threat assets, they must be associated with individual bases. While this refers primarily to threat air bases, it can, however, be broadly viewed to include SSM launch points and tactical helipads used for SOF insertions.

c. **Notional Installation Classes.** The allocation model uses installation damage data produced by the detailed damage model. For each class of notional installations, damage profiles are given for defined threats. Note that an installation class need not have profiles for all possible threats. For example, performance limitations might indicate that SSM accuracy precludes use against bridges. The exclusion or inclusion of particular threat installation profiles can be used to control allocations.

d. **Targets.** This file lists the name, installation class, and location of all targets to be considered. Most targets are fixed installations. Since continuous targets such as roads and pipelines do not have discrete saturation levels, the user can designate those targets for continuous attack (i.e., they cannot be saturated). Likewise, the user can define mobile military targets that, if attacked, may not generate engineer repair requirements, but will divert sorties from other missions.

e. **Scenario.** While some explicit scenario information is built into the threat file (e.g., attrition), the other controlling data are entered at the beginning of program execution. The parameters that decide how the model will operate are information such as duration of simulation, frequency of reports, countries or organizations to be reported, suppression frequencies, and names of input files.

8. **OUTPUT.** DAMOC provides a full range of useful reports and messages. More definitive descriptions appear in Annex B.

a. **Data Summaries.** At the beginning of DAMOC's execution the program reads threat base, threat, damage profile, and target files. In addition to converting data elements into internal textual and numeric formats, the program checks data validity: threat groups cannot be assigned to non-existent bases, targets must have a valid installation type, damage profiles within a notional installation must be consistent across facility sizes, etc. In constructing an application, the user should review the data summaries to assure that intended entries are accepted.

(1) ***Threat.*** Threat information is entered in the base and threat asset files. Base files identify valid threat locations from which attacks originate. Although the user can enter a base's full name, the identifier used internal to DAMOC is the code identification. It is this code that is checked against entries found on the threat asset files. If a nonexistent base is encountered, the asset entry is rejected.

(2) ***Damage Profiles.*** The installation profiles, derived from the detailed damage model (or models), are read and assembled into a damage profile table. While building the reference table, DAMOC culls all the category codes encountered and lists them. It also summarizes the damage table by providing the notional installations that have been encountered; the threat types that can be used against them; the number of catcodes comprising each profile; and the size of the associated threat packages. It also reports when an internal check on the data fails from either a facility inventory inconsistency or an unknown threat type.

(3) ***Targets.*** Target installations are reviewed against the profiles found in the damage table. A target's reference type must correspond to a defined notional installation type. Country codes are not checked--the user must define the country field depending on the problem's demands.

b. **Facility Damage Summaries.** Periodically during DAMOC's execution a summary of damage for all selected installations is printed. It shows the extent of each facility in the installation subset and the associated damage, hits, and craters that occurred during the period. The user may designate a subset of installations for the summary reports (this subset will also decide which installations will appear in the installation summaries). The designation uses the country codes found in the target file. The reporting depends on how the codes were initially defined and suggests that some thought should be given to their initial definition. While the obvious use is to designate nationality, one could also use it to discriminate among U.S. facilities in different nations, services, or major commands (e.g., "U" = U.S. installations; "T" = Turkish installations; but "t" = U.S. installations in Turkey). Note that the facility totals represent only those found in installations in the report set. It should also be emphasized that the report set has nothing to do with targeting. Given the same threat and target input, sorties allocation will be identical, regardless of the report selection.

c. **Installation Summaries.** The facility summaries are convenient to get a general idea of attack intensity. By itself, however, it would be of little use to engineer planners. The individual installations provide the planner with an idea of what, when, and where engineers will be needed. The report breaks out facility damage, facility hits, and critical crater percentages by time periods. It also shows when attacks were made. The damage can be used in engineer workload models to assess the adequacy of engineer capability.

d. **Sortie Log.** A log file is created by DAMOC to record all sortie allocations, unused assets, and threat changes (i.e., redeployments) during the scenario. This file is only intended to enable the user to confirm that sorties and movements occurred as expected.

9. **PROGRAM DESIGN.** This section is a quick overview of the damage allocation (DAMOC) program. The success of DAMOC[16], with respect to extensibility and execution speed, is largely attributable to its design. It uses a software technique called object-oriented programming (OOP).[17] This enhances the ability of the modeler to decompose a problem. In more traditional program languages (e.g., FORTRAN) the programmer must represent the model using only a few data structures (integer, real, and alphanumeric variables). OOP languages enable the programmer to define additional structures, which can be problem specific. In DAMOC there are types for installations and profiles, as well as types for integers and strings. Studied decisions on how to define object types will greatly influence how well a problem can be modeled. The interested reader is referred to Annex C where the individual program elements are described more fully.

a. **Object Hierarchy.** One feature of OOP enables the programmer to build or extend previously defined objects. DAMOC's general structure has three layers. The first layer defines data structuring classes that are used extensively by other objects in the model. The middle, and by far the largest, layer contains the object classes that define the methods and elements that comprise the threat-installation-damage context. The third layer is the main program that uses the object structure to simulate theater damage results. **Figure 2** shows this stratification.

b. **Unit SIMSETx.** One of the benefits of OOP is the memory utilization derived from tighter control over data structuring. Rather than defining large arrays (which either constrain the number of entries or are purposely too large) to retain information, as FORTRAN would require, the programmer can use objects to request only as much memory as needed, as well as to encapsulate data. When an object is dynamically created, a way must be preserved to reference or "point" to it, otherwise the program has no way to make use of it. One device used extensively in DAMOC is the two-way list. Such lists are realized in the model by employing derived types of *HEAD* and *LINK* objects. First, the list must be created (*new HEAD*), and then objects can be added to the list (*LINK.into(HEAD)*). Various list functions are defined for both *HEAD* and *LINK* objects (and consequently for objects derived from them). Such methods designate the first or last object in the list; indicate whether the list has any objects, or is empty; enable an object to be put in, or taken out of, a list; and count how many items are currently in the list. When, for example, a new ***installation*** is created (defined as a derived object of *LINK*), it is placed in an ***area*** object (defined as a derived object of *HEAD*). The program can then search through ***area*** to access that ***installation***. This list device is a common structure in OOP languages.[18]

c. **Unit COMMZ: Object Classes.** The structure of DAMOC can be viewed as a collection of different objects that have certain attributes and procedures. Separately, the objects should represent a reasonable decomposition of the problem environment. Together, they should provide a substrate upon which an application can be built. The attributes describe the state of the object, and the procedures define how interactions between or among objects occur.

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[16] Compared to some other possible approaches, DAMOC was quite efficient. Initially, ESC contemplated using a spreadsheet-based methodology. The danger of using spreadsheets on the wrong problem was dramatically illustrated. That approach was marked by inflexibility, constant human attention, mushrooming storage demands, and completion times measured in days, possibly weeks. DAMOC did it all by using a fraction of the storage needs, by reducing data to manageable levels by eliminating needless deviations, by requiring little more than a few data parameters from the user, and by executing in seconds on the very same machine.

[17] DAMOC was written in TURBO PASCAL 5.5, a dialect of PASCAL that incorporates true object-oriented capability.

[18] See explanation of CLASS SIMSET in *Introduction to Simula 67*, Gunther Lamprecht (Friedr. Vieweg & Sohn, 1983).

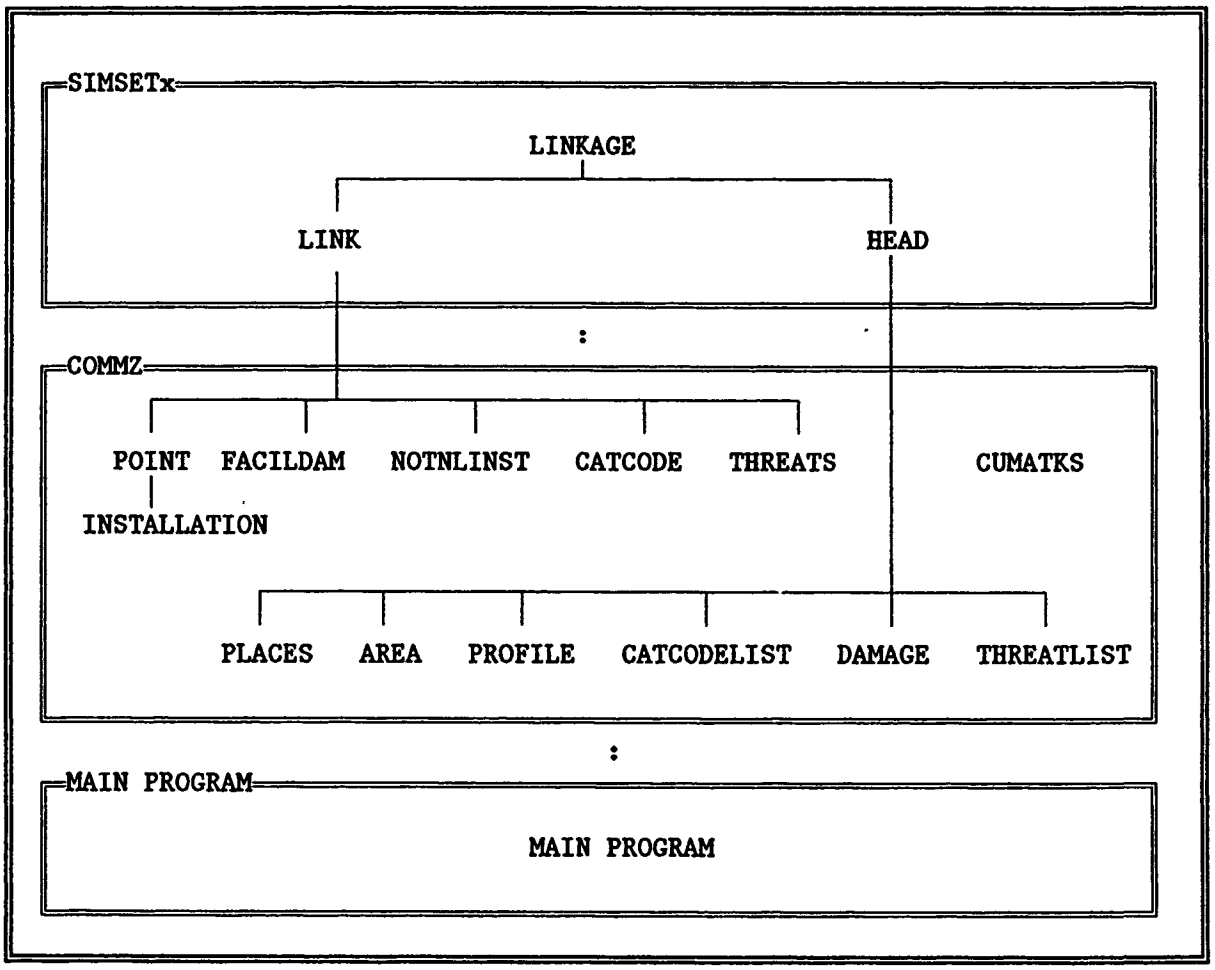

Figure 2. OBJECT CLASS HIERARCHY OF DAMOC

d. **Main Program.** After defining the elements, or objects, that comprise the theater damage environment, their behaviors must be orchestrated. The main program initiates the creation of the scenario components, decides what threat assets are available and where they should attack, and collects data for or initiates the various reports.

10. **MODELS EXECUTION.** The damage methodology is a two-stage process. Before DAMOC is run, the user must decide what damage profiles are required. If existing profiles are sufficient, there may be no need to generate new profiles--it may be enough to merely create a few special installations. (While consistency may weigh heavily on a decision, it is not necessary to use the same detailed damage model for all the profiles.) After the needed profiles have been revised or created, the user must assemble the necessary threat and target information required by the damage allocation model. Below are some general comments about execution characteristics of NAASP and DAMOC.

a. **NAASP.** Being PC-based is the greatest advantage of the Navy damage model. Having ready access to the program allows a user to explore input variations and their affect on output. The only special hardware requirement is the need for a math co-processor.

(1) *Operation.* The NAASP has a menu-driven data preparation module which provides an interactive session to build the various input files (target, weapons, damage, plot, and attack). Different portions of the model can be run separately, or all the input can be combined to run an entire case.

(2) *Environment.* The NAASP contains support logic for certain optional hardware peripherals that facilitate using the system. Unfortunately, ESC did not have one of these items--a compatible digitizer. This meant that much of the site plans had to be manually entered--a frustrating task.

b. **DAMOC.** Like the NAASP, DAMOC was designed to run on any PC/AT or PC/AT-compatible. No special hardware requirements are necessary to run the program. The only caution is in the area of security. Because threat and target input are likely drawn from classified sources, local security limitations would have to control the execution environment. Annex A describes DAMOC input in detail. Some of the operational characteristics of interest to potential users are listed below.

(1) *Interactive.* The program is designed to be run interactively. A series of questions are posed to which the user must respond before the program will go forward. In the interactive mode, all output goes to the screen, except for threat dispositions written to the SORTIE.LOG file.

(2) *DOS Redirection.* While it may be useful to run DAMOC interactively to see how things proceed or what errors might be uncovered in the input, the amount of information that appears on the screen will overwhelm a user. To capture this information, one can use DOS's file redirection feature. The normal query-response cycle can be bypassed by entering the following command:

DAMOC < control.file > output.file

The *control.file* contains responses to the questions posed during interactive processing. The *output.file* will receive all the data that would otherwise go to the screen. Note that it is not unusual for output files to require 300, 500, or as much as 1,000 kilobytes of storage (the number of installations is the controlling factor). The user should keep this in mind when designating destination files (a hard drive or Bernoulli-like removable disk may be necessary).

(3) *Specifications.* DAMOC currently runs comfortably on a standard AT machine with 640 kilobytes of random access memory. Execution speed is a function of scenario length, report selections, number of threat assets, and number of targets. Run times on 80286-based machines have ranged from a few minutes to several hours. A test run on an 80386-based PC-compatible saw immediate three-fold execution time improvements. The number of lines of code for the three program units in DAMOC (SIMSETx, COMMZ, and DAMOC) together total less than 1800 lines of code. The memory requirements for the associated symbolic files are less than 60 kilobytes. The executable element (DAMOC.EXE) is less than 40 kilobytes. This last value should not be misinterpreted; the executable size refers only to code. The actual memory requirements is a function of the input data. ESC has run scenarios that use close to 400 kilobytes of random access memory (RAM) for data. Even at that, the model runs comfortably within the 640-kilobyte DOS address space.

(4) ***Limitations.*** ESC has tried to make the model as unrestrictive as possible. Nonetheless, there are several internal parameters of which a user should be aware:

- there are only 4 threat types--fighter, bomber, SOF, and SSM
- 3 changes in threat rates or redeployments can be made
- 75 facility categories can be tracked
- scenarios can be up to 180 days long
- the number of time periods must be less than or equal to 10 (i.e., length_of_scenario/length_of_period $\leq$ 10)

Increasing any of these parameters, except the threat types, requires nothing more than changing several internal dimension statements. Changes to threat types have much larger implications and necessarily can be accomplished only after making substantial changes to the model.

IV. SUMMARY

11. **FUTURE ENHANCEMENTS.** As ESC applies its damage methodology, modifications and improvements continue to be made, particularly to DAMOC. One of the advantages of the allocation model is its receptiveness to change. It has proven to be highly extensible. Based on discussions and experience, ESC foresees the following modifications being made to refine the allocation model and further enhance its utility.

a. **Installation Modularization.** Presently the model deals with 27 classes of notional installations. For representational and targeting robustness, it might be desirable to visualize installations as groups of sub-installations. An air base might have runway; petroleum, oils, and lubricants (POL); maintenance; and other facility subsets. By supporting a certain amount of modularization, DAMOC could adopt more selective targeting than the currently-used installation priorities. This approach might be more imperative if smart munitions were included and used against facilities rather than installations.

b. **Threat Types.** The use of only four threat types may be restrictive, especially in reducing fighters and bombers to common units. Aircraft are currently standardized on one type of munition. While this simplifies the process and reduces the number of NAASP cases, it would be more realistic to consider several munition types (conventional and smart) and the carriers that can or cannot deliver them. Although this would require a few internal changes to DAMOC, the real impact would be on the analyst having to make that many more preparatory runs of the detailed damage model to develop the various attack package-facility damage sub-tables.

c. **Reconstitution (Implied Engineer Capability).** DAMOC currently has a global switch that resets damage.[19] It was included under the premise that U.S. and indigenous engineer capability might be able to reconstitute (i.e., repair all damage) an installation. This is different in degree from the need for suppression that contemplates selective repair (in particular runway craters). The all-or- nothing impact of "toggling" reconstitution across all installations seems too broad in retrospect. Clearly, it would be more desirable to selectively reconstitute installations based on knowledge of local engineer capability and the time required to effect repairs. It would be relatively easy to modify DAMOC so that reconstitution can occur at designated installations. However, it is difficult to determine when and where reconstitution should occur because there is no explicit engineer representation in DAMOC.

d. **Threat Ordering.** As noted in paragraph 6c, the user should be cognizant of the sequential nature of sortie allocation. It would be an easy task to have DAMOC order the threat according to range, with the option of disabling that feature if theater geometry reduces its importance. (If necessary, an "assignment problem" algorithm could conceivably be incorporated. This would probably have, however, major execution and memory implications.)

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[19] See Annex A discussion of Run Control File elements.

e. **CESPG/JEPES Linkage.** ESC's war damage approach is an adjunct to theater planning. Calculating where, when, and how much damage occurs is usually preliminary to determining if planned engineer capability is adequate. Since capability must also be applied to new construction requirements, damage and construction should be addressed together. One obvious way to do this is to use DAMOC results as input to the CESPG (or its eventual successor--the Joint Engineer Planning and Execution System (JEPES)). DAMOC could be modified to produce damage information in a mutually compatible format.

12. **ASSESSMENT.** ESC's damage methodology espouses a pragmatic approach to the insoluble problem of predicting war damage. Its primary purpose is to provide engineer and military planners with a reasonable estimate of potential theater-wide war damage. The estimate couples output from facility damage simulations with scenario-dependent factors--threat capability, target priorities, and campaign factors. As such, the approach extends rather than replaces current damage models by framing the amount of damage within the context of theater threat capability. Other attributes of DAMOC--its modest size and its PC compatible implementation--make it highly portable. To encourage potential users to evaluate and hopefully utilize the methodology, ESC will provide, upon request, a distribution disk containing an executable version of the allocation program (DAMOC.EXE), program files, and sample data. This is enough to make a test run and observe the execution time and ease of use. To obtain this disk, contact the Office of the Director, U.S. Army Engineer Studies Center, Casey Building 2594, Fort Belvoir, Virginia 22060-5583; phone number (703) 355-2373. (NOTE: For a copy of a detailed damage model such as the NAASP, a user would have to contact the organization responsible for its development.) Overall, the accessibility of the system, the separation of facility damage and targeting, and the relative ease of use enable planners to adapt to varying amounts of available information to estimate damage and quickly explore alternative scenarios or hypotheses.

LAST PAGE OF MAIN PAPER

ANNEX A

DAMOC INPUT

ANNEX A

DAMOC INPUT

Paragraph **Page**

Figure

1. **PURPOSE.** This annex describes the input file formats and data used by the Damage Allocation Model (DAMOC).

2. **SCOPE.** The annex is limited to input discussions for DAMOC. Insofar as DAMOC is a data-driven model, this might also be viewed as a user's guide. The companion to this annex would be a description of input for whatever detailed damage model is used, if additions or alternative damage profiles are necessary. For such information, the user should consult the applicable user's manual.

3. **DESCRIPTIONS.** The scheme used to define the data uses both examples and textual descriptions. First an extract or portion of the file is shown. That is followed by a field format definition showing character and field positions. (NOTE: Character or string entries should be left justified in their subfields because leading blanks are not stripped out.) Finally a brief description of individual datum is provided along with desiderata that should be heeded while constructing the files.[1]

a. **Threat Bases File.** This file defines the locations from which various attacking forces originate and fixes the location (latitude and longitude) at which the attack starts. It is used to calculate whether particular attacking types are within range of specified targets. This file can also be used to define locations to which threat assets will withdraw or forward deploy.

(1) *Formats.* **Figure A-1** below is an example of the Threat Bases file and the file format.

Example: Threat Bases File

```
airbase number 1        base0        100000N   0500000E
airbase number 5        base5        150000N   0600000E
Alpha                   base2        110000N   0520000E
Beta                    base3        120000N   0540000E
IV Corps                base4        130000N   0560900E
Capital                 base6        140000N   0585000E
Upsilon                 base1        150000N   0580200E
```

Format: Threat Bases File

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
         |         |         |         |
    Base Name  Base Code  Latitude  Longitude
```

Figure A-1. THREAT BASES FILE EXAMPLE

(2) *Explanation.* **Figure A-2** provides the definitions of Threat Bases file input. Several things about the Threat Bases file are worthy of mention. First, the model **does** consider hemisphere; therefore, latitude *V* must equal *N* or *S* and longitude *H* must equal *E* or *W*. Second, although the base code is user-defined, a standard code, such as geographic location (GEOLOC), is recommended where possible. Third, by purposely defining bases well beyond the range of threat systems, one can, by using the redeployment entries for threat systems, simulate movement into and out of the theater of operations.

[1] File sizes are not restricted. There is no specific limit on the number of records contained in the data files. To do this, DAMOC exploits the dynamic memory facility of PASCAL 5.5 (objects are dynamically allocated on the *heap* rather than on the *stack*). While ESC has defined some rather large scenarios (120 days; 15 bases; 20 threat systems; 500 targets), the *heap* has not come close to being used up. It is not, however, inexhaustible, and in the event that it is exceeded, the system will lock up.

Input Item	Start Col	End Col	Description
Base Name	1	20	Name of location from which threat attacks will originate
Base Code	25	29	Code (≤ 5 characters) assigned to threat base location (used for threat placement and moves)
Latitude	41	47	Latitude expressed in: ddmmssV
Longitude	51	58	Longitude expressed in: dddmmssH

Figure A-2. DEFINITIONS OF TIIREAT BASES FILE INPUT

b. **Threat File.** This file provides the scenario dependent description of how the threat will operate against the targets. At designated times, groups can be moved from base to base to correspond to scenario-based movements. Operational, casualty, or expenditure rates can also be designated and can be made both group and time specific.

(1) *Format.* Examples of a Threat file and the file formats are found in **Figure A-3** on the next page.

```
Example:  Threat File

FLOGGERS          FIGHTER   base0 1281   50   20    6base1          <--type 1 record
            1  .90  .10                                             <--type 2 record
BADGERS           BOMBER    base3  750   20   10    3base9
            5  1.0 .10   10  .70  .20
SPETSNAZ DIV      SOF       base0  150   20    0
           10  .10  .10
SPETSNAZ CORPS    SOF       base4  300   20    0
            5  .15  .15
SCUD              SSM       base6  400   50    0   15base0
           12  1.   .20


Format:  Threat File  [record type 1]

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
         |              |    |    |    |    |    |    |    |    |    |    |    |
Threat Description    Threat  Start Rng  Amt  Amt  Move Base Move Base Move Base
                       Class   Base      Beg  Min  day1      day2      day3


Format:  Threat File  [record type 2]

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
              |   |   |   |   |   |   |   |   |   |
            day  rate rate day  rate rate day  rate rate
             1   1/1  2/1   2   1/2  2/2   3   1/3  2/3

   day #d:= day at which rate change occurs
   rate type/#d :=  for planes rate 1 = operational ready rate
                               rate 2 = casualty/loss rates
                    for SSM    rate 1 = availability (0 or 100)
                               rate 2 = usage rate
                    for SOF    rate 1 = pre target attrition
                               rate 2 = recovery losses

NOTE:  The days associated with movement and rate changes need not be the same.
```

Figure A-3. TIIREAT FILE EXAMPLE

(2) ***Explanation.*** Two things should be considered when assembling the threat system file. First, threat assets are allocated each day according to the order in which they were initially entered. Second, beginning amounts may not be the actual number of available aircraft or units. In response to the former, the user should probably put short-range systems at the beginning of the file and long-range assets near the end of the file. In regard to beginning amounts, the important thing to remember about threat types (e.g., FIGHTER, SOF) is that they must be counted in terms of standard units. The model has no internal knowledge of threat organization or configuration. If SOF teams simulated in the detailed damage model (e.g., the NAASP) were 20-man teams, than a SPETSNAZ Brigade would be defined by the number of such teams it controlled. The units can also vary within a platform: one FLOGGER might have a normal sortie capability of 2 units, but a long-range "B" version (range increases because external tanks are used) would only be worth "1." Also, there is no implicit correlation between "move" and "change" days. These values need not correspond to each other--they are to simulate

events and conditions in the controlling scenario. It should be emphasized, however, that there are no default rates or presumption of availability on day 1. Consequently, there must be an entry in "change day 1" and associated rate. (NOTE: "change day 1" can indicate any day in the scenario; it should not be interpreted as meaning day=1.) Definitions of Threat File input for records 1 and 2 are found in **Figures A-4 and A-5** respectively.

Input Item	Start Col	End Col	Description
Threat Description	1	20	Name of associated threat group. It might indicate weapon type and organization: 5th SPETSNAZ Bde or Fencers/1st Air Wing
Threat Type	21	30	Type of threat asset: FIGHTER, SOF, BOMBER, or SSM
Base (starting)	31	35	Starting base
Range	36	40	Range of threat system (nautical miles)
Beginning Amount	41	45	Starting number of assets. (Note that this is not necessarily a count. Plane sorties must be in notional sortie terms; SOF counts should be multiples of nominal group size.)
Minimum Amount	46	50	Lowest level that asset can reach. (replacement pipeline)
Move day #1	51	55	Day on which 1st asset redeployment occurs from starting base to next location
Base	56	60	Base code of new location
Move day #2	61	65	(see above)
Base	66	70	(see above)
Move day #3	71	75	(see above)
Base	76	80	(see above)

Figure A-4. DEFINITIONS OF THREAT FILE INPUT (RECORD 1)

Input Item	Start Col	End Col	Description
Change Day 1	11	15	Day at which initial rates are active (if > 1 then asset considered initially unavailable)
Rate#1 for day 1	16	20	Value of first rate#1. (NOTE: Rate#1 is interpreted differently for each threat type: for FIGHTER and BOMBER, it is the operational readiness rate (decimal); for SOF, it is the before target attrition rate; for SSM, it is used as a switch--if > 0, then available; otherwise assumed not available.)
Rate#2 for day 1	21	25	Value of first rate#2. (NOTE: Rate#2 has different meanings for each threat type: for FIGHTER and BOMBER, it is an attrition rate; for SOF, it is the post-attack loss rate; for SSM, it is usage and might be a function of launchers or doctrine.)
Change day 2	26	30	(see change day explanation above)
Rate#1 for day 2	31	35	(see rate#1 explanation above)
Rate#2 for day 2	36	40	(see rate#2 explanation above)
Change day 3	41	45	(see change day explanation above)
Rate#1 for day 3	46	50	(see rate#1 explanation above)
Rate#2 for day 3	51	55	(see rate#2 explanation above)

Figure A-5. DEFINITIONS OF THREAT FILE INPUT (RECORD 2)

c. **Target File.** This file contains all the targets that will be considered in the scenario. At present, the target priority is established preemptively by the ordering in the file. The attacker will try to "saturate" (i.e., meet the primary attack quota) target (n) before beginning to attack target ($n+1$).

(1) *Format.* An example of the Target file and the file format is found in **Figure A-6** below.

Example: Target File

```
NUCAF #1                U     NUCAF          200000N   0600000E
NUCSTOR #2              U     NUCSTOR        200000N   0600000E
COB1                    U     COB            200000N   0600000E
COB2                    U     COB            200000N   0600000E
Alpha City              U *   SMPORT         200000N   0600000E
Metropolis              U     LGPORT         200000N   0600000E
COB3                    U     COB            200000N   0600000E
COMMO1                  U     TEL FX         200000N   0600000E
COMMO2 (XX Corps)       U     TEL FX         200000N   0600000E
MSR #1 (grid a)         T *   HWY            200000N   0600000E
MSR #1 (grid b)         T *   PORT           203000N   0630000E
AMMO Site 1             A     AMMO           200000N   0600000E
PORT3                   A     PORT           200000N   0600000E
```

Format: Target File

```
        1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
|                  |  |      |                 |         |
Target Name        |  |      Installation      Lat       Long
                   |  |        Code
          Nation/group|
                      |
                      Saturation Flag
```

Figure A-6. TARGET FILE EXAMPLE

(2) *Explanation.* **Figure A-7** contains the definitions of the Target file input. One consideration to keep in mind is the location. The model does not know if the latitude and longitude are correct, but it assumes they are. The user should ensure that coordinate entries fall within known north-south, east-west ranges. While this might be somewhat tedious for a large number of targets, it is necessary because DAMOC accepts "out-of-range" conditions, whether real or inadvertent.

Input Item	Start Col	End Col	Description
Target Name	1	20	Full name of target installation
Nation/group	25	25	Installation group identification. Could be nationality ('U' = United States); could be organizational ('4' = 4th ASG or '7' = VII Corps); or it could identify foreign bases ('T' = Turkish, but 't' = United States in Turkey). The group code is presently used only to select report scope.
Saturation Flag	27	27	This overrides the primary attack axiom. Normally when an installation receives its primary attack quota, it is no longer attacked (except for suppression and reconstitution situations). For some targets (roads, railroads, pipelines) this is unrealistic. By setting this flag to '*' a target will continue to be hit by each successive threat group.
Installation Code	30	39	This code indicates to which class of notional installations this target belongs.
Latitude	50	56	Latitude of target in ddmmssH
Longitude	60	67	Longitude of target in dddmmssV

Figure A-7. DEFINITION OF TARGET FILE INPUT

d. **Damage Profile File.** The Damage Allocation Model does not directly calculate damage. It actually apportions attackers according to target priority and nominal sortie requirements necessary to achieve predetermined damage levels. Damage is derived from the damage profiles developed during the first phase of the methodology. In its studies using DAMOC, ESC has relied on the Navy Air Attack Simulation Program (NAASP) as the detailed damage model. The Damage Profile file represents the information extracted from the NAASP[2].

[2] There are several models that could conceivably be used: NAASP, AAP, TSARINA. ESC opted for the NAASP because of its PC-availability. What DAMOC needs from a damage model such as NAASP is a damage template which relates damage to an appropriate level of standardized attacks.

(1) *Format.* **Figure A-8** below is an example of a Damage Profile file and the file formats.

```
Example:  Damage Profile File

*NCAF                    FIGHTER         30   12                          <--type 1 record
  RUNWAY                 111A     11200     0.00    15.14       6.5       <--type 2 record
  TAXIWAY                112A     22400     0.00    30.08      14.38
  APRON                  113A   5490000     0.00     6.82       0
  RAILROAD               860A     12000     0.00     3.16       0
  10K POL TANKS (BBL)    411E     50000    27.20     4.88       0
  AFCT MAINT FAC         211F    450000   100.00    17.16       0
  WTR STOR FAC  (GAL)    841C    100000   100.00     3.72       0

Format:  Damage Profile File [record type 1]

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
|    |                         |           |  |
|    Installation Code         Threat      |  L- Suppression Attacks
|    (Notional Type)           Type        L---- Primary Attacks
|
L-if = '*' then new Profile beginning

Format:  Damage Profile File [record type 2]

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
          |              |        |          |         |         |
     Facility Description  JCS     Amount        %        Hits/    Critical
                          Catcode  onhand      damage    craters    craters
```

Figure A-8. DAMAGE PROFILE FILE EXAMPLE

(2) *Explanation.* An important element of a damage profile is the facility set. It is important that there be no misconception about the facility entries. They need not represent all the facilities presumed to exist at a notional installation, only the ones that are damaged in a postulated attack. Undamaged facilities could be added, but would be gratuitous. Therefore, the minimum facility list for a notional installation class contains all facility types that have been damaged. These facilities need not be the same for different attackers. One would not expect that a SPETSNAZ team would have the same targets as a FIGHTER bomber. The program retains dissimilar facility lists within a notional installation. There is an internal check--if there are multiple profiles (i.e., more than one attacker type for a notional installation), then the onhand amounts for common facilities must be the same. Internally, DAMOC uses percentages. It combines percentages of threat types. Thus, it makes a difference if a FIGHTER's 50% damage is for 10,000 sq. ft. of 211F maintenance facilities, while an SOF's 30% damage is for only 500 sq. ft. of the same facility. (NOTE: When the model identifies such inconsistencies, it does not completely reject the information. It does presume, however, that the first encountered amount is true. The user, therefore, is advised to review the "DAMAGE TEMPLATE" report where such inconsistencies are reported.) Definitions of Damage Profile file input for Records 1 and 2 are found in **Figures A-9 and A-10** respectively.

Input Item	Start Col	End Col	Description
Record flag	1	1	Since there can be a variable number of associated facility records in a profile set, a '*' in column 1 identifies the record as the start of a new installation-threat system profile (e.g., "COB").
Installation code	2	11	The code used to identify the class of notional installations
Threat type	26	35	Indicates which threat asset class (FIGHTER, etc.) profile is being defined for the notional class
Primary attacks	42	45	The number of attacks necessary to achieve threshold damage levels (derived from detailed damage model results)
Suppression attacks	47	50	For those installation classes that have runways and piers, suppression attacks can be designated. These are the portion of the primary attacks directed against the specific facilities.

Figure A-9. DEFINITIONS OF DAMAGE PROFILE FILE INPUT (RECORD 1)

Input Item	Start Col	End Col	Description
Facility name	13	22	A descriptive name of the facility in the profile
JCS Catcode	26	29	The code associated with the facility
Amount onhand	31	40	The total amount (sq ft, bbls, lf, etc.) of this facility class subject to damage
Percent damaged	45	50	The average % of the onhand amount that is damaged when a full primary attack is made on the notional installation
Hits/craters	45	50	The average hits or craters on the onhand facilities resulting from a primary attack
Critical craters	64	70	The average craters on runways (or taxiways in some cases) that must be repaired to attain a minimum operational strip as defined for the detailed damage model

Figure A-10. DEFINITIONS OF DAMAGE PROFILE FILE INPUT (RECORD 2)

e. **Run Control File.** The normal execution of the Damage Model begins with the user responding to questions. The responses set some key variables defining scenario and model parameters. While not onerous, there may be reasons why one would prefer to have the model obtain this information from a file rather than through keyboard entry. Under DOS this is easily done using redirection: **DAMOC.EXE < RunCntrl.Fyl.** By the same token, redirection can be used to direct output from the screen (the default) to a designated file: **DAMOC.EXE > Output.Fyl.** Moreover, the operations can be concatenated: **DAMOC.EXE < RunCntrl.Fyl > Output.Fyl.** This section portrays the form and contents of this alternative input.

(1) *Format.* **Figure A-11** below is an example of a Run Control file.

Example: Run Control File

```
30                number of days in scenario
ABC               countries in reports (summary and installation)*
5                 reports every 5 days
5   3             double sortie & suppression periods
4   5             SOF & SSM sortie periods
10  1             reconstitution: cycle days & times to do it
bases.t                 enemy bases file name
threat.t                the threat file
damtable                notional damage arrays
targets.t               installation list
```

* A country code (a single alphanumeric character) is user defined. There is one requirement--the code must correspond to the convention used in the Target file. Also, there are two reserved characters: an "*" indicates that all countries are to be reported; an "!" indicates that installation reports are not required.

Figure A-11. RUN CONTROL FILE EXAMPLE

(2) *Explanation.* TURBO PASCAL allows numerical free formatting from the input device, with a space(s) acting as a delimiter. Textual input must, however, be confined to a specified field and length. The example in Figure A-11 above shows the number of data and file.name entries that are expected. The comments that appear to the right are ignored. The entries in this file define global variables and identify appropriate data files. Comments regarding each entry appear below.

(a) *Scenario Days.* This entry defines the number of days in the scenario (limitation: days $\leq$ 180).

(b) *Country Reports.* This entry defines which target damage information will be portrayed in rollup and installation reports (see Annex B). By choosing different subsets of country/group identifiers, reports are limited to only those qualifying installations. However, the report mask has no affect on the simulation itself. The model does not attack targets based on their country/group ("*" = report all installations; "!" = summary reports only, no installations).

(c) *Report Frequency.* The summary reports are produced at set intervals, or cycles. If, in a 50-day scenario, one wanted summary reports every other day for the first 10 days and every 10th day thereafter, one would run the model twice: the first run would set report frequency to 2 days and scenario length to 10 days; the second would set frequency to 10 days and length to 50 days. The results will be consistent because the reports cycles have nothing to do with targeting (limitation: number of summary report periods $\leq$ 10).

(d) *Double Sorties.* The model will permit double sorties for aircraft during the first days of the scenario. This is to simulate the likely "surge" capability of the attackers during that period. This entry indicates the number of "surge" days (limitation: none, days = 0, 1, 2, 3, ...).

(e) *Suppression Periods.* Suppression attacks are defined for certain installation damage profiles. Their intent is to re-target certain facility types (pavement and piers) that can be repaired, thus restoring, to some degree, installation operability. This entry determines how many days after receiving its primary quota an installation can expect suppression attacks. Such attacks will continue until the suppression quota is reached, at which time the installation's suppression clock will be reset.

(f) *SOF and SSM Periods.* Since SOF and SSM assets are limited to some degree by delivery means, the user can husband these assets by setting use cycles. For example, the user might indicate that SOF will only be used every 4th day and SSM will only be used every 5th day.

(g) *Reconstitution.* One feature in the model allows a user to reset all damage counters. This theoretically simulates repair. Currently, it can only be done globally--damage is reset at all installations at the same time. If reconstitution is not wanted, simply set the cycle to "length-of-scenario + 1."

(h) *File Names.* Self explanatory.

4. **CHANGES.** The damage methodology has been used by ESC in three assessment studies. The first study created the requirement for DAMOC's existence; the second study identified other desirable features to be added to the model (e.g., ranging); the third study recognized the desirability of combining notional and actual target profiles. The formats and data defined in this annex reflect current needs. From experience, however, one might anticipate that the model and ESC's overall damage methodology will continue to evolve. This will doubtlessly require associated changes to input and formats.

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ANNEX B

OUTPUT DESCRIPTIONS

ANNEX B

OUTPUT DESCRIPTIONS

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Figure

1. **PURPOSE.** This annex provides examples of the various reports produced by the Damage Allocation Model (DAMOC).

2. **SCOPE.** Reports and other routine information described in this annex represent the output produced by DAMOC. A review of this section will assist the user in interpreting output from DAMOC. As similarly stated in the Scope of Annex A, however, no attempt is made here to describe output from any damage model used in conjunction with DAMOC.

3. **OUTPUT DESCRIPTIONS.** Output in DAMOC can be categorized into three areas: input verification, results, and execution monitoring.

a. **Input Verification.** With several interrelated input files, DAMOC attempts to assure data consistency to the extent possible. Since the user is given the freedom to define several fields (although standardized codes are desirable), the model is relegated to resolving differences or omissions rather than judging correctness. It can't know when the user meant to do something different. The user should, therefore, review the input verification section of the output. This is especially important since the normal course is to reject questionable entries, but not necessarily to terminate processing. Because the program does not consider inconsistencies to be fatal errors, execution and results might look correct, even though threat or target data may have been omitted. The various reports described below can assist the user in verifying content.

(1) *Scenario Queries.* When DAMOC is executed interactively (the default mode), the program asks a series of questions to set various scenario parameters and identify data files to be used (See **Figure B-1**). For a fuller explanation of the desired responses, the user is referred to Annex A's discussion of the Run Control file (the alternative to interactive processing).

```
Enter the number of days in the scenario ->
Select country codes ( a "*" means all included)-->
Length of period (and report cycle) -->
Enter days of double sorties & suppression period-->
enter SOF & SSM frequencies ->
enter reconstitution period and number-->
enter filename of threat bases-->
enter filename of threat systems-->
enter filename of installation-attack profiles-->
enter filename of target installations -->
```

Figure B-1. SCENARIO DEFINITION

(2) *Threat Bases.* The first data to be read in is the Threat Base file. This establishes the air bases and other military installations where threat assets can be located. **Figure B-2** shows an example of the list of bases produced by DAMOC. The base code is in brackets and the *x* and *y* coordinates (originally expressed in latitude and longitude) is expressed in radians.

```
.......attack bases defined

    airbase number 1      [base0]     0.17453   0.87266
    airbase number 5      [base5]     0.26180   1.04720
    airbase #2            [base2]     0.19199   0.90757
    airbase sac           [base3]     0.20944   0.94248
    corps hq              [base4]     0.22689   0.98000
    fixed launch #1       [base6]     0.24435   1.02684
    airbase forward       [base1]     0.26180   1.01287
```

Figure B-2. THREAT BASES SUMMARY

(3) *Threat Systems.* When processing the Threat Systems file, two fields are checked: the *threat type* (must be one of the four defined classes) and the *threat base* (must be a base code defined in the Threat Bases file). In the example shown in **Figure B-3**, an entry is rejected because DAMOC could not find one of the bases. After processing the data, a list of accepted systems, along with their type and range, is reported.

```
- redeploy error in BADGERS            BOMBER    base3  750   20   10    3base9
..threat rejected --BADGERS            BOMBER    base3  750   20   10    3base9


.......threat definition

          FLOGGERS      [FIGHTER  ]  1281.0
          FENCERS       [FIGHTER  ]   500.0
          SPETSNAZ DIV  [SOF      ]   150.0
          SPETSNAZ COR  [SOF      ]   300.0
          SCUD          [SSM      ]   400.0
```

Figure B-3. THREAT SYSTEMS SUMMARY

(4) *Damage Profiles.* The damage profiles comprise the largest input file. While the file is being processed, information is printed, followed by two reports that summarize facility and profile-related information.

(a) *Installation Log.* Each time a new notional or actual installation is encountered in the file, a message records its creation. **Figure B-4** gives an example of that record.

```
instalprofile created for [NCAF      ]
instalprofile created for [MOB       ]
instalprofile created for [COB       ]
instalprofile created for [FLDCMP    ]
instalprofile created for [TELFX     ]
instalprofile created for [TELFD     ]
instalprofile created for [HAWK      ]
instalprofile created for [LGPORT    ]
instalprofile created for [SMPORT    ]
instalprofile created for [LGPOL     ]
instalprofile created for [SMPOL     ]
instalprofile created for [NATOPL    ]
instalprofile created for [POLFLD    ]
instalprofile created for [AMMOFX    ]
instalprofile created for [AMMOFD    ]
instalprofile created for [STORFX    ]
instalprofile created for [STORFD    ]
instalprofile created for [CPOWER    ]
instalprofile created for [FPOWER    ]
instalprofile created for [WATER     ]
instalprofile created for [WHIWAY    ]
instalprofile created for [NHIWAY    ]
instalprofile created for [HWYBRG    ]
instalprofile created for [HWYTNL    ]
instalprofile created for [RR        ]
instalprofile created for [RRBRG     ]
instalprofile created for [RRTNL     ]
instalprofile created for [RRYD      ]
```

Figure B-4. NOTIONAL INSTALLATION CREATION RECORD

(b) *Facility List.* Rather than redundantly retaining the full text name of each facility within a profile, DAMOC creates a facility master list which is indexed by the catcode. During the processing of a profile, each facility entry is checked against the master list. If the facility is not found, a new entry (facility name and catcode) is placed in the master list. **Figure B-5** shows the contents of the master list that was created after processing one version of installation profiles. Ranking is by JCS catcode. Note that this list determines the entries and order in the summary rollup reports.

```
#REFERENCE JCS CATCODE LIST:
(    1)  111A----RUNWAY
(    2)  111C----HELO LANDING PAD
(    3)  112A----TAXIWAY
(    4)  113A----APRON
(    5)  123A----POL DISPENSING PT
(    6)  125A----POL PIPELINE
(    7)  125B----VALVE BOX      (EA)
(    8)  131A----ANTENNA        (EA)
(    9)  131B----COMMO EQUIP FLD
(   10)  131D----TRANSMITTER BLDG
(   11)  131E----TELEMETRY BLDG
(   12)  133A----CONTROL TOWER
(   13)  141D----AIRCRAFT SHLTR
(   14)  151C----PIER
(   15)  159C----WATER FRONT OPS
(   16)  163A----LANDING DOCK
(   17)  211F----AFCT MAINT FAC
(   18)  216A----AMMO MAINT FAC
(   19)  217A----COMMO MAINT FAC
(   20)  219A----FAC MAINT SHOP
(   21)  411A----FUEL TANK      (BBL)
(   22)  411B----POL BLADDERS   (BBL)
(   23)  411D----3K POL TANKS   (BBL)
(   24)  411E----10K POL TANKS  (BBL)
(   25)  411F----POL STOR YARD
(   26)  421A----AMMO STORAGE FAC
(   27)  422A----NUC AMMO STOR
(   28)  425A----OPEN AMMO STORAGE
(   29)  441A----WAREHOUSE (PORT)
(   30)  442A----GP COVERED STOR
(   31)  451A----GP OPEN STORAGE
(   32)  452A----PORT OPEN STORAGE
(   33)  610A----ADMIN FACILITY
(   34)  811A----ELECT SUB-STAT
(   35)  841C----WTR STOR FAC   (GAL)
(   36)  842A----PUMP UNIT      (EA)
(   37)  842B----WATER PIPELINE
(   38)  851A----HIGHWAY WIDE
(   39)  851B----TWO LANE ROAD
(   40)  851C----ROAD BRIDGE    (SPANS)
(   41)  860A----RAILROAD
(   42)  860B----RAILROAD BRIDGE (SPANS)
(   43)  860C----RAILROAD TUNNEL
(   44)  860D----RAILROAD YARD
(   45)  9999----FLD CMD POST
(   46)  999B----LOADER/TRANSPTR
(   47)  999C----CRANE          (EA)
(   48)  999D----FLD CMD POST
(   49)  999F----GENERATORS     (KW)
```

Figure B-5. FACILITY/CATCODE MASTER LIST

(c) *Damage Profile Summary.* The final subreport for damage profiles is the template summary. It summarizes individual installation threat damage profiles. The two numbers that appear in brackets after the threat name give the primary and suppression attack quotas. That, in turn, is followed by the damaged facility count for the installation threat. During the production of this summary, on-hand facility amounts are checked across profiles within a notional installation. The example (**Figure B-6**) shows an inconsistency message for ammo storage (421A) at a MOB. This tells the user that the on-hand conformity requirement was violated. DAMOC builds one facility list for each notional installation and only one on-hand amount is kept. If on-hand assets are not equal, it makes a large difference when calculating damage. For example, if FIGHTERS and SOF each damage 50% of on-hand assets, but the SOF's presumed target was two orders of magnitude smaller than the planes, then adding the percents together will result in 100% damage when the SOF contribution should have been 0.5% of the larger on-hand figure. The program presumes the first on-hand amount is correct. Upon encountering such a message, the user must resolve the discrepancy. Note also that in this example there is no profile for SOF attacks against nuclear capable airfields (NCAFs). This may indicate a deliberate policy (without a profile, DAMOC will not target SOF against NCAFs), or perhaps something was inadvertently left out of the file or mislabeled.

```
#==DAMAGE TEMPLATE INPUT SUMMARY!

NCAF
    FIGHTER     [  30   12]       13  facilities damaged.
    BOMBER      [  24   12]       13  facilities damaged.
    SSM         [   1    0]        2  facilities damaged.
MOB
    FIGHTER     [  30   12]       13  facilities damaged.
    BOMBER      [  24   12]       13  facilities damaged.
    SOF         [   1    0]        1  facilities damaged.
    SSM         [   1    0]        2  facilities damaged.
* on-hand inconsistency for 421A--[     1200 <>     120000]   <----Inconsistency Error
COB
    FIGHTER     [  14   12]        9  facilities damaged.
    BOMBER      [  14   12]        6  facilities damaged.
    SOF         [   1    0]        1  facilities damaged.
    SSM         [   1    0]        1  facilities damaged.
FLDCMP
    FIGHTER     [   1    0]        1  facilities damaged.
    BOMBER      [   1    0]        1  facilities damaged.
    SOF         [   1    0]        1  facilities damaged.
    SSM         [   1    0]        1  facilities damaged.
TELFX
    FIGHTER     [   4    0]        5  facilities damaged.
    BOMBER      [   2    0]        5  facilities damaged.
    SOF         [   1    0]        2  facilities damaged.
    SSM         [   1    0]        5  facilities damaged.
TELFD
    FIGHTER     [   1    0]        1  facilities damaged.
    BOMBER      [   1    0]        1  facilities damaged.
    SSM         [   1    0]        1  facilities damaged.
HAWK
    FIGHTER     [   1    0]        5  facilities damaged.
    BOMBER      [   1    0]        5  facilities damaged.
    SOF         [   1    0]        3  facilities damaged.
    SSM         [   1    0]        5  facilities damaged.
LGPORT
    FIGHTER     [  18   14]        4  facilities damaged.
    BOMBER      [  18   14]        3  facilities damaged.
    SSM         [   1    0]        3  facilities damaged.
                    .
                    .
```

Figure B-6. DAMAGE PROFILE SUMMARY

(5) *Targets.* The target file is the list of installations in priority order. These real-world locations also designate to which country/group and which notional installation they belong. The final input is latitude and longitude. **Figure B-7** gives an example of the output that accompanies the target file processing. It shows several targets being rejected because they do not have recognizable notional installation designations. DAMOC has no way of knowing if the country/group is right or wrong since it is user defined. The user, therefore, should check this field (Nat=?), especially if installation subset reporting will be used.

```
..no ref-install for NUCAF    a          U    NUCAF        200C00N   0600000E
..no ref-install for NUCSTOR  b          U    NUCSTOR      200000N   0600000E
..no ref-install for COMMO1   k          U    TEL FX       200000N   0600000E
..no ref-install for COMMO2   l          U    TEL FX       200000N   0600000E
..no ref-install for PORT2    aa         T    PORT         200000N   0600000E
..no ref-install for AMMO     bb         A    AMMO         200000N   0600000E
..no ref-install for PORT3    cc         A    PORT         200000N   0600000E


#Regional installations in priority order
(    1)          COB1     c          [Nat=U]      COB
(    2)          COB2     d          [Nat=U]      COB
(    3)          xyz                 [Nat=U]      SMPORT
(    4)          ABC                 [Nat=U]      LGPORT
(    5)          COB3     e          [Nat=U]      COB
(    6)          COB4     f          [Nat=U]      COB
(    7)          COB5     g          [Nat=U]      COB
(    8)          COB6     h          [Nat=T]      COB
(    9)          COB7     i          [Nat=T]      COB
(   10)          COB8     j          [Nat=T]      COB
```

Figure B-7. TARGET INSTALLATION SUMMARY

b. **Results.** The reason for DAMOC's existence is a need for a reasonable estimate of war damage at echelons above corps. When one considers the scores or hundreds of targets, the varying number o days or periods, the groups of targets, and the varying target makeups, it is understandable that no single report can capture all information.

(1) *Facility Rollups.*

(a) *Period Reports.* Among the scenario parameters are report frequency and country codes. While the frequency has no influence on damage calculations, it does set the timing of damage result summaries. These reports give periodic rollups of facility damage across a subset of installations defined by the country codes (**Figure B-8**). It is important to recognize that the on-hand and damage amounts in the report are only for targets of the countries or organizations in this subset.

#Summary Report for period ending day 5 for countries T

CatCode	Facility	On-hand	Damage	Hits	Craters
[111A]	RUNWAY	67200	0.0	211.01	19.17
[111C]	HELO LANDING PAD	0	0.0	0.00	0.00
[112A]	TAXIWAY	23400	0.0	81.68	0.00
[113A]	APRON	1500000	0.0	10.91	0.00
[123A]	POL DISPENSING PT	0	0.0	0.00	0.00
[125A]	POL PIPELINE	0	0.0	0.00	0.00
[125B]	VALVE BOX (EA)	0	0.0	0.00	0.00
[131A]	ANTENNA (EA)	0	0.0	0.00	0.00
[131B]	COMMO EQUIP FLD	0	0.0	0.00	0.00
[131D]	TRANSMITTER BLDG	0	0.0	0.00	0.00
[131E]	TELEMETRY BLDG	0	0.0	0.00	0.00
[133A]	CONTROL TOWER	16875	0.0	0.12	0.00
[141D]	AIRCRAFT SHLTR	195000	1950.0	12.00	0.00
[151C]	PIER	0	0.0	0.00	0.00
[159C]	WATER FRONT OPS	0	0.0	0.00	0.00
[163A]	LANDING DOCK	0	0.0	0.00	0.00
[211F]	AFCT MAINT FAC	180000	0.0	0.00	0.00
[216A]	AMMO MAINT FAC	0	0.0	0.00	0.00
[217A]	COMMO MAINT FAC	0	0.0	0.00	0.00
[219A]	FAC MAINT SHOP	0	0.0	0.00	0.00
[411A]	FUEL TANK (BBL)	0	0.0	0.00	0.00
[411B]	POL BLADDERS (BBL)	0	0.0	0.00	0.00
[411D]	3K POL TANKS (BBL)	0	0.0	0.00	0.00
[411E]	10K POL TANKS (BBL)	0	0.0	0.00	0.00
[411F]	POL STOR YARD	75000	18750.0	11.22	0.00
[421A]	AMMO STORAGE FAC	0	0.0	0.00	0.00
[425A]	OPEN AMMO STORAGE	360000	25272.0	11.40	0.00
[441A]	WAREHOUSE (PORT)	0	0.0	0.00	0.00
[442A]	GP COVERED STOR	0	0.0	0.00	0.00
[451A]	GP OPEN STORAGE	0	0.0	0.00	0.00
[452A]	PORT OPEN STORAGE	0	0.0	0.00	0.00
[610A]	ADMIN FACILITY	0	0.0	0.00	0.00
[811A]	ELECT SUB-STAT	45000	0.0	0.00	0.00
[841C]	WTR STOR FAC (GAL)	0	0.0	0.00	0.00
[842A]	PUMP UNIT (FA)	0	0.0	0.00	0.00
[851A]	HIGHWAY WIDE	0	0.0	0.00	0.00
[851B]	TWO LANE ROAD	0	0.0	0.00	0.00
[851C]	ROAD BRIDGE (SPANS)	0	0.0	0.00	0.00
[860A]	RAILROAD	0	0.0	0.00	0.00
[860B]	RAILROAD BRIDGE (SPANS)	0	0.0	0.00	0.00
[860C]	RAILROAD TUNNEL	0	0.0	0.00	0.00
[860D]	RAILROAD YARD	0	0.0	0.00	0.00
[9999]	FLD CMD POST	0	0.0	0.00	0.00
[999B]	LOADER/TRANSPTR	0	0.0	0.00	0.00
[999C]	CRANE (EA)	0	0.0	0.00	0.00
[999D]	FLD CMD POST	0	0.0	0.00	0.00
[999F]	GENERATORS (KW)	0	0.0	0.00	0.00

Figure B-8. FACILITY DAMAGE ROLLUP BY PERIOD

(b) *Scenario Rollup.* This report is identical to the period report except that it is for the entire scenario. Format and interpretation are the same.

(2) ***Installation Summaries.***

(a) *Attack Record.* To see the pattern of which, or to know when, installations were actually attacked, a record of attacks is kept for each installation. **Figure B-9** gives an example of this information which is routinely printed along with the facility damage results for each installation. It indicates the number of sorties (attacks), by threat type, by period. For air

attacks, it also indicates primary ("/p") and suppression ("/s") sorties. In this figure, there are two instances of the period report. This is because an attack record is created at the beginning of the scenario and at the time of reconstitution of an installation. Here a reconstitution necessarily occurred sometime in periods 2, 3, or 4.

		PERIODS					
		1	2	3	4	5	6
[FIGHTER	/p]	14.0	0.0	0.0	0.0	0.0	0.0
[BOMBER	/p]	0.0	0.0	0.0	0.0	0.0	0.0
[SOF	/p]	0.0	0.0	0.0	0.0	0.0	0.0
[SSM	/p]	0.0	0.0	0.0	0.0	0.0	0.0
[FIGHTER	/s]	12.0	11.0	0.0	0.0	0.0	0.0
[BOMBER	/s]	0.0	1.0	0.0	0.0	0.0	0.0
[FIGHTER	/p]	0.0	0.0	0.0	7.9	4.2	0.0
[BOMBER	/p]	0.0	0.0	0.0	1.8	0.1	0.0
[SOF	/p]	0.0	0.0	0.0	0.0	0.0	0.0
[SSM	/p]	0.0	0.0	0.0	1.0	0.0	0.0
[FIGHTER	/s]	0.0	0.0	0.0	0.0	0.0	4.2
[BOMBER	/s]	0.0	0.0	0.0	0.0	0.0	1.8

Figure B-9. INSTALLATION ATTACK SUMMARY BY PERIOD

(b) *Facility Damage.* The second part of the Installation Summary shows facility damage (**Figure B-10**). Unlike the facility summaries that list all defined catcodes, only the facilities actually included on the installation are listed for damage and hits. The critical crater section is limited to appropriate facilities (pavement and piers).

FACILITY DAMAGE

Facility	Catcode	period 1	period 2	period 3	period 4	period 5	period 6
RUNWAY	111A	0.0	0.0	0.0	0.0	0.0	0.0
TAXIWAY	112A	0.0	0.0	0.0	0.0	0.0	0.0
APRON	113A	0.0	0.0	0.0	39600.0	3027.2	0.0
CONTROL TOWER	133A	0.0	0.0	0.0	46.3	3.5	0.0
AIRCRAFT SHLTR	141D	0.0	0.0	0.0	650.0	0.0	0.0
AFCT MAINT FAC	211F	0.0	0.0	0.0	0.0	0.0	0.0
POL STOR YARD	411F	6250.0	0.0	0.0	5112.3	1997.5	0.0
OPEN AMMO STORAGE	425A	8424.0	0.0	0.0	4730.9	2527.2	0.0
ELECT SUB-STAT	811A	0.0	0.0	0.0	0.0	0.0	0.0

FACILITY HITS

Facility	Catcode	period 1	period 2	period 3	period 4	period 5	period 6
RUNWAY	111A	53.0	27.1	0.0	19.2	8.3	14.3
TAXIWAY	112A	20.5	10.5	0.0	7.4	3.2	5.5
APRON	113A	2.3	1.3	0 0	1.0	0.4	0.8
CONTROL TOWER	133A	0.0	0.0	0.0	0.1	0.0	0.0
AIRCRAFT SHLTR	141D	0.0	0.0	0.0	4.0	0.0	0.0
AFCT MAINT FAC	211F	0.0	0.0	0.0	0.0	0.0	0.0
POL STOR YARD	411F	3.7	0.0	0.0	3.4	1.2	0.0
OPEN AMMO STORAGE	425A	3.8	0.0	0.0	3.6	1.3	0.0
ELECT SUB-STAT	811A	0.0	0.0	0.0	0.0	0.0	0.0

CRITICAL CRATERS

RUNWAY	111A	5.9	2.7	0.0	1.7	0.9	1.1
TAXIWAY	112A	0.0	0.0	0.0	0.0	0.0	0.0
APRON	113A	0.0	0.0	0.0	0.0	0.0	0.0

Figure B-10. INSTALLATION FACILITY DAMAGE SUMMARY BY PERIOD

(3) *Installation Class Attacks.* It is sometimes useful to check how the installation classes are being covered by attacks. **Figure B-11** shows an example of accumulated sorties sent against installation classes, by period. All sorties are added together (i.e., FIGHTER, BOMBER, SOF, and SSM). The user can use this report to appraise the impact of priority ordering, suppression, and reconstitution on attack allocations.

Sortie/Installation Breakout: .....

<< NCAF	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< MOB	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< COB	>>	78.0	19.7	0.0	3.0	0.0	0.0
<< FLDCMP	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< TELFX	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< TELFD	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< HAWK	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< LGPORT	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< SMPORT	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< LGPOL	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< SMPOL	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< NATOPL	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< POLFLD	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< AMMOFX	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< AMMOFD	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< STORFX	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< STORFD	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< CPOWER	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< FPOWER	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< WATER	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< WHIWAY	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< NHIWAY	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< HWYBRG	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< HWYTNL	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< RR	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< RRBRG	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< RRTNL	>>	0.0	0.0	0.0	0.0	0.0	0.0
<< RRYD	>>	0.0	0.0	0.0	0.0	0.0	0.0

Figure B-11. INSTALLATION CLASS ATTACK SUMMARY BY PERIOD

(4) *Sortie Summaries.* The previous report rolled up total attacks against installation class. The sortie summary information records the total number of available sorties on a daily basis. **Figure B-12** shows the four threat types (e.g., 1 = FIGHTER, 2 = BOMBER) and the total available sorties each day for a 30-day scenario. Note that this report lists "available" sorties while the installation attack report lists "actual" sorties.

```
Sorties summary:.....

(T=1)154125101 82 66 | 30 29 28 28 22 | 22 22 22 22 22 |
      22 22 22 22 22 | 22 22 22 22 22 | 22 22 22 22 22 |
(T=2)  0  0  0  0 20 | 20 20 20 20 11 |  9  7  6  6  6 |
       6  6  6  6  6 |  6  6  6  6  6 |  6  6  6  6  6 |
(T=3)  0  0  0  0 17 |  0  0  0 12  0 |  0  0 27  0  0 |
       0 21  0  0  0 | 17  0  0  0 13 |  0  0  0 11  0 |
(T=4)  0  0  0  0  0 |  0  0  0  0  0 |  0  0  0  0  0 |
      10  0  0  0  0 |  8  0  0  0  0 |  6  0  0  0  0 |
```

Figure B-12. DAILY THREAT CLASS SORTIE SUMMARY

c. Execution Monitoring.

(1) ***Machine Performance.*** At different times during execution information is printed regarding memory and execution performance (**Figure B-13**). This information is useful in assuring that nothing untoward occurs. Heap memory readouts occur at the start and end of execution. If memory demands become a problem, the user might check to see if as much memory as possible has been made available. In the example, the initial heap measure is 427,728. Since the instruction portion of DAMOC occupies less than 40K, then *[640 - 40] - 430 = 170* implies that around 170K of memory is not being used by DAMOC. The user should remove unnecessary drivers and resident programs to free up some of this memory. The other message shown here indicates how much time has elapsed since the previous elapsed-time readout. This allows the user to ensure that execution time for various phases of the model is reasonable.

```
 heap memory =    427728, time is 16:21:45
                      .
                      .
=====day(1)  [elapsed time is   0.083 minutes]
=====day(2)  [elapsed time is   0.017 minutes]
=====day(3)  [elapsed time is   0.000 minutes]
=====day(4)  [elapsed time is   0.000 minutes]
=====day(5)  [elapsed time is   0.000 minutes]
                      .
                      .
 heap memory =    397600, time is 16:22:03
```

Figure B-13. MODEL PERFORMANCE AND TIMING MESSAGES

(2) *Event Log.* An event history is produced automatically during each execution of the model. It is written to file "SORTIE.LOG" (**Figure B-14**). Currently, this is not a user-designated file and a name change of the existing file would be required if one wanted to retain the information. The information found in the file is very useful to confirm that the attacks and movement are happening as they should. **Figure B-15** gives an annotated excerpt of a typical SORTIE.LOG file. The user should read these comments.

```
(  1)   1 /COB1      c          14.0-FLOGGERS      77.0
(  2)   1 /COB2      d          14.0-FLOGGERS      63.0
(  3)   1 /xyz                   8.0-FLOGGERS      49.0
(  4)   1 /ABC                  18.0-FLOGGERS      41.0
(  5)   1 /COB3      e          14.0-FLOGGERS      23.0
(  6)   1 /COB4      f          14.0-FLOGGERS       9.0
(  7)  ...[ 1]...FLOGGERS      - unused   0.0
(  8)   1 /xyz                   8.0-FENCERS       77.0
(  9)   1 /COB4      f           5.0-FENCERS       69.0
( 10)   1 /COB5      g          14.0-FENCERS       63.9
( 11)   1 /COB6      h          14.0-FENCERS       49.9
( 12)   1 /COB7      i          14.0-FENCERS       35.9
( 13)   1 /COB8      j          14.0-FENCERS       21.9
( 14)  ...[ 1]...FENCERS       - unused   7.9
( 15)  ...[ 1]...BADGERS       - unused   0.0
( 16)  ...[ 1]...SPETSNAZ DIV  - unused   0.0
( 17)  ...[ 1]...SPETSNAZ COR  - unused   0.0
( 18)  ...[ 1]...SCUD          - unused   0.0
( 19)            .                 .
( 20)   3 /xyz                   8.0-FLOGGERS      50.5
( 21)  ...[ 3]...FLOGGERS      - unused  42.5
( 22)   3 /xyz                   8.0-FENCERS       50.5
( 23)  ...[ 3]...FENCERS       - unused  42.5
( 24)  ---[ 3]--- BADGERS     moves from airbase sac   to airbase #2
( 25)            .                 .
( 26)   4 /COB1      c          12.0 (sup) FLOGGERS     40.9
( 27)   4 /COB2      d          12.0 (sup) FLOGGERS     28.9
( 28)   4 /xyz                   8.0-FLOGGERS      16.9
( 29)   4 /ABC                  14.0 (sup) FLOGGERS      8.9
( 30)  ...[ 4]...FLOGGERS      - unused   0.0
( 31)   4 /xyz                   8.0-FENCERS       40.9
( 32)   4 /ABC                   5.1 (sup) FENCERS      32.9
( 33)   4 /COB3      e          12.0 (sup) FENCERS      27.8
( 34)   4 /COB4      f          12.0 (sup) FENCERS      15.8
( 35)   4 /COB5      g          12.0 (sup) FENCERS       3.8
( 36)  ...[ 4]...FENCERS       - unused   0.0
( 37)  ...[ 4]...BADGERS       - unused   0.0
( 38)  ...[ 4]...SPETSNAZ DIV  - unused   0.0
( 39)  ...[ 4]...SPETSNAZ COR  - unused   0.0
( 40)            .                 .
( 41)  16 /COB1      c           1.0-SCUD         10.0
( 42)  16 /COB2      d           1.0-SCUD          9.0
( 43)  16 /xyz                   1.0-SCUD          8.0
( 44)  16 /ABC                   1.0-SCUD          7.0
( 45)            .                 .
( 46)            .                 .
( 47)  ...[17]...BADGERS       - unused   0.0
( 48)  ...[17]...SPETSNAZ DIV  - unused  14.0
```

Figure B-14. SORTIE LOG FILE EXTRACT

Line	Explanation
1	On day 1 Target "COB1 c" requires 14 sorties to satisfy a primary FIGHTER attack quota of 14. There are 77 available FLOGGER sorties. Since 14 < 77 "COB1 c" can be saturated. An indicator in the target will indicate when primary sorties have been met, and FLOGGER availables are reduced accordingly.
6	On day 6 requirements at "COB4 f" exceed available FLOGGERS (14 > 9). Rather than look for other targets whose requirements are less than or equal to 9, the model allocates the 9 against the target.
8	Target "xyz" was saturated by FLOGGERS on day 1 (see line 3). "Xyz" has come up again as a potential target on day 1. The reason for this is that "xyz" must have had its saturation flag set. Therefore with each change of threat asset (in this case FLOGGER to FENCER) it can be targeted again as if it were unscathed by previous attacks.
9	Here target "COB4 f" is finished off. The requirement is now for 5 air sorties, and that is well within FENCER availabilities. Note that a partially saturated condition can continual indefinitely.
14	The model attempts to allocate threat assets completely. If all targets are saturated, out of range, or immune to attack (no damage profile for asset type), then the model has no place to put excess capability. The message on this line indicates the uncommitted assets. (Upon examination one would find that FENCERS have a shorter range than the previously assigned FLOGGERS. Perhaps reversing the order would better use assets.)
24	The message here records a redeployment. A BADGER has moved from one base to another.
26	The "(sup)" found in this entry indicates that this was a suppression attack. Indeed assuming "COB1 c" was saturated on day 1 (see line 1) and that the suppression cycle was set at 3, then this is as it should be. A check of the damage profiles would also verify that suppression attacks require 12, not 14, attacks for this notional installation class.
41	SCUDs are available on day 16 (cycle = 5) and are used against targets.
48	SOF are available but unused. Saturation is not the reason since no other SOF attacks had been made. The most likely reason is that targets are simply out of range.

Figure B-15. SORTIE LOG FILE EXTRACT--LINE EXPLANATIONS

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ANNEX C

DAMOC DOCUMENTATION

ANNEX C

DAMOC DOCUMENTATION

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1. **PURPOSE.** This annex is an overview of the structure and object types used in the Damage Allocation Model (DAMOC) Program.

2. **SCOPE.** DAMOC is written in TURBO PASCAL 5.5.[1] This version adds object-oriented programming (OOP) constructs to the popular PC programming language. ESC made good use of the new features throughout DAMOC. As a result, however, programmers familiar with PASCAL may have to disabuse themselves of certain preconceptions. Despite retaining all of the old commands, DAMOC's representation in PASCAL 5.5 is sufficiently different in style and approach to almost be a different language because of the OOP design. Appreciating these differences can take time, but is necessary to understand how these features are used. This annex is not a tutorial on 5.5 or OOP.[2] It addresses only DAMOC and consequently does not attempt to school the reader on virtual functions, constructors, inheritance, etc.

3. **LIMITATION.** ESC has not prepared line-by-line descriptions of the program units. Nor will ESC claim that the code is self-documenting--it isn't. On the other hand, if a user needs to change the program, it must be with knowledge of the program at code level. Inline code remarks are sometimes more misleading than helpful and frequently frustrate readability that indenting provides. One need only remember that after compilation and linking, the **code** is executed. While OOP is probably the best decomposition technique currently available, program changes should not be made in isolation. With the object-oriented approach used by DAMOC, someone looking at the code may have to reorient his/her programming paradigm in order to understand and to modify the code.

4. **OBJECT TYPE DESCRIPTIONS.** Becoming familiar with the object types used in DAMOC goes a long way toward understanding the structure of the model. Indeed, this is an often-quoted advantage of OOP-based systems. **Figure C-1** graphically represents the object type hierarchy and the variables and methods associated with the types. The individual object types (class definitions) are described below using a common framework (**Figures C-2 through C-17**). The name of the type and its ancestor, if applicable, are given first. Next the object variable attributes (TURBO PASCAL refers to them as fields) are defined. The variable types are also indicated. Arrays are indicated by a "[ ]" after the type. Finally, the functional and procedural attributes (TURBO PASCAL's methods) are described. The descriptions are intended to introduce the object types. The user must look to the actual code (in the appendices) to see how the concepts are realized. Some object methods have the same (e.g., "dump" or "build") or similar (e.g., "init" or "init2") names--this usually indicates a similar functional intent although perhaps with an entirely different code. For example, build methods are common to all set-type objects and internalize the creation of the disparate lists.

---

[1] *TURBO PASCAL 5.5· Object-Oriented Programming Guide* (Borland International, 1988).

[2] As OOP grows in popularity, scores of books are appearing on the subject. Not all of the books are equal, and some may even be misleading. One well known software pundit published a book about OOP using ADA, but only a short time later went on record saying one couldn't do OOP in ADA. While one can use OOP-like ideas such as decomposition and data localization in FORTRAN, C, ADA, etc., those languages lack the compiler-provided hallmarks of true object languages such as C++ and SIMULA (the nestor of OOP languages). Modelers with experience in other languages will go through a learning curve on the way to becoming object-oriented.

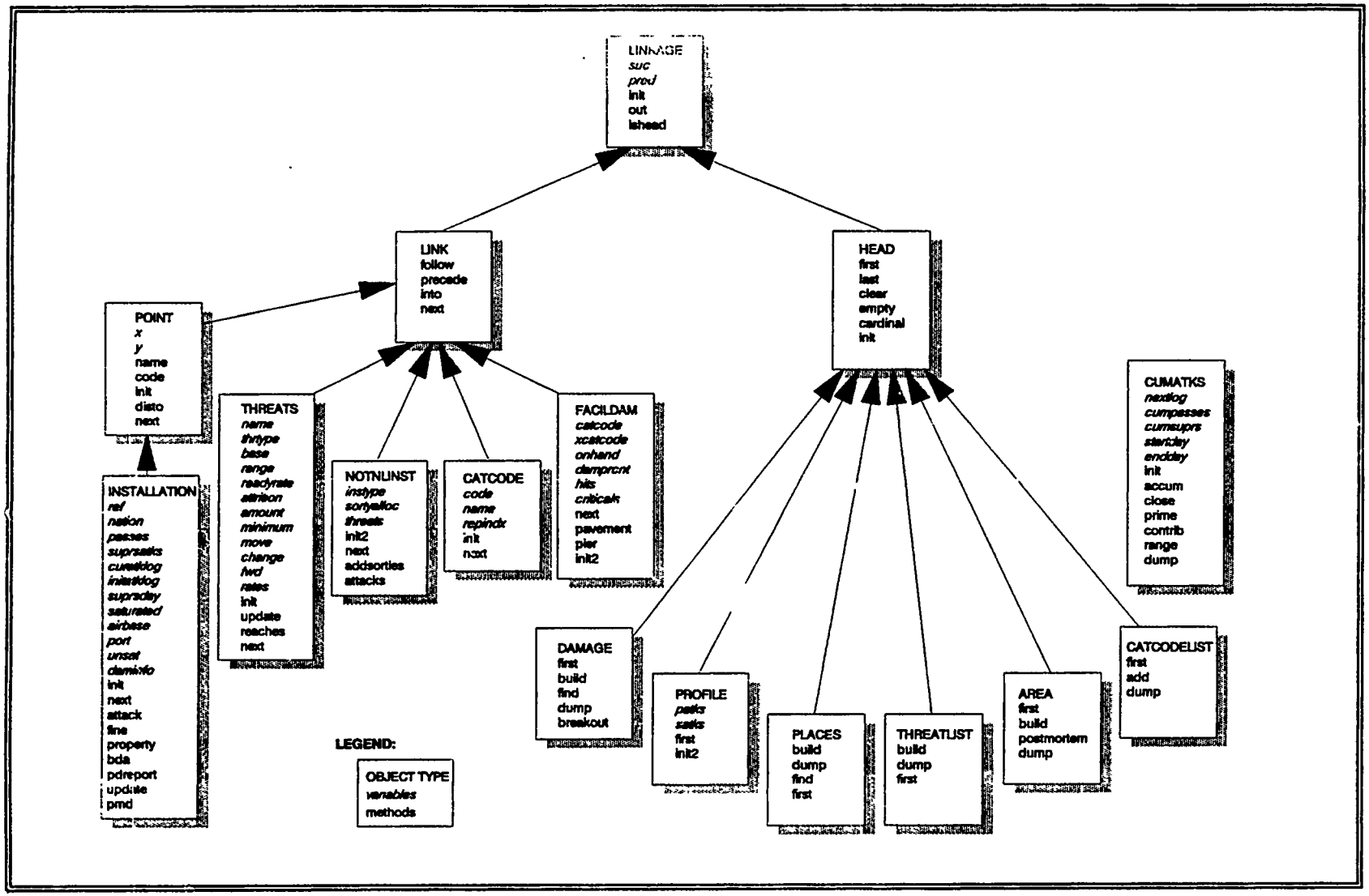

Figure C-1. DAMOC OBJECT TYPE CLASS HIERARCHY

a. **Linkage.** The main report discusses the purpose of the SIMSETx layer of the program, which contains facilities for the manipulation of circular two-way lists (a.k.a. *sets*). Attributes of object type *linkage* are not accessed directly. In a more recent version of PASCAL 5.5, they would be "protected" variables. *Link* and *head* are the derived types used by the modeler to construct his or her own two-way lists.

OBJECT TYPE: linkage		**ANCESTOR TYPE:** none
VARIABLES:		
suc	reflinkage	points to the following linkage object
pred	reflinkage	points to the preceding linkage element
PROCEDURES:		
init	this is the PASCAL constructor called when creating a linkage object	
out	this extracts an object from a set, setting suc and pred equal to nil and adjusting linkage values of adjacent linkage objects	

Figure C-2. ATTRIBUTE DESCRIPTION OF OBJECT LINKAGE

b. **Link.** When an object is defined as a descendent of *link*, it enables list membership and can avail itself of the set manipulation routines. Various method attributes are provided to position the object upon insertion. Note that a *link* object can be in only one list at a time. If one wants to place a single object in several lists, then aliases (other *link* objects pointing to the common object) would have to be used.

OBJECT TYPE: link	**ANCESTOR TYPE:** linkage
PROCEDURES:	
follow	places object after a referenced linkage object
precede	places object before a referenced linkage object
into	puts object into referenced list

Figure C-3. ATTRIBUTE DESCRIPTION OF OBJECT LINK

c. **Head.** Whereas *link* enables list or set membership, the list itself is established by instantiating objects or descendants of object type *head.*

OBJECT TYPE: head		ANCESTOR TYPE: linkage
FUNCTIONS:		
first	reflinkage	returns the first member of the set or nil if list is empty
last	reflinkage	returns the last member in the set
empty	boolean	true if set is empty, false otherwise
cardinal	integer	returns the number of objects in list
PROCEDURES:		
init	the constructor called when a head object is created	
clear	clears contents of a set	

Figure C-4. ATTRIBUTE DESCRIPTION OF OBJECT HEAD

d. **Point.** *Point* endows an object with characteristics to support orthodromic distance calculations. Objects in DAMOC that have locations (bases and installations) are, or are descendants of, this type. It accepts latitude and longitude entries (converting them internally to radians for spherical trigonometric calculations) as well as location-naming information.

OBJECT TYPE: point		ANCESTOR TYPE: link
VARIABLES:		
x	real	the internal spherical equivalent of the place's latitude
y	real	the internal spherical equivalent of the place's longitude
name	string	the common place name
code	string	the code used to identify the place (e.g., a GEOLOC)
FUNCTIONS:		
disto	real	calculates great circle arc distance (nm) from this point to a designated place
next	refpoint	returns the next object in the referenced list
PROCEDURES:		
init	the constructor that converts input values into place variables	

Figure C-5. ATTRIBUTE DESCRIPTION OF OBJECT POINT

e. **Threats.** The information read in for each entry in the THREAT file is used to create *threats* objects. These objects comprise the threat set.

OBJECT TYPE: threats		**ANCESTOR TYPE:** link
VARIABLES:		
name	string	familiar name of threat system
thrtype	integer	internally used threat index (bomber = 2, etc.)
base	refpoint	points to initial location base
range	real	system range
readyrate	real	operational readiness rate for planes (see threat in file annex for ssm and sof)
attrition	real	attrition or use percent
amount	real	initial starting quantity
minimum	real	minimum level of onhand stocks
move	integer[]	move times
change	integer[]	rate change dates
fwd	refpoint[]	stores base pointers used for theater moves
rates	real[]	saves rate change table
FUNCTIONS:		
reaches	boolean	test if target is in range
next	refthreats	gets next object in threats list
PROCEDURES:		
init	constructor used to initialize threat objects	
update	checks to see if move or change should be made	

Figure C-6. ATTRIBUTE DESCRIPTION OF OBJECT THREATS

f. **Threatlist.** *Threatlist* is the list in which all *threat* objects are saved. During processing, threat items are always accessed seriatim.

OBJECT TYPE: threatlist		ANCESTOR TYPE: head
FUNCTIONS:		
first	refthreats	returns first threat system in this list
PROCEDURES:		
build		initiates construction of attacker objects (consistency checks are within threats)
dump		prints validated attacker list

Figure C-7. ATTRIBUTE DESCRIPTION OF OBJECT THREATLIST

g. **Damage.** This object--only one is created during execution--is the damage table. Its purpose is to group all the notional installations and their associated damage profiles.

OBJECT TYPE: damage		ANCESTOR TYPE: head
FUNCTIONS:		
first	refnotnlinst	returns the first notional installation in the table
find	refnotnlinst	looks for a particular notional installation (if not present then find <- null)
PROCEDURES:		
build		this method opens the damage file and reads in the profiles. It also creates the category code (facility identification) list based on the facilities found
breakout		this method sums all the attacks (sorties, raids, missiles) against installation classes (i.e., notional installations) and prints it by period
dump		produces the summary of damage profiles, including the check of facility quantities

Figure C-8. ATTRIBUTE DESCRIPTION OF OBJECT DAMAGE

h. **Places.** This object type is for the list of attacker bases to which threat systems can be deployed.

OBJECT TYPE: places		ANCESTOR TYPE: head
FUNCTIONS:		
find	refpoint	searches for point with requested code
first	refpoint	returns first member of list
PROCEDURES:		
build	initiates construction of base list	
dump	prints places contents	

Figure C-9. ATTRIBUTE DESCRIPTION OF OBJECT PLACES

i. **Notnlinst.** This type encapsulates the information associated with a notional installation of type "instype." The damage profiles (*profile*) against this "instype" are accessed through the *threats* array. Collectively, the *notnlinst* objects comprise the damage table.

OBJECT TYPE: notnlinst		ANCESTOR TYPE: link
VARIABLES:		
instype	string	the user designated identification code for notional type (e.g., COB for collocated operating bases)
sortyalloc	sortyp	an array type used to record how many sorties were launched against this notional instal
threats	refpro-file[]	a pointer array to damage profiles (every threat type need not be present)
FUNCTIONS:		
next	refnotnl-inst	returns the next notional installation in the damage table
PROCEDURES:		
init2	constructor creates the notional installations	
addsorties	information from target cumataks are added to notional installations	
attacks	at the end of an execution the total sorties are rolled up and summarized by period (but only if installation reports are requested)	

Figure C-10. ATTRIBUTE DESCRIPTION OF OBJECT NOTNLINST

j. **Catcodelist.** This object type contains the facility master list. It is derived from the facilities encountered in the damage profiles. It conserves memory and enforces uniformity by using a common label for each facility type.

OBJECT TYPE: catcodelist		ANCESTOR TYPE: head
FUNCTIONS:		
first	refcatcode	this returns the first catcode in the list
add	refcatcode	this routine checks if the catcode is already in the list--if it is not, a new catcode is created and filed in its sorted location
PROCEDURES:		
dump	prints out the contents of the list	

Figure C-11. ATTRIBUTE DESCRIPTION OF OBJECT CATCODELIST

k. **Catcode.** Catcode stands for the category code designation for facilities. While there is no stricture against defining unique facility codes, it is recommended that DAMOC use the JCS 4-character version (for example, the Army uses a 5-character code in its facility component system).[3] *Catcode* objects contain a descriptive title of the catcode, and their relative location in the *catcodelist* set is used as an index in the facility rollup reports.

OBJECT TYPE: catcode		ANCESTOR TYPE: link
VARIABLES:		
code	string	a 4 character code used internally to identify facilities (DAMOC does not validate codes, the user must ensure consistency)
name	string	the long name for a facility
repindx	integer	the relative location of the facility in the reference list
FUNCTIONS:		
next	refcatcode	returns the next catcode in the list
PROCEDURES:		
init	the constructor which initializes the object	

Figure C-12. ATTRIBUTE DESCRIPTION OF OBJECT CATCODE

[3] *Department of Defense Facility Classes and Construction Categories, DOD Instruction 4165.3* (24 October 1978).

l. **Profile.** This object embodies the individual damage profiles. It is accessed through the *threats* array in *notnlinst* objects. It contains the list of facility amounts and damage (*facildam* objects) as well as the attack package sizes that produce the damage.

OBJECT TYPE: profile		ANCESTOR TYPE: head
VARIABLES:		
patks	integer	the number of primary attacks necessary to produce the associated damage
satks	integer	the suppression attack package sizes (planes against air bases and ports)
FUNCTIONS:		
first	refacildam	returns the first facildam object in the template (i.e., damage profiles)
PROCEDURES:		
init2	the constructor method that initializes the object and decodes the primary and secondary attack amounts from input	

Figure C-13. ATTRIBUTE DESCRIPTION OF OBJECT PROFILE

m. **Installation.** The focus of DAMOC is on installations. To whom do they belong? Where are they? What attacks are made against them? What facilities are damaged? To satisfy these demands, this object class incorporates more variable and method attributes than any other class.

OBJECT TYPE: installation		ANCESTOR TYPE: point
VARIABLES:		
ref	string	notional installation ID
nation	char	single character nation/organization indicator (user defined)
passes	real[]	primary attacks made that day, by threat type
suprsatks	real[]	suppression attacks
curatklog	^cumatks	pointer to current phase attack log
initatklog	^cumatks	first log in stack
suprsday	integer	last day either saturated or suppressed (air bases & ports only)
saturated	boolean[]	flags threat type attainment of threshold attack level
airbase	boolean	true if COB, MOB, or other air base
port	boolean	true if SMPORT or LGPORT
unsat	boolean	if "unsaturated" type installation then true
daminfo	refnotnl-inst	points to appropriate notional entry in damage table
FUNCTIONS:		
next	refinstal-lation	returns the next installation in the "front" list
PROCEDURES:		
init		constructor which initializes the many installation attributes
attack		this method determines how many attackers are necessary to saturate or suppress; how many are available, and how they will be allocated
fine		executed when an installation is finished, i.e., saturated
property		returns a list of onhand facility quantities (found in the notional list)
bda		performs the damage assessment
pdreport		checks to see if any attacks have been made against this installation during the period--if yes, then the amounts are added to the cumulative period table
update		if installation is "reconstituted," this method closes and creates attack logs
pmd		performs the postmortem dump (PMD) that prints each attack log phase and damage, hits, and crater summaries

Figure C-14. ATTRIBUTE DESCRIPTION OF OBJECT INSTALLATION

n. **Facildam.** This object type contains the damage information. Each attack *profile* object has a variable number of these objects corresponding to the particular types of facilities that are damaged during an attack.

OBJECT TYPE: facildam		ANCESTOR TYPE: link
VARIABLES:		
catcode	string	the JCS category code (4 characters)
xcatcode	refcatcode	pointer to catcode list with long title
onhand	longint	the installations onhand quantity
damprcnt	real	the percent damaged in full attack
hits	real	the associated number of hits
criticals	real	the number of critical craters to restore a minimum operational strip (MOS)
FUNCTIONS:		
next	refacildam	returns the next facility damage entry in the profile
pavement	boolean	true if the catcode is either 111A, 112A, or 113A
pier	boolean	true if the catcode is 151C
PROCEDURES:		
init2	the constructor which initializes the object and decodes the input record values	

Figure C-15. ATTRIBUTE DESCRIPTION OF OBJECT FACILDAM

o. **Cumatks.** This is a special object type used to record the attacks made against an installation. Except for the possibility of a target being *reconstituted* (i.e., the damage fully repaired), this information could have been part of an *installation* object. Anticipating the possible addition of repair capability being added to the model (directly or indirectly), *cumatks* now enables the model to track successive phases of attacks. "Phase" here means the time from when a target could be attacked to when it is considered fully repaired, thereby initiating a new phase.

OBJECT TYPE: cumatks		**ANCESTOR TYPE:** none
VARIABLES:		
nextlog	refcumatks	points to the next cumatks object found at a target
cumpasses	sortyp	stores the primary attack sorties for this attack phase
cumsuprs	sortys	stores suppression attacks during phase
startday	integer	the day this phase begins
endday	integer	the day this phase ends
FUNCTIONS:		
contrib	boolean	checks start and end days to see if period and phase intersect
PROCEDURES:		
init		the constructor which sets up timing and reference values
accum		adds current period's running totals to the '0th' column of the pass and suppress arrays
close		when an installation is reconstituted, a new cumatks is created; this method terminates the prior object
prime		zeroes the accumulator (running total) portions of the pass and suppress arrays
range		since start and end dates for the object may not be on period boundaries, this routine determines the period range for the "breakout" reports
dump		this report is part of the installation end summary

Figure C-16. ATTRIBUTE DESCRIPTION OF OBJECT CUMATKS

p. Area. This is the set object where *installation* objects are assigned. Note that as the model is presently configured, the order of the installations determines their relative priority as a target.

OBJECT TYPE: area		ANCESTOR TYPE: head
FUNCTIONS:		
first	refinstal-lation	returns the first installation in the list
PROCEDURES:		
build	this routine opens the target file and if the data meets certain internal consistency checks, creates installation objects for each valid entry	
postmortem	at the end of execution this routine will initiate reporting of damage assessments at installations in the selected set (the default is to report; use '!' in the country string if reports are not wanted)	
dump	prints the list of valid installation targets in list order	

Figure C-17. ATTRIBUTE DESCRIPTION OF OBJECT AREA

5. **MAIN PROGRAM.** The third software layer of DAMOC is the main program. This code defines the scenario parameters, requests input file identities, initiates appropriate table (damage, catcode) and list build routines, coordinates threat allocation against targets, and defines or invokes the various reports.

6. **PROGRAM LISTINGS.** The actual program listings are found in **Appendices C-1, C-2, and C-3** that accompany this annex.

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LAST PAGE OF ANNEX C

APPENDIX C-1

SIMSETx PROGRAM LISTING

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```
1           unit SIMSETx;
2
3           INTERFACE
4
5           TYPE
6
7               reflinkage =     ^linkage;
8               reflink    =     ^link;
9               refhead    =     ^head;
10
11              linkage      =  object
12                 suc,pred  :   reflinkage;
13                 constructor init;
14                 procedure out;
15                 end;
16
17              link = object(linkage)
18                 procedure follow(x:reflinkage);
19                 procedure precede(x:reflinkage);
20                 procedure into(s:refhead);
21                 function next:reflink;
22                 end;
23
24              head = object(linkage)
25                 function first: reflinkage;
26                 function last: reflinkage;
27                 procedure clear;
28                 function empty: boolean;
29                 function cardinal: integer;
30                 constructor init;
31                 end;
32
33          IMPLEMENTATION
34
35          {.............................. ..................LINKAGE...}
36
37              constructor linkage.init;
38                 begin pred := nil; suc := nil; end;
39
40              procedure linkage.out;
41                 begin
42                 pred^.suc := suc; suc^.pred := pred;
43                 suc := nil; pred := nil;
44                 end;
45
46          {.....................................................LINK......}
47
48              procedure link.follow(x:reflinkage);
49                 begin
50                 out;
51                 if x <> nil then
52                    begin
53                    if x^.suc <> nil then
54                        begin
55                        pred := x;suc := x^.suc;
56                        suc^.pred := @self;x^.suc := @self;
57                        end;
58                    end;
59                 end;
60
61              procedure link.precede(x:reflinkage);
62                 begin
63                 out;
64                 if x <> nil then
65                    begin
66                    if x^.suc <> nil then
67                       begin
```

```
68                      suc := x; pred := x^.pred;
69                      pred^.suc := @self; x^.pred := @self;
70                      end;
71                   end;
72                end;
73
74             procedure link.into(s:refhead);
75                begin precede(s);  end;
76
77             function link.next:reflink;
78                begin
79                if typeof(suc^) <> typeof(self) then
80                   next := nil
81                   else
82                   next := @suc^;
83                end;
84
85          {.....................................................HEAD......}
86
87             function head.cardinal: integer;
88                var
89                i  :  integer;
90                p  :  reflinkage;
91                begin
92                i := 0;
93                p := first;
94                while p <> nil do
95                   begin
96                   i := i + 1;
97                   p := p^.suc ; if p = @self then p := nil;
98                   end;
99                cardinal := i;
100               end;
101
102            function head.first:reflinkage;
103               begin
104               if not empty then first := suc else first := nil;
105               end;
106
107            function head.last:reflinkage;
108               begin
109               if not empty then last := pred else last := nil;
110               end;
111
112            function head.empty:boolean;
113               begin   empty := suc = @self;   end;
114
115            procedure head.clear;
116               var
117               x  :  reflinkage;
118               begin
119               while first <> nil do
120                  begin
121                  x := first;
122                  x^.out;
123                  end;
124               end;
125
126            constructor head.init;
127               begin  suc:=@self;  pred:=@self;  end;
128
129         end {  SIMSET UNIT }.
```

LAST PAGE OF APPENDIX C-1

APPENDIX C-2

COMMZ PROGRAM LISTING

Blank Page

```
1   unit commz;
2
3   interface
4
5   uses simsetx;
6
7   const
8       nthrt       :    integer = 4;
9       maxperiod   :    integer = 10;
10      threat : array[1..4] of string[10]=('FIGHTER   ','BOMBER    ',
11                                          'SOF       ','SSM       ');
12  type
13      refdamage       =  ^damage;
14      refnotnlinst    =  ^notnlinst;
15      refprofile      =  ^profile;
16      refcatcodelist  =  ^catcodelist;
17      refthreatlist   =  ^threatlist;
18      refacildam      =  ^facildam;
19      refinstallation =  ^installation;
20      refcatcode      =  ^catcode;
21      refarea         =  ^area;
22      refthreats      =  ^threats;
23      refpoint        =  ^point;
24      refplaces       =  ^places;
25      refcumatks      =  ^cumatks;
26
27      sortyp          =  array[1..4,0..10] of real;
28      sortys          =  array[1..2,0..10] of real;
29      damrep          =  array[1..75,1..3] of real;
30      inventory       =  array[1..75] of real;
31
32      point          =  object(link)
33         x,y         :  real;
34         name,code   :  string[20];
35         constructor init(nm,short,lat,lon:string);
36         function disto(dest:refpoint):real;
37         function next: refpoint;
38         end { point };
39
40      threats       =  object(link)
41         name       :  string[12];
42         thrtype    :  integer;
43         base       :  refpoint;
44         range      :  real;
45         readyrate  :  real;
46         attrition  :  real;
47         amount     :  real;
48         minimum    :  real;
49         move,change:  array[1..3] of integer;
50         fwd        :  array[1..3] of refpoint;
51         rates      :  array[1..3,1..2] of real;
52
53         constructor init(s,r:string;bases:refplaces;var good:boolean);
54         procedure update(dy:integer;var logfyl:text);
55         function reaches(tgt:refinstallation):boolean;
56         function next: refthreats;
57         end { threats };
58
59      places    = object(head)
60         procedure build;
61         procedure dump;
62         function find(itype:string):refpoint;
63         function first: refpoint;
64         end { places };
65
66      threatlist  = object(head)
67         procedure build(bases:refplaces);
```

```
68              procedure dump;
69              function first: refthreats;
70              end { threatlist };
71
72            notnlinst     =   object(link)
73               instype    :   string[10];
74               sortyalloc :   sortyp;
75               threats    :   array[1..4] of refprofile;
76               constructor init2(t:string);
77               function next: refnotnlinst;
78               procedure addsorties(prbeg,prend:integer;var m1:sortyp;var m2:sortys);
79               procedure attacks(per:integer);
80               end { notnlist };
81
82            damage        =   object(head)
83               function first: refnotnlinst;
84               procedure build(faclist:refcatcodelist);
85               function find(itype:string):refnotnlinst;
86               procedure dump(maxcats:integer);
87               procedure breakout(nprd:integer)
88               end { damage };
89
90            profile       =  object(head)
91               patks      :  integer;
92               satks      :  integer;
93               function first: refacildam;
94               constructor init2(s:string);
95               end { profile };
96
97            facildam      =  object(link)
98               catcode    :  string[4];
99               xcatcode   :  refcatcode;
100              onhand     :  longint;
101              damprcnt   :  real;
102              hits       :  real;
103              criticals  :  real;
104              function next: refacildam;
105              function pavement : boolean;
106              function pier : boolean;
107              constructor init2(st:string);
108              end { facildam };
109
110
111           cumatks       =  object
112              nextlog    :   refcumatks;
113              cumpasses  :   sortyp;
114              cumsuprs   :   sortys;
115              startday   :   integer;
116              endday     :   integer;
117              constructor init(day:integer);
118              procedure accum(period:integer);
119              procedure close(nxtlog:refcumatks;day:integer);
120              procedure prime;
121              function contrib(period:integer): boolean;
122              procedure range(nper,perlen:integer;daminfo:refnotnlinst;
123                              var perstrt,perend:integer);
124              procedure dump(supatks:boolean;pr:integer);
125              end {cumatks};
126
127
128           installation  =   object(point)
129              ref        :   string[10];
130              nation     :   char;
131              passes     :   array [1..4] of real;
132              suprsatks  :   array [1..2] of real;
133              curatklog  :   ^cumatks;
134              initatklog :   ^cumatks;
```

```
135                suprsday    :   integer;
136                saturated   :   array [1..4] of boolean;
137                airbase,port:   boolean;
138                unsat       :   boolean;
139                daminfo     :   refnotnlinst;
140                constructor init(var s:refdamage;rec:string;var accept:boolean);
141                function next: refinstallation;
142                procedure attack(var amt:real;var log:text;thrtyp,dy,npr,
143                            sprcycle:integer;tn:string);
144                procedure fine(thrt,dy:integer);
145                procedure property(var assets:inventory);
146                procedure bda(ip,mf:integer;atks:refcumatks;
147                             var assets:inventory;var results:damrep);
148                procedure pdreport(period,day,maxf:integer;var results:damrep);
149                procedure update(pr,day:integer;reset:boolean);
150                procedure pmd(fx,pr,periodlen:integer;clist:refcatcodelist);
151                end { installation };
152
153             area      =   object(head)
154                function first: refinstallation;
155                procedure build(d:refdamage);
156                procedure postmortem(nfacs,nprd,lenprd:integer;
157                                     ftab:refcatcodelist;mask:string);
158                procedure dump;
159                end { area };
160
161             catcode    =   object(link)
162                code    :   string[4];
163                name    :   string[20];
164                repindx :   integer;
165                constructor init(c,n:string);
166                function next: refcatcode;
167                end { catcode };
168
169             catcodelist    =   object(head,
170                function first: refcatcode;
171                function add(s:string) : refcatcode;
172                procedure dump;
173                end { catcodelist };
174
175          implementation
176
177          {...................POINT  METHODS.....................................}
178
179             constructor point.init(nm,short,lat,lon:string);
180                var
181                xd,xm,xs,yd,ym,ys,degperad : real;
182                c  :  integer;
183                begin
184                link.init;
185                val(copy(lat,1,2),xd,c);
186                val(copy(lat,3,2),xm,c);
187                val(copy(lon,1,3),yd,c);
188                val(copy(lon,4,2),ym,c);
189                name := nm; code := short;
190                degperad := 360/(2 * Pi);
191                x := (xd+xm/60) / degperad;
192                y := (yd+ym/60) / degperad;
193                if copy(lat,7,1) = 'S' then x := - x;
194                if copy(lon,8,1) = 'W' then y := - y;
195                end;
196
197                function point.disto(dest:refpoint):real;
198                   var
199                   arc,delta,cose,radist : real;
200                   begin
201                   delta := Abs(y - dest^.y);
```

```
202                if delta > Pi then delta := (2*Pi) - delta;
203                cose := sin(x)*sin(dest^.x) + cos(x)*cos(dest^.x)*cos(delta);
204                radist := (Pi/2) - arctan( cose / sqrt( 1 - cose*cose) );
205                arc := radist * (360/(2 * Pi) ) * 60; {minutes of arc}
206              {  disto := 1.852 * arc;  kilometer conversion of 1' arc}
207                disto := arc;         {distance in nautical miles}
208                end;
209
210             function point.next: refpoint;
211                var lnk  :  reflink;
212                begin  lnk := link.next;  next := @lnk^;  end;
213
214
215          {.................PLACES  METHODS.................................}
216
217             procedure places.build;
218                var
219                fn : text; fyle : string[20]; buf : string[80];
220                p  :  refpoint;
221                begin
222                write(' enter filename of threat bases--> ');
223                readln(fyle); assign(fn, fyle); reset(fn);
224                while not eof(fn) do
225                   begin
226                   readln(fn,buf);
227                   new(p);
228                   if p^.init(copy(buf,1,20),copy(buf,25,5),
229                              copy(buf,41,7),copy(buf,51,8)) then
230                      p^.into(@self)
231                      else
232                      writeln('..base rejected --',buf);
233                   end;
234                close(fn);
235                end;
236
237             function places.first: refpoint;
238                var lkg  :  reflinkage;
239                begin  lkg := head.first;  first := @lkg^;  end;
240
241          function places.find(itype:string):refpoint;
242             var
243             p  :  refpoint;
244             begin
245             find := nil;
246             p := first;
247             while p <> nil do
248                   if p^.code = itype then
249                      begin
250                      find := p;
251                      p := nil;
252                      end
253                      else
254                      p := p^.next;
255             end;
256
257
258             procedure places.dump;
259               var t : refpoint; cnt : integer;
260               begin
261               writeln('.......attack bases defined');
262               t := first;
263               while t <> nil do
264                 begin
265                 writeln(t^.name:25,' [',t^.code,']  ',
266                       t^.x:10:5,t^.y:10:5);
267                 t := t^.next;
268                 end;
```

```
269                writeln;
270                end;
271
272
273
274          {.................THREATS METHODS.....................................}
275
276
277          constructor threats.init(s,r:string;bases:refplaces;var good:boolean);
278              var typ : string[10]; i,err : integer;
279              begin
280              link.init;
281              base := bases^.find(copy(s,31,5));
282              if base = nil then
283                 begin
284                 writeln('...threat start base error - ',s);
285                 good := false;
286                 end
287                 else
288                 begin
289                 typ := copy(s,21,10); thrtype := -1;
290                 for i := 1 to nthrt do if typ = threat[i] then thrtype := i;
291                 if thrtype > 0 then
292                    begin
293                    good := true;
294                    name := copy(s,1,20);
295                    val(copy(s,36,5),range,err);
296                    val(copy(s,41,5),amount,err);
297                    val(copy(s,46,5),minimum,err);
298                    readyrate := 0.0;   attrition := 0.0;
299                    for i := 1 to 3 do
300                       begin
301                       val(copy(s,51+10*(i-1),5),move[i],err);
302                       if move[i] > 0 then
303                           begin
304                           fwd[i] := bases^.find(copy(s,56+10*(i-1),5));
305                           if fwd[i] = nil then
306                              begin
307                              writeln('  - redeploy error in ',s);
308                              good:=false;
309                              end;
310                           end;
311                       end;
312                    for i := 1 to 3 do
313                        begin
314                        val(copy(r,11+15*(i-1),5),change[i],err);
315                        if change[i] > 0 then
316                           begin
317                           val(copy(r,16+15*(i-1),5),rates[i,1],err);
318                           val(copy(r,21+15*(i-1),5),rates[i,2],err);
319                           if rates[i,1]*rates[i,2] > 1 then
320                              begin
321                              writeln('   - rate range error in ',name);
322                              good := false;
323                              end;
324                           end;
325                        end;
326                    end
327                    else
328                    good  := false;
329                 end;
330              end;
331
332           function threats.reaches(tgt:refinstallation):boolean;
333              begin
334              if base^.disto(tgt) < range then reaches := true
335                 else reaches := false;
```

```
336                end;
337
338             procedure threats.update(dy:integer;var logfyl:text);
339                var i : integer;
340                begin
341                for i := 1 to 3 do
342                   begin
343                   if dy = move[i] then
344                      begin
345                      writeln(logfyl,'---[',dy:2,']---',name,
346                         ' moves from ',base^.name,' to ',fwd[i]^.name);
347                      base := fwd[i];
348                      end;
349                   if dy = change[i] then
350                      begin
351                      readyrate := rates[i,1];
352                      attrition := rates[i,2];
353                      end;
354                   end;
355                end;
356
357             function threats.next: refthreats;
358                var lnk  :  reflink;
359                begin  lnk := link.next;  next := @lnk^;  end;
360
361
362
363          {.................THREATLIST METHODS.............................}
364
365
366             procedure threatlist.build(bases:refplaces);
367                var
368                fn : text; fyle : string[20]; buf1,buf2 : string[80];
369                t  :  refthreats;   ok   :  boolean;
370                begin
371                write(' enter filename of threat systems--> ');
372                readln(fyle); assign(fn, fyle); reset(fn);
373                while not eof(fn) do
374                   begin
375                   readln(fn,buf1);readln(fn,buf2);
376                   new(t,init(buf1,buf2,bases,ok));
377                   if ok then t^.into(@self)
378                      else
379                      writeln('..threat rejected --',buf1);
380                   end;
381                close(fn);
382                end;
383
384             function threatlist.first: refthreats;
385                var lkg  :  reflinkage;
386                begin  lkg := head.first;  first := @lkg^;  end;
387
388
389             procedure threatlist.dump;
390               var t : refthreats; cnt : integer;
391               begin
392               writeln('.......threat definition');
393               t := first;
394               while t <> nil do
395                 begin
396                 writeln(t^.name:25,' [',threat[t^.thrtype],']  ',
397                       t^.range:6:1);
398                 t := t^.next;
399                 end;
400               writeln;
401               end;
402
```

```
403          {.................DAMAGE METHODS.....................................}
404
405              function damage.find(itype:string):refnotnlinst;
406                 var
407                 ri  :  refnotnlinst;
408                 begin
409                 find := nil;
410                 ri := first;
411                 while ri <> nil do
412                       if ri^.instype = itype then
413                          begin
414                          find := ri;
415                          ri := nil;
416                          end
417                          else
418                          ri := ri^.next;
419                 end;
420
421              procedure damage.build(faclist:refcatcodelist);
422                 var
423                    fn  :  text;
424                    i,it:  integer;
425                    fyle  :   string[20];
426                    iobuf  :  string[80];
427                    facrec :  refacildam;
428                    thrt   :  refprofile;
429                    tinst  :  refnotnlinst;
430                    thrtyp :  string[10];
431                 begin
432                 write(' enter filename of installation-attack profiles--> ');
433                 readln(fyle); assign(fn, fyle); reset(fn);
434                 while not eof(fn) do
435                    begin
436                    readln(fn,iobuf);
437                    if iobuf[1] = '*' then
438                       begin
439                       tinst := find(copy( iobuf,2,10 ));
440                       if tinst = nil then
441                          begin
442                          writeln('instalprofile created for [',copy(iobuf,2,10),']');
443                          tinst:=new(refnotnlinst,init2( iobuf ));
444                          tinst^.into(@self);
445                          end;
446                       thrtyp := copy(iobuf,26,10);
447                       it:=0;for i:= 1 to nthrt do if thrtyp = threat[i] then it := i;
448                       if it = 0 then
449                          writeln('----invalid threat type -- ',thrtyp)
450                          else
451                          if tinst^.threats[it] = nil then
452                             begin
453                             tinst^.threats[it]:=
454                                 new(refprofile,init2(iobuf));
455                             thrt:=tinst^.threats[it];
456                             end
457                             else
458                             begin
459                             thrt := nil;
460                             writeln('...duplicate threat encountered-',iobuf);
461                             end;
462                       end
463                       else
464                       if thrt <> nil then
465                          begin
466                          facrec:=new(refacildam,init2(iobuf));
467                          facrec^.into(thrt);
468                          facrec^.xcatcode := faclist^.add(iobuf);
469                          end;
```

```
470                end;
471              close(fn);
472              end;
473
474            function damage.first: refnotnlinst;
475                var lkg  :  reflinkage;
476                begin  lkg := head.first;  first := @lkg^;  end;
477
478
479            procedure damage.breakout(nprd:integer);
480               var
481               instclass  :  refnotnlinst;
482               begin
483               writeln;
484               writeln('Sortie/Installation Breakout: .....');
485               writeln;
486               instclass := first;
487               while instclass <> nil do
488                  begin
489                  instclass^.attacks(nprd);
490                  instclass := instclass^.next;
491                  end;
492               end;
493
494
495               procedure damage.dump(maxcats:integer);
496                  var
497                     x : refnotnlinst;
498                     f : refacildam;
499                     assetchk  :  array [1..100] of longint;
500                     i,j : integer;
501                  begin
502                  writeln('#==DAMAGE TEMPLATE INPUT SUMMARY!');
503                  x := first;
504                  while x <> nil do
505                     begin
506                     writeln(x^.instype:15);
507                     for i := 1 to nthrt do
508                        if x^.threats[i] <> nil then
509                           writeln('       ',threat[i]:12,'  [',
510                            x^.threats[i]^.patks:5,x^.threats[i]^.satks:5,']',
511                            x^.threats[i]^.cardinal:10,'  facilities damaged.');
512                     for i := 1 to maxcats do assetchk[i] := 0;
513                     for i := 1 to nthrt do
514                         begin
515                         f := x^.threats[i]^.first;
516                         while f <> nil do
517                             begin
518                             j := f^.xcatcode^.repindx;
519                             if assetchk[j] = 0 then
520                                  assetchk[j]:=f^.onhand
521                                  else
522                                  if assetchk[j] <> f^.onhand then
523                                       writeln('    * onhand inconsistency for ',
524                                          f^.catcode,'--[',assetchk[j]:10,
525                                          ' <> ',f^.onhand:10,']');
526                             f := f^.next;
527                             end;
528                         end;
529                     x := x^.next;
530                     end;
531                  end;
532
533         {.................NOTNLINST METHODS.....................................}
534
535            constructor notnlinst.init2(t:string);
536               var i,j,err : integer;
```

```
537                 begin
538                 link.init;
539                 instype := copy(t,2,10);
540                 for i := 1 to 4 do
541                    begin
542                    threats[i] := nil;
543                    for j := 1 to maxperiod do
544                       sortyalloc[i,j] := 0.0;
545                    end;
546                 end;
547
548              function notnlinst.next: refnotnlinst;
549                  var lnk  :  reflink;
550                  begin  lnk := link.next;  next := @lnk^;  end;
551
552
553
554              procedure notnlinst.addsorties(prbeg,prend:integer;var m1:sortyp;var
555           m2:sortys);
556                 var i,j  :  integer;
557                 begin
558                 for j := prbeg to prend do
559                    for i := 1 to 4 do
560                       begin
561                       sortyalloc[i,j] := sortyalloc[i,j] + m1[i,j];
562                       if i < 3 then
563                          sortyalloc[i,j] := sortyalloc[i,j] + m2[i,j];
564                       end;
565                 end;
566
567              procedure notnlinst.attacks(per:integer);
568                 var  i,j : integer;s : real;
569                 begin
570                 writeln;write('<< ',instype,' >>');
571                 {writeln;
572                  for i := 1 to nthrt do
573                      begin
574                      write(threat[i]);
575                      for j := 1 to per do write(sortyalloc[i,j]:8:1);
576                      writeln;
577                      end;}
578                  for j:= 1 to per do
579                      begin
580                      s:= sortyalloc[1,j] + sortyalloc[2,j] + sortyalloc[3,j]
581                           +sortyalloc[4,j];
582                      write(s:8:1);
583                      end;
584                  writeln;
585                  end;
586
587           {.................FACILDAM METHODS.....................................}
588
589
590              constructor facildam.init2(st:string);
591                 var err : integer;
592                 begin
593                 link.init;
594                 catcode := copy(st,26,4);
595                 val(copy(st,31,10),onhand,err);
596                 val(copy(st,41,10),damprcnt,err); damprcnt:= 0.01 * damprcnt;
597                 val(copy(st,51,10),hits,err);
598                 val(copy(st,61,10),criticals,err);
599                 end;
600
601              function facildam.next: refacildam;
602                  var lnk  :  reflink;
603                  begin  lnk := link.next;  next := @lnk^;  end;
```

```
604
605             function facildam.pavement: boolean;
606                begin
607                if (catcode='111A') or (catcode='112A') or (catcode='113A') then
608                   pavement := true
609                   else
610                   pavement := false;
611                end;
612
613             function facildam.pier: boolean;
614                begin
615                if (catcode='151C')  then
616                   pier := true
617                   else
618                   pier := false;
619                end;
620
621
622
623          {..................... CUMATAKS METHODS .....................................}
624
625
626             constructor cumatks.init(day:integer);
627                var i,j  :  integer;
628                begin
629                nextlog := nil;
630                startday := day;
631                endday := 999;
632                for i := 0 to 10 do
633                   begin
634                   for j := 1 to 4 do cumpasses[j,i] := 0.0;
635                   cumsuprs[1,i] := 0.0;
636                   cumsuprs[2,i] := 0.0;
637                   end;
638                end;
639
640             procedure cumatks.accum(period:integer);
641                var i : integer;
642                begin
643                for i := 1 to 4 do
644                   cumpasses[i,0] := cumpasses[i,0] + cumpasses[i,period];
645                cumsuprs[1,0] := cumsuprs[1,0] + cumsuprs[1,period];
646                cumsuprs[2,0] := cumsuprs[2,0] + cumsuprs[2,period];
647                end;
648
649             function cumatks.contrib(period:integer): boolean;
650                var i : integer; test  :  real;
651                begin
652                test := cumsuprs[1,period] + cumsuprs[2,period];
653                for i := 1 to nthrt do
654                    test := test + cumpasses[i,period];
655                if test > 0.0 then
656                   contrib := true
657                   else
658                   contrib := false;
659                end;
660
661             procedure cumatks.close(nxtlog:refcumatks;day:integer);
662                begin
663                nextlog := nxtlog;
664                endday := day;
665                end;
666
667
668             procedure cumatks.prime;
669                var j : integer;
670                begin
```

```
671                  for j := 1 to 4 do cumpasses[j,0] := 0.0;
672                  cumsuprs[1,0] := 0.0;
673                  cumsuprs[2,0] := 0.0;
674                  end;
675
676               procedure cumatks.range(nper,perlen:integer;daminfo:refnotnlinst;
677                                       var perstrt,perend:integer);
678                  begin
679                  perstrt :=    ( (startday-1) div perlen ) +1;
680                  if endday = 999 then
681                     perend := nper
682                     else
683                     perend :=  ((endday-1) div perlen) + 1;
684                  daminfo^.addsorties(perstrt,perend,cumpasses,cumsuprs);
685                  end;
686
687
688               procedure cumatks.dump(supatks:boolean;pr:integer);
689                 var i,j  :  integer;
690                 begin
691                 for j := 1 to 4 do
692                    begin
693                    write('[',threat[j],'/p] ');
694                    for i := 1 to pr do write(cumpasses[j,i]:5:1);writeln;
695                    end;
696                 if supatks then
697                    for j := 1 to 2 do
698                       begin
699                       write('[',threat[j],'/s] ');
700                       for i := 1 to pr do write(cumsuprs[j,i]:5:1);writeln;
701                       end;
702                 writeln;
703                 end;
704
705
706            {.................INSTALLATION METHODS.................................}
707
708               constructor installation.init(var s:refdamage;
709                                             rec:string;var accept:boolean);
710                  var
711                  instype :  string;
712                  indam   :  refnotnlinst;
713                  c,i,p   :  integer;
714                  begin
715                  instype := copy(rec,30,10);
716                  indam :=  s^.find(instype);
717                  if indam <> nil then
718                     begin
719                     point.init(copy(rec,1,20),'',copy(rec,50,7),copy(rec,60,8));
720                     ref   := instype;   daminfo  := indam;      nation := rec[25];
721                     accept := true;      suprsday := 0;
722                     for i := 1 to nthrt do
723                        begin passes[i] := 0.0; saturated[i] := false; end;
724                     if rec[27] = '*' then unsat := true else unsat := false;
725                     suprsatks[1] := 0.0; suprsatks[2] := 0.0;
726                     initatklog := new(refcumatks,init(1));
727                     curatklog := initatklog;
728                     if indam^.threats[1]^.satks > 0 then
729                        begin
730                        if (ref = 'NCAF      ') or
731                           (ref = 'COB       ') or
732                           (ref = 'MOB       ') then
733                           begin airbase := true; port := false; end
734                           else
735                           if (ref = 'LGPORT    ') or
736                              (ref = 'SMPORT    ') then
737                              begin port := true; airbase := false; end
```

```
738                     else
739                     begin
740                     airbase := false;
741                     port := false;
742                     end;
743               end
744               else
745               begin
746               airbase := false;
747               port := false;
748               end;
749            end
750            else
751            accept := false;
752         end;
753
754      function installation.next: refinstallation;
755            var lnk  :  reflink;
756            begin  lnk := link.next;  next := @lnk^;  end;
757
758
759      procedure installation.attack(var amt:real;var log:text;thrtyp,dy,npr,
760                     sprcycle:integer;tn:string);
761         var
762         pcntair:  real;
763         needs  :  real;
764         begin
765         if daminfo^.threats[thrtyp] <> nil then
766           begin
767
768              if (not saturated[thrtyp]) then
769                 begin
770                 if unsat then
771                    needs := daminfo^.threats[thrtyp]^.patks
772                    else
773                    begin
774                    if thrtyp > 2 then
775                       needs := daminfo^.threats[thrtyp]^.patks
776                                - passes[thrtyp]
777                       else
778                       begin
779                       pcntair :=
780                         ( passes[1] / daminfo^.threats[1]^.patks )   +
781                         ( passes[2] / daminfo^.threats[2]^.patks );
782                       needs := (1-pcntair)*daminfo^.threats[thrtyp]^.patks;
783                       end;
784                    end;
785                 writeln(log,dy:2,' /',name,needs:4:1,
786                                 '-',tn,amt:5:1);
787                 if needs < amt then
788                    begin
789                    amt := amt - needs;
790                    passes[thrtyp] := 0;
791                    if thrtyp < 3 then passes[3 - thrtyp] := 0;
792                    curatklog^.cumpasses[thrtyp,npr] :=
793                         curatklog^.cumpasses[thrtyp,npr] + needs;
794                    fine(thrtyp,dy);
795                    end
796                    else
797                    begin
798                    passes[thrtyp]:= passes[thrtyp] + amt;
799                    curatklog^.cumpasses[thrtyp,npr] :=
800                         curatklog^.cumpasses[thrtyp,npr] + amt;
801                    amt := 0;
802                    end;
803                 end
804                 else
```

```
805                     if (airbase or port) and (thrtyp <= 2) then
806                        begin
807                        if (dy - suprsday) >= sprcycle then
808                           begin
809                           pcntair :=
810                             ( (suprsatks[1])/daminfo^.threats[1]^.satks )   +
811                             ( (suprsatks[2])/daminfo^.threats[2]^.satks ) ;
812                           needs := (1-pcntair)*daminfo^.threats[thrtyp]^.satks;
813                           writeln(log,dy:2,' /',name,needs:4:1,
814                                       ' (sup) ',tn,amt:5:1);
815                           if (0 < needs) then
816                              begin
817                              if (needs < amt) then
818                                 begin
819                                 amt := amt - needs;
820                                 suprsday := dy;
821                                 suprsatks[1] := 0.0;
822                                 suprsatks[2] := 0.0;
823                                 curatklog^.cumsuprs[thrtyp,npr] :=
824                                    curatklog^.cumsuprs[thrtyp,npr] + needs;
825                                 end
826                                 else
827                                 begin
828                                 suprsatks[thrtyp] := suprsatks[thrtyp] + amt;
829                                 curatklog^.cumsuprs[thrtyp,npr] :=
830                                         curatklog^.cumsuprs[thrtyp,npr] + amt;
831                                 amt := 0;
832                                 end;
833                              end;
834                           end;
835                        end;
836                  end;
837               end;
838
839            procedure installation.fine(thrt,dy:integer);
840               begin
841               if not upsat then saturated[thrt] := true;
842               if thrt < 3 then
843                  begin
844                  suprsday := dy;
845                  suprsatks[1] := 0;
846                  suprsatks[2] := 0;
847                  saturated[3-thrt] := saturated[thrt];
848                  end;
849               end;
850
851            procedure installation.update(pr,day:integer;reset:boolean);
852               var t : integer;
853               newatklog  :  refcumatks;
854               begin
855               if reset then
856                  begin
857                  newatklog := new(refcumatks,init(day));
858                  curatklog^.close( newatklog,day);
859                  curatklog := newatklog;
860                  for t := 1 to nthrt do saturated[t] := false;
861                  end;
862               end;
863
864
865
866            procedure installation.property(var assets:inventory);
867               var
868               tgtfac    :   refacildam;
869               findx,nt  :   integer;
870               begin
871               for nt := 1 to nthrt do
```

```
872                 begin
873                 if daminfo^.threats[nt] <> nil then
874                    tgtfac := daminfo^.threats[nt]^.first
875                    else
876                    tgtfac := nil;
877                 while tgtfac <> nil do
878                    begin
879                    findx := tgtfac^.xcatcode^.repindx;
880                    if assets[findx] = 0.0 then
881                       assets[findx] := tgtfac^.onhand;
882                    tgtfac := tgtfac^.next;
883                    end;
884                 end;
885              end {property};
886
887
888           procedure installation.pdreport(period,day,maxf:integer;
889                                           var results:damrep);
890              var atkrec    : refcumatks;
891                  fassets   : inventory;
892                  i,j       : integer;
893                  damage    : damrep;
894              begin
895              for i := 1 to maxf do
896                 begin
897                 fassets[i] := 0.0;
898                 damage[i,1] := 0.0;
899                 damage[i,2] := 0.0;
900                 damage[i,3] := 0.0;
901                 end;
902              property(fassets);
903              atkrec := initatklog;
904              while atkrec <> nil do
905                 begin
906                 if atkrec^.contrib(period) then
907                    begin
908                    bda(period,maxf,atkrec,fassets,damage);
909                    for i := 1 to maxf do
910                       if fassets[i] > 0.0 then
911                          for j := 1 to 3 do
912                             begin
913                             results[i,j]:=results[i,j]+damage[i,j];
914                             damage[i,j] := 0;
915                             end;
916                    end;
917                 atkrec := atkrec^.nextlog;
918                 end;
919              end;
920
921
922           procedure installation.bda(ip,mf:integer;atks:refcumatks;
923                                      var assets:inventory;
924                                      var results:damrep);
925              var
926              factr          :   array [1..4] of real;
927              factrs         :   array [1..2] of real;
928              tgtfacil       :   refacildam;
929              damchk         :   inventory;
930              i,nt,findx     :   integer;
931              pfactr         :   real;
932
933              begin
934              for i := 1 to mf do damchk[i] := 0.0;
935              for nt := 1 to nthrt do
936                 begin
937                 if (daminfo^.threats[nt] <> nil) then
938                    begin
```

```
939                 factr[nt] :=
940                     (atks^.cumpasses[nt,ip]) / daminfo^.threats[nt]^.patks;
941                 pfactr :=
942                     (atks^.cumpasses[nt, 0]) / daminfo^.threats[nt]^.patks;
943                 if (airbase or port) and (nt < 3) then
944                    begin
945                    if (daminfo^.threats[nt] <> nil) and
946                       (daminfo^.threats[nt]^.satks > 0) then
947                          factrs[nt] :=
948                           (atks^.cumsuprs[nt,ip]) /
949                               daminfo^.threats[nt]^.satks
950                          else
951                          factrs[nt] := 0.0;
952                    end;
953                 tgtfacil := daminfo^.threats[nt]^.first;
954                 while tgtfacil <> nil do
955                    begin
956                    findx := tgtfacil^.xcatcode^.repindx;
957                    results[findx,1] := results[findx,1]
958                      + factr[nt] * tgtfacil^.damprcnt * assets[findx];
959                    damchk[findx] := damchk[findx]
960                      + pfactr * tgtfacil^.damprcnt * assets[findx];
961                    results[findx,2] := results[findx,2]
962                      + factr[nt] * tgtfacil^.hits;
963                    results[findx,3] := results[findx,3]
964                      + factr[nt] * tgtfacil^.criticals;
965                    if nt < 3 then
966                       begin
967                       if factrs[nt] > 0 then
968                          begin
969                          if airbase then
970                             begin
971                             if tgtfacil^.pavement then
972                                begin
973                                results[findx,3] := results[findx,3]
974                                    + factrs[nt] * tgtfacil^.criticals;
975                                results[findx,2] := results[findx,2]
976                                    + factrs[nt] * tgtfacil^.hits;
977                                end;
978                             end
979                             else
980                             if port then
981                                begin
982                                if tgtfacil^.pier then
983                                   begin
984                                   results[findx,2] := results[findx,2]
985                                           + factrs[nt] * tgtfacil^.hits;
986                                   end;
987                                end;
988                          end;
989                       end;
990                    tgtfacil := tgtfacil^.next;
991                    end;
992                end;
993             end {nt loop};
994          for i := 1 to mf do
995             if assets[i] <> 0 then
996                begin
997                if (damchk[i] + results[i,1] > assets[i] ) then
998                   results[i,1] := assets[i] - damchk[i];
999                if results[i,1] < 0 then
1000                  results[i,1] := 0.0;
1001               end;
1002         atks^.accum(ip);
1003         end;
1004
1005
```

```
1006    procedure installation.pmd(fx,pr,periodlen:integer;
1007                               clist:refcatcodelist);
1008      var
1009      totdam          :   array [1..10] of damrep;
1010      check           :   inventory;
1011      ip,findx        :   integer;
1012      stper,endper    :   integer;
1013      nt,i,j          :   integer;
1014      catcd           :   refcatcode;
1015      phase           :   refcumatks;
1016
1017      begin
1018      writeln;writeln('++++++Installation summary for ',
1019              name:20,'+++++++++++++++');writeln;
1020      for i := 1 to pr do
1021         for j := 1 to fx do
1022            begin
1023            totdam[i,j,1] := 0.0;
1024            totdam[i,j,2] := 0.0;
1025            totdam[i,j,3] := 0.0;
1026            end;
1027
1028      for i := 1 to fx do check[i] := 0.0;
1029      property(check);
1030      phase := initatklog;
1031      while phase <> nil do
1032        begin
1033        phase^.dump( (airbase or port), pr );
1034        phase^.prime;
1035        phase^.range(pr,periodlen,daminfo,stper,endper);
1036        for ip := stper to endper do
1037           begin
1038           bda(ip,fx,phase,check,totdam[ip]);
1039           end;
1040        phase := phase^.nextlog;
1041        end;
1042      catcd := clist^.first;
1043      writeln;writeln('FACILITY DAMAGE');
1044      write('     Facility     Catcode');
1045        for i := 1 to pr do write(' period',i:3); writeln;
1046      write('----------------- -------');
1047        for i := 1 to pr do write(' ---------'); writeln;
1048      while catcd <> nil do
1049         begin
1050         findx := catcd^.repindx;
1051         if check[findx] > 0 then
1052            begin
1053            write(catcd^.name:20,catcd^.code:4);
1054            for i := 1 to pr do write(totdam[i,findx,1]:10:1);
1055            writeln;
1056            end;
1057         catcd := catcd^.next;
1058         end;
1059      catcd := clist^.first;
1060      writeln;writeln('FACILITY HITS');
1061      write('     Facility     Catcode');
1062        for i := 1 to pr do write(' period',i:3); writeln;
1063      write('----------------- -------');
1064        for i := 1 to pr do write(' ---------'); writeln;
1065      while catcd <> nil do
1066         begin
1067         findx := catcd^.repindx;
1068         if check[findx] > 0 then
1069            begin
1070            write(catcd^.name:20,catcd^.code:4);
1071            for i := 1 to pr do write(totdam[i,findx,2]:10:1);
1072            writeln;
```

```
1073                    end;
1074                 catcd := catcd^.next;
1075                 end;
1076              if airbase then
1077                 begin
1078                 catcd := clist^.first;
1079                 writeln;writeln;writeln('CRITICAL CRATERS');
1080                 while catcd <> nil do
1081                    if catcd^.code < '120A' then
1082                       begin
1083                       findx := catcd^.repindx;
1084                       if check[findx] > 0 then
1085                          begin
1086                          write(catcd^.name:20,catcd^.code:4);
1087                          for i := 1 to pr do write(totdam[i,findx,3]:10:1);
1088                          writeln;
1089                          end;
1090                       catcd := catcd^.next;
1091                       end
1092                       else
1093                       catcd := nil;
1094                 end;
1095              end;
1096
1097        {.................PROFILE METHODS.....................................}
1098
1099           constructor profile.init2(s:string);
1100              var err : integer;
1101              begin
1102              head.init;
1103              val(copy(s,41,5),patks,err);
1104              if err<>0 then
1105                 begin
1106                 writeln('primary attack err ',s);
1107                 patks := 0;
1108                 end;
1109              val(copy(s,46,5),satks,err);
1110              if err<>0 then
1111                 begin
1112                 writeln('secondary attack err ',s);
1113                 satks := 0;
1114                 end;
1115              end;
1116
1117           function profile.first: refacildam;
1118               var lkg  :  reflinkage;
1119               begin  lkg := head.first;  first := @lkg^;  end;
1120
1121
1122        {.................AREA METHODS.....................................}
1123
1124           function area.first: refinstallation;
1125               var lkg  :  reflinkage;
1126               begin  lkg := head.first;  first := @lkg^;  end;
1127
1128
1129           procedure area.build(d : refdamage);
1130                var
1131                   fn     :  text;
1132                   valid  :  boolean;
1133                   fyle   :   string[20];
1134                   iobuf  :  string[80];
1135                   inst   :  refinstallation;
1136                begin
1137                write(' enter filename of target installations --> ');
1138                readln(fyle); assign(fn, fyle); reset(fn);
1139                while not eof(fn) do
```

```
1140                    begin
1141                    readln(fn,iobuf);
1142                    new(inst,init(d,iobuf,valid));
1143                    if not valid then
1144                       writeln('..no ref-install for ',iobuf:40)
1145                       { dispose(inst) }
1146                       else
1147                       inst^.into(@self);
1148                    end;
1149                 close(fn);
1150                 end;
1151
1152           procedure area.postmortem(nfacs,nprd,lenprd:integer;
1153                                     ftab:refcatcodelist;mask:string);
1154              var
1155              target :  refinstallation;
1156              begin
1157              target := first; write('#');
1158              while target <> nil do
1159                 begin
1160                 if (pos(target^.nation,mask) > 0 ) or (mask[1] = '*') then
1161                   target^.pmd(nfacs,nprd,lenprd,ftab);
1162                 target := target^.next;
1163                 end;
1164              end;
1165
1166           procedure area.dump;
1167              var c : refinstallation;cnt : integer;
1168              begin
1169              writeln('#Regional installations in priority order');
1170              c := first; cnt := 0;
1171              while c <> nil do
1172                begin
1173                cnt := cnt + 1;
1174                writeln('(',cnt:5,')  ',c^.name:30,' [Nat=',c^.nation,']  ',
1175                      c^.ref:15);
1176                c := c^.next;
1177                end;
1178              writeln;
1179              end;
1180
1181        {.................CATCODE METHODS.....................................}
1182
1183           constructor catcode.init(c,n:string);
1184              begin
1185              link.init;
1186              code := c; name := n;
1187              end;
1188
1189           function catcode.next: refcatcode;
1190               var lnk  :  reflink;
1191               begin  lnk := link.next;  next := @lnk^;  end;
1192
1193
1194
1195        {.................CATCODELIST METHODS.................................}
1196
1197           function catcodelist.first: refcatcode;
1198               var lkg  :  reflinkage;
1199               begin  lkg := head.first;  first := @lkg^;  end;
1200
1201
1202            function catcodelist.add(s:string) : refcatcode;
1203              var
1204              c1,c2 : refcatcode;
1205              cd    : string[4];
1206              begin
```

```
1207                    cd := copy(s,26,4);
1208                    if empty then
1209                       begin
1210                       c2 := new(refcatcode,init(cd,copy(s,3,20)));
1211                       c2^.into(@self);
1212                       add := c2;
1213                       end
1214                       else
1215                       begin
1216                       c1 := first;
1217                       while c1 <> nil do
1218                          begin
1219                          if c1^.code < cd then
1220                             begin
1221                             c1 := c1^.next;
1222                             if c1 = nil then
1223                                begin
1224                                c2 := new(refcatcode,init(cd,copy(s,3,20)));
1225                                c2^.into(@self);
1226                                add := c2;
1227                                end;
1228                             end
1229                             else
1230                             if c1^.code > cd then
1231                                begin
1232                                c2 := new(refcatcode,init(cd,copy(s,3,20)));
1233                                c2^.precede(c1);
1234                                add := c2;
1235                                c1 := nil;
1236                                end
1237                                else
1238                                begin
1239                                add := c1;
1240                                c1 := nil;
1241                                end;
1242                          end;
1243                       end;
1244                    end;
1245
1246                 procedure catcodelist.dump;
1247                    var c  :  refcatcode; cnt : integer;
1248                    begin
1249                    writeln('#REFERENCE JCS CATCODE LIST:');
1250                    c := first;
1251                    cnt := 0;
1252                    while c <> nil do
1253                       begin
1254                       cnt := cnt + 1; c^.repindx := cnt;
1255                       writeln('(',cnt:5,')  ',c^.code,'----',c^.name);
1256                       c := c^.next;
1257                       end;
1258                    end;
1259
1260           end.
```

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LAST PAGE OF APPENDIX C-2

APPENDIX C-3

DAMOC PROGRAM LISTING

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DAMOC PROGRAM LISTING

```
1   program damoc;
2
3   uses simsetx,commz,dos;
4
5
6   {==========DAMOC========== MAIN PROGRAM ================(8 MAY 91)==}
7
8
9   var
10     log                 :   text;
11     front               :   area;
12     dtable              :   refdamage;
13     instclass           :   refnotnlinst;
14     ftable              :   refcatcodelist;
15     facil               :   refcatcode;
16     btable              :   refplaces;
17     ttable              :   refthreatlist;
18     thrtgrp             :   refthreats;
19     itgt                :   refinstallation;
20     day,maxday          :   integer;
21     period,nperiod      :   integer;                { maxperiod <= 10 }
22     i,j,xt              :   integer;
23     maxfac,facindex     :   integer;                  { maxfac <= 75 }
24     avail,needs         :   real;
25     factor,factorsup    :   real;
26     double,sofrq        :   integer;
27     ssmfrq,sprsdays     :   integer;
28     reconst,reconstno   :   integer;
29     sorties             :   array [1..180,1..4] of real;  {maxday <= 180}
30     reportbl,totals     :   damrep;
31     rollup,rpis         :   inventory;
32     countries           :   string[10];
33     repinstal           :   boolean;
34     minutes             :   real;
35
36
37     procedure space;
38         begin
39         writeln('   Avail Memory (heap) = ',memavail);
40         end;
41
42
43     function elapsed(min:real):real;
44     var  h,m,s,s1  :  word;min2  :  real;
45     begin
46     gettime(h,m,s,s1);
47     min2 := (60.0*h + 1.0*m + s/60.0);
48     if min = 0 then
49        writeln(', time is ',h:2,':',m:2,':',s:2)
50        else
51        writeln('  [elapsed time is ',min2-min:7:3,' minutes]');
52     elapsed := min2;
53     end;
54
55  begin
56
57  {-----------------------------------------Scenario Definition------}
58
59  write(' heap memory =',memavail:10);
60  minutes := elapsed(0.0);
61  write('Enter the number of days in the scenario ->');
62       readln(maxday);
63  write('Select country codes ( a "*" means all included-->');
64       readln(countries);
65  write('Length of period (and report cycle) -->');
66       readln(period);
67       if (maxday/period) > 10 then
```

```
68              begin
69              writeln(' .. period maxday overflow.');
70              halt;
71              end;
72          write('Enter days of double sorties & suppression period-->');
73              readln(double,sprsdays);
74          write('Enter SOF & SSM frequencies ->');
75              readln(sofrq, ssmfrq);
76          write('Enter reconstitution period and number-->');
77              readln(reconst, reconstno);
78
79          {-----------------------------------------Table Construction-----.}
80
81          ftable := new(refcatcodelist,init);
82          btable := new(refplaces,init);
83          btable^.build;                      btable^.dump;
84          ttable := new(refthreatlist,init);
85          ttable^.build(btable);              ttable^.dump;
86          dtable := new(refdamage,init);
87          dtable^.build(ftable);
88             ftable^.dump;    maxfac := ftable^.cardinal;
89             dtable^.dump(maxfac);
90          front.init;
91          front.build(dtable);
92             front.dump;
93
94          assign(log,'sortie.log');rewrite(log);
95
96          {--------------------------------PARAMETERS & INITIALIZATION.......}
97
98          nperiod := 1;
99          if (pos('!',countries) > 0 ) then
100            repinstal := false
101            else
102            repinstal := true;
103
104         for i := 1 to maxfac do
105            begin
106            rollup[i] := 0.0;
107            rpis[i] := 0.0;
108            for j := 1 to 3 do
109               begin
110               totals[i,j] := 0.0;
111               reportbl[i,j] := 0.0;
112               end;
113            end;
114
115         itgt := front.first;
116            while itgt <> nil do
117               begin
118               if (pos(itgt^.nation,countries) > 0) or (countries[1] = '*') then
119                     begin
120                     itgt^.property(rpis);
121                     for i := 1 to maxfac do
122                        begin
123                        rollup[i] := rollup[i] + rpis[i];
124                        rpis[i] := 0.0;
125                        end;
126                     end;
127               itgt := itgt^.next;
128               end;
129
130         for i := 1 to nthrt do for j := 1 to maxday do sorties[j,i] := 0.0;
131
132         {..............start day by day simulation.....................}
133
134         for day := 1 to maxday do
```

```
135             begin
136             write('=====day(',day,')');minutes := elapsed(minutes);
137
138             {...attack process=========================================}
139
140             thrtgrp := ttable^.first;
141
142             while thrtgrp <> nil do
143                begin
144                xt := thrtgrp^.thrtype;
145                thrtgrp^.update(day,log);
146                case xt of
147          {ftr}
148                  1: if thrtgrp^.readyrate > 0 then
149                     begin
150                     avail := thrtgrp^.amount * thrtgrp^.readyrate
151                              * (1.0 - thrtgrp^.attrition);
152                     thrtgrp^.amount := (1.0 - thrtgrp^.attrition) * thrtgrp^.amount;
153                     if day <= double then
154                        begin
155                        avail := avail + thrtgrp^.amount * thrtgrp^.readyrate
156                                 * (1.0 - thrtgrp^.attrition);
157                        thrtgrp^.amount := (1.0 - thrtgrp^.attrition) * thrtgrp^.amount;
158                        end;
159                     if thrtgrp^.amount < thrtgrp^.minimum then
160                           thrtgrp^.amount := thrtgrp^.minimum;
161                     end
162                     else
163                     avail := 0;
164
165          {bmbr}
166                  2: if thrtgrp^.readyrate > 0 then
167                     begin
168                     avail := thrtgrp^.amount * thrtgrp^.readyrate
169                              * (1.0 - thrtgrp^.attrition);
170                     thrtgrp^.amount := (1.0 - thrtgrp^.attrition) * thrtgrp^.amount;
171                     if thrtgrp^.amount < thrtgrp^.minimum then
172                           thrtgrp^.amount := thrtgrp^.minimum;
173                     end
174                     else
175                     avail := 0;
176
177          {sof   days 1, 1+sofrq, 1+2*sofrq...}
178                  3: if (day mod sofrq = 1) and (thrtgrp^.readyrate > 0) then
179                        begin
180                        avail :=int(thrtgrp^.amount
181                                 * (1-thrtgrp^.readyrate)+0.5); {pre tgt attrit}
182                        thrtgrp^.amount :=int(avail *
183                              (1 - thrtgrp^.attrition)+0.5); {post tgt attrition}
184                        end
185                        else
186                        avail := 0.0;
187
188          {ssm}
189                  4: if (day mod ssmfrq = 1) and (thrtgrp^.readyrate > 0) then
190                        begin
191                        if thrtgrp^.amount > 0 then
192                           begin
193                           avail := int(thrtgrp^.amount*thrtgrp^.attrition+0.5);
194                           if avail > 0 then
195                              thrtgrp^.amount := thrtgrp^.amount - avail
196                              else
197                              if thrtgrp^.amount > 1 then
198                                 begin
199                                 avail := 1;
200                                 thrtgrp^.amount := thrtgrp^.amount - avail;
201                                 end
```

```
                                else
                                avail := 0.0;
                          end
                          else
                          avail := 0.0;
                       end
                       else
                       avail := 0.0;

                 else avail := 0.0;
              end;

              sorties[day,xt] := sorties[day,xt] + avail;
              if avail > 0 then
                 itgt := front.first
                 else
                 itgt := nil;
              while itgt <> nil do
                 begin
                 if thrtgrp^.reaches(itgt) then
                    itgt^.attack(avail,log,xt,day,nperiod,sprsdays,
                          thrtgrp^.name);
                 if avail <= 0 then
                    itgt := nil
                    else
                    itgt := itgt^.next;
                 end;
              writeln(log,'...[',day:2,']...',thrtgrp^.name,
                                    ' - unused ',avail:5:1);
              thrtgrp := thrtgrp^.next;
              end {xt loop};

           {.................report process.................................}

              if ((day mod period) = 0) or (day = maxday) then
                 begin
                 itgt := front.first;
                 while itgt <> nil do
                    begin
                    if (pos(itgt^.nation,countries) > 0) or (countries[1] = '*') then
                       begin
                       itgt^.pdreport(nperiod,day,maxfac,reportbl);
                       end;
                    itgt := itgt^.next;
                    end;
                 writeln;writeln('#Report for period ending day',day:3,' for countries
           ',countries);
                 facil := ftable^.first;
                 i := 0;
                 writeln;writeln('CatCode        Facility      ',
                     '    Onhand      Damage      Hits    Craters ');
                 writeln('-------   -------------------',
                     '  ----------  ----------  --------  --------');
                 while facil <> nil do
                    begin
                    i := i + 1;
                    write('[',facil^.code,'] ');
                    write(facil^.name:22);
                    write(rollup[i]:12:0);
                    write(reportbl[i,1]:12:1);
                    writeln(reportbl[i,2]:10:2,reportbl[i,3]:10:2 );
                    for j := 1 to 3 do
                       begin
                       totals[i,j] := totals[i,j] + reportbl[i,j];
                       reportbl[i,j] := 0.0;
                       end;
                    facil := facil^.next;
```

```
269                end;
270             end;
271
272          {.....Installation damage reconstitution process.....}
273
274             begin
275             if (day mod reconst) = 0 then
276                begin
277                if reconstno > 0 then
278                   begin
279                   reconstno := reconstno - 1;
280                   writeln('===installations reconstituted at day ',day:5);
281                   itgt := front.first;
282                   while itgt <> nil do
283                      begin
284                      itgt^.update(nperiod,day,((day mod reconst)= 0));
285                      itgt := itgt^.next;
286                      end;
287                   end
288                   else
289                   reconst := 999;
290                end;
291          {.....}
292
293             if  ((day mod period) = 0) then nperiod := nperiod + 1;
294             { writeln('---facility damage accumulated at day',day:5); }
295             end;
296
297          end {day loop};
298
299          {.............simulation portion completed.....................}
300
301          close(log);
302
303          writeln;writeln('#Summary Report for entire period (',day:4,
304                                  'days) for countries ',countries);
305          facil := ftable^.first;      i := 0;
306          writeln;writeln('CatCode        Facility      ',
307              '    Onhand      Damage      Hits    Craters ');
308          writeln('-------   -------------------',
309              '  ----------  ----------  --------  --------');
310          while facil <> nil do
311             begin
312             i := i + 1;
313             write('[',facil^.code,'] ');
314             write(facil^.name:22);
315             write(rollup[i]:12:0);
316             write(totals[i,1]:12:1);
317             writeln(totals[i,2]:10:2,totals[i,3]:10:2 );
318             facil := facil^.next;
319             end;
320          minutes := elapsed(minutes);
321
322          {.........................optional reports '!'.................}
323
324          if repinstal then
325             begin
326             front.postmortem(maxfac,nperiod-1,period,ftable,countries);
327             minutes := elapsed(minutes);
328             dtable^.breakout(nperiod-1);
329             minutes := elapsed(minutes);
330             end;
331
332          writeln;writeln('Sorties summary:.....');writeln;
333
334          for j := 1 to nthrt do
335             begin
```

```
336             write('(T=',j:1,')');
337             for i := 1 to maxday do
338                begin
339                write(sorties[i,j]:3:0);
340                if (i mod period) = 0 then write(' |');
341                end;
342             writeln;
343             end;
344
345          writeln;write(' heap memory =',memavail:10);minutes := elapsed(0.0);
346          end.
```

LAST PAGE OF APPENDIX C-3

Engineer Studies Center	A THREAT-BASED THEATER WAR DAMAGE METHODOLOGY	STUDY GIST CEESC-R-91-20

PRINCIPAL FINDINGS: Among the most difficult tasks confronting engineer and logistics planners is estimating war damage to infrastructure and installation facilities. The U.S. Army Engineer Studies Center (ESC) has been wrestling with this problem since the late 1970s while analyzing engineer requirements under various operational plans. The early assessments used different approaches to estimating war damage. The lack of uniformity and inability to reuse these disparate approaches prompted ESC to develop a general damage methodology that has the following advantages:

- *Threat-Based*: Damage is purposely constrained to the capability of threat forces. Damage from threat fighter, bomber, surface-to-surface missiles, and special operations forces can be assessed. Various operational attributes are also identified (e.g., range, ordnance load, readiness).

- *Scenario-Dependent*: The methodology requires that all installation targets and applicable enemy bases, or origins, be identified. While not a combat model, it can emulate changes in the theater disposition by varying attrition and readiness rates, as well as threat redeployments. These data would correspond to guidance from intelligence sources, operational plans, or wargamed results.

- *Detailed Results*: Results are calculated at installation/facility level. While rollup reports on user-defined time periods and installation groupings are available, the user can modify the software and access or portray even more detailed data.

- *Accessible and Adaptable*: ESC's implementation uses software that can run on any PC-compatible microcomputer. This makes the methodology as universally available as possible. Furthermore, the threat-dependent theater portion of the methodology employs an object-oriented model that greatly facilitates extensibility if additional features are desired.

SCOPE OF THE STUDY: The study consists of a main paper and three annexes. The main portion describes the rationale, assumptions, and operational features. (The methodology is essentially two-phased: the first requires the use of a detailed damage assessment computer program; the second utilizes a theater damage model developed by ESC.) The annexes document the input, output, and internal code of the theater model.

REPORT OBJECTIVE: The purpose of this document is to describe the background and features of ESC's threat-based war damage methodology, define data requirements, and present examples of input and output. A secondary objective is to promote the transfer and distribution of the methodology to defense organizations concerned with the problem.

BASIC APPROACH: ESC's objective was to develop a reasonable and reproducible, threat-based system to estimate facility damage across a theater. A two-phased approach evolved. A detailed installation-level damage model is used to generate a library of attack results (damage profiles). The

library is then one input to the deterministic theater damage assessment model, along with scenario specific information regarding threat capability and targets. The assessment model is more an allocation than an explicit damage model since its purpose is to distribute threat assets among theater targets according to defined target priorities, mission requirements, and sortie constraints. Damage is calculated by referencing the appropriate entry in the profile library. Therefore, it is not necessary to repeat the calculations already made in the detailed damage model. Theater damage thus becomes a process of allocating missions against identified targets or classes of targets and assessing the expected damage associated with that allotment.

REASONS FOR PERFORMING THE STUDY: In addition to their mission of constructing and maintaining the theater sustainment base, engineers are responsible for repairing or replacing facilities that are damaged. Planning for the expected amount and kinds of repair, however, is confounded by the vagaries of war. Theater wargames typically ignore most rear area installations, or estimate rear area damage in such broad (or parochial) terms as to be useless for repair estimates. Separate installation-level programs exist that model the effect of individually-targeted munitions and the resulting direct and collateral facility damage. But such programs usually examine one attack against one installation, and are too cumbersome and detailed to be useful at theater-level. ESC has developed a methodology that builds on the capabilities of these detailed installation-level models. An approach was formulated that utilizes the output of these high resolution models, the best available intelligence, and the estimates of theater-level enemy capability to project damage by facility, installation, and time. Having succeeded in implementing this approach, ESC sought to document the methodology and publicize its availability.

STUDY SPONSOR: Deputy Director for Plans and Resources, J-4, Joint Chiefs of Staff.

PERFORMING ORGANIZATION AND PRINCIPAL AUTHORS: The study was prepared by the U.S. Army Engineer Studies Center. The principal author was Robert Halayko.

DTIC ACCESSION NUMBER OF FINAL STUDY: Pending.

COMMENTS AND SUGGESTIONS MAY BE SENT TO: Commander, U.S. Army Engineer Studies Center, Casey Building #2594, Fort Belvoir, Virginia 22060-5583.

START AND COMPLETION DATES OF STUDY: Starting Date: January 1991
Completion Date: June 1991