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DNA 5350F-3

PRELAUNCH SURVIVABILITY OF GROUND LAUNCHED CRUISE MISSILE (GLCM)

Volume III – SAVAGE Code Version 1.0 User's Guide

Ship Systems, Incorporated
11750 Sorrento Valley Road
San Diego, California 92121

20 June 1980

Final Report for Period 1 July 1979—20 June 1980

CONTRACT No. DNA 001-79-C-0415

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20061130088

Prepared for
Director
DEFENSE NUCLEAR AGENCY
Washington, D. C. 20305

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER DNA 5350F-3	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) PRELAUNCH SURVIVABILITY OF THE GROUND LAUNCHED CRUISE MISSILE (GLCM) Volume III—SAVAGE Code Version 1.0 User's Guide		5. TYPE OF REPORT & PERIOD COVERED Final Report for Period 1 Jul 79—20 Jun 80 6. PERFORMING ORG. REPORT NUMBER SSI-80-203(S)
7. AUTHOR(s) Gary G. Erickson, John F. Brown George E. Jacobssen, Jr., Edwin M. Crow Kenneth G. Hamilton, Fletcher B. Maddox		8. CONTRACT OR GRANT NUMBER(s) DNA 001-79-C-0415
9. PERFORMING ORGANIZATION NAME AND ADDRESS Ship Systems, Incorporated 11750 Sorrento Valley Road San Diego, California 92121		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS A99QAXFA105-06
11. CONTROLLING OFFICE NAME AND ADDRESS Director Defense Nuclear Agency Washington, D.C. 20305		12. REPORT DATE 20 Jun 1980 13. NUMBER OF PAGES 58
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This work sponsored by the Defense Nuclear Agency under RDT&E RMSS Code B390079465 A99QAXFA10506 H2590D.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

SAVAGE (Survivability and Vulnerability Assessment of GLMC Elements)
User's Manual

Deterministic Computer Program	FORTRAN	Weapons
User-Specified Input	Structure	Geography
Dispersal Site Analysis	Vehicles	Graphics

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This manual represents an unclassified user handbook for the SAVAGE (Survivability and Vulnerability Assessment of GLCM Elements) deterministic computer program. The manual represents Volume III of a three volume set; Volume I details the data base that was developed to support SAVAGE, while Volume II addresses the architecture and modeling included in SAVAGE.

7. AUTHOR(s) Continued

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Brian B. Dunne

Conversion factors for U.S. customary to metric (SI) units of measurement.

To Convert From	To	Multiply By
angstrom	meters (m)	1.000 000 X E -10
atmosphere (normal)	kilo pascal (kPa)	1.013 25 X E +2
bar	kilo pascal (kPa)	1.000 000 X E +2
barn	meter^2 (m^2)	1.000 000 X E -28
British thermal unit (thermochemical)	joule (J)	1.054 350 X E +3
calorie (thermochemical)	joule (J)	4.184 000
cal (thermochemical)/cm^2	mega joule/m^2 (MJ/m^2)	4.184 000 X E -2
curie	*giga becquerel (GBq)	3.700 000 X E +1
degree (angle)	radian (rad)	1.745 329 X E -2
degree Fahrenheit	degree kelvin (K)	$t_K = (t^\circ f + 459.67)/1.8$
electron volt	joule (J)	1.602 19 X E -19
erg	joule (J)	1.000 000 X E -7
erg/second	watt (W)	1.000 000 X E -7
foot	meter (m)	3.048 000 X E -1
foot-pound-force	joule (J)	1.355 818
gallon (U.S. liquid)	meter^3 (m^3)	3.785 412 X E -3
inch	meter (m)	2.540 000 X E -2
jerk	joule (J)	1.000 000 X E +9
joule/kilogram (J/kg) (radiation dose absorbed)	Gray (Gy)	1.000 000
kilotons	terajoules	4.183
kip (1000 lbf)	newton (N)	4.448 222 X E +3
kip/inch^2 (ksi)	kilo pascal (kPa)	6.894 757 X E +3
ktap	newton-second/m^2 (N-s/m^2)	1.000 000 X E +2
micron	meter (m)	1.000 000 X E -6
mil	meter (m)	2.540 000 X E -5
mile (international)	meter (m)	1.609 344 X E +3
ounce	kilogram (kg)	2.834 952 X E -2
pound-force (lbs avoirdupois)	newton (N)	4.448 222
pound-force inch	newton-meter (N·m)	1.129 848 X E -1
pound-force/inch	newton/meter (N/m)	1.751 268 X E +2
pound-force/foot^2	kilo pascal (kPa)	4.788 026 X E -2
pound-force/inch^2 (psi)	kilo pascal (kPa)	6.894 757
pound-mass (lbm avoirdupois)	kilogram (kg)	4.535 924 X E -1
pound-mass-foot^2 (moment of inertia)	kilogram-meter^2 (kg·m^2)	4.214 011 X E -2
pound-mass/foot^3	kilogram/meter^3 (kg/m^3)	1.601 846 X E +1
rad (radiation dose absorbed)	**Gray (Gy)	1.000 000 X E -2
roentgen	coulomb/kilogram (C/kg)	2.579 760 X E -4
shake	second (s)	1.000 000 X E -8
slug	kilogram (kg)	1.459 390 X E +1
torr (mm Hg, 0° C)	kilo pascal (kPa)	1.333 22 X E -1

*The becquerel (Bq) is the SI unit of radioactivity; 1 Bq = 1 event/s.
**The Gray (Gy) is the SI unit of absorbed radiation.

A more complete listing of conversions may be found in "Metric Practice Guide E 380-74," American Society for Testing and Materials.

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SECTION 1

INTRODUCTION

1.1 MANUAL OBJECTIVES

This document describes the useage of the SAVAGE (Survivability and Vulnerability Assessment of GLCM Elements) code, version 1.0, under the Control Data Corporation NOS/BE 1 Operating System. It is intended to be an unclassified quick-reference guide, and also for tutorial use.

1.2 INTENDED AUDIENCE

The manual is intended for use by personnel coming in direct contact with the SAVAGE program, including programmers and analysts. SAVAGE is written predominantly in Fortran; while a knowledge of that language would be helpful, it is not a requirement for the use of the code. Persons intending to modify or extend the databases must be familiar with the NOS/BE Intercom Text Editor, or other software product which performs the equivalent function.

1.3 ASSOCIATED DOCUMENTS

The numerical algorithms used in SAVAGE are derived in Volume II of this set, "Prelaunch Survivability of the Ground-Launched Cruise Missile (GLCM)," Volume II - SAVAGE Computer Simulation Program", SSI Corporation. In addition, Volume II also contains classified identifications of specific weapons types and potentially sensitive geographical information.

Other documents of interest include the following:

a. "NOS/BE Version 1 Reference Manual," Control Data Corporation Manual Number 60497800.

b. "Fortran Extended Version 4 Reference Manual," Control Data Corporation Manual Number 60497800.

c. "Intercom Version 4 Reference Manual," Control Data Corporation Manual Number 60494600.

SECTION 2

PURPOSE AND STRUCTURE

SAVAGE is a large modular, deterministic computer program which has been constructed according to top-down design principles to assist in the study of the survivability of ground convoys, specifically those associated with the Ground-Launched Cruise Missile (GLCM).

It is assumed that the weapons system being studied is deployed in three stages.

a. Initially, the system is located inside shelters on a Main Operating Base (MOB) in GLCM Weapon Storage Areas (WSA).

b. Following a command, the wheeled vehicles drive out onto the highways and surface streets, form convoys, and disperse, with each military unit taking a different route.

c. Eventually, each of the convoys reaches a unique field position, where it attempts to conceal itself in order to evade destruction by hostile forces.

The SAVAGE program models the movement of one such unit from the MOB to its hidden field location; for a missile-carrying system, this latter point is often called the Dispersed Launch Site (DLS) or Covert Field Firing Position (CFFP). The three phases are shown symbolically in Figure 1.

In order to achieve its purpose, SAVAGE is portioned into a large number of subroutine models, as can be seen in the partial organizational chart, Figure 2. The five logical program phases should be considered from left to right.

In the "Input Phase," the program first calls subroutine INCARD, which obtains user-specified data from the input stream. This would be a part of the card deck, in an over-the-counter batch run. The data is specified in the form of one Hollerith header card, plus a NAMELIST group IND. Complete specifications can be found in Section 6 of this document.

Following the acquisition of the user-specified data, the Input Phase continues with subroutine INFILE, which controls the three subsidiary routines INFIL1Ø, INFIL11, and INFIL12, which read database information from Fortran logical units 1Ø, 11, and 12, respectively. Table 1 provides an overview of the information in these files which, by historical CDC convention are known to the program as TAPE1Ø, TAPE 11, and TAPE 12, even though they normally reside on disk.

The types of information in the databases are described more fully in Sections 3, 4, and 5.

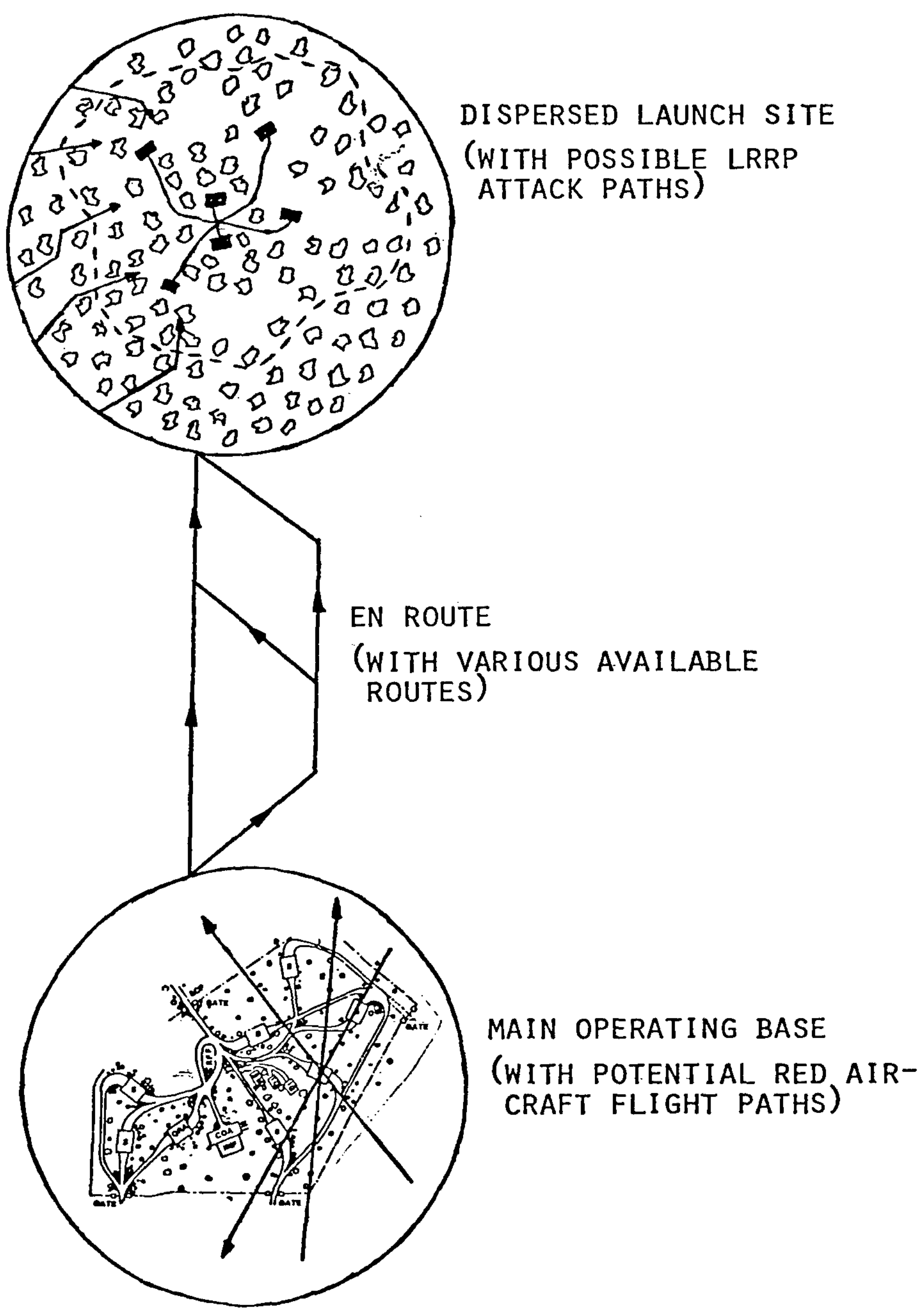

Figure 1. A schematic of the SAVAGE computer program ability to compute the GLCM PLS at various locations involved in the operational concept.

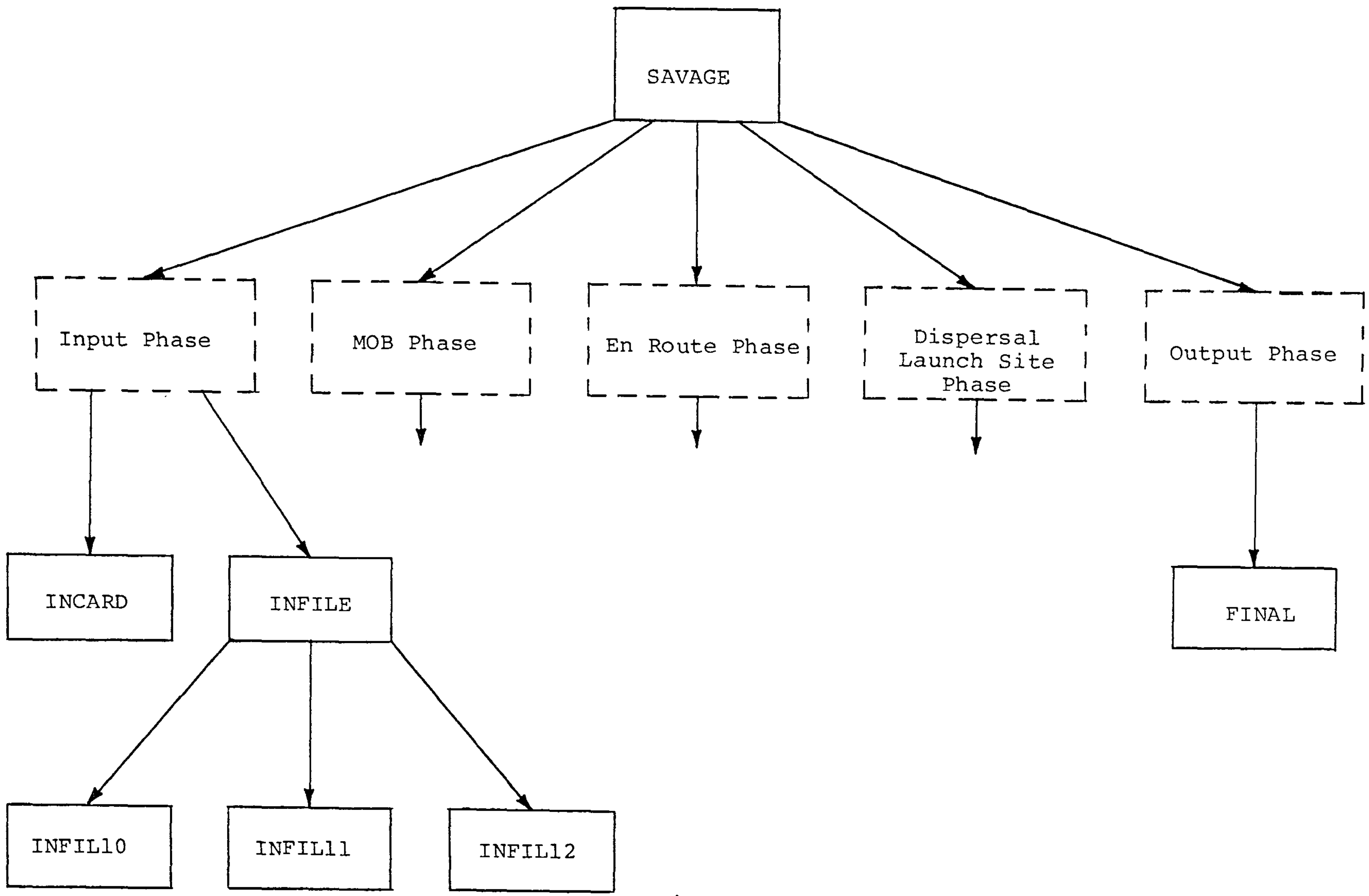

Figure 2. General structural overview of the SAVAGE code. Refer to Figures 3, 4, and 5 for detail of central three phases.

Table 1. An outline of the information stored in the SAVAGE data base.

- LOGICAL UNIT TAPE1Ø - VEHICLE DESCRIPTIONS
  - DIMENSIONS
  - SPEEDS ON VARIOUS ROAD TYPES
  - VULNERABILITY RATINGS
  - TARGET TYPES
- LOGICAL UNIT TAPE11 - WEAPON DESCRIPTIONS
  - STRAFING
  - AIR-TO-SURFACE ROCKETS
  - HE BOMBS
  - CONCRETE PENETRATORS
  - CLUSTER BOMB UNITS
  - CBR WEAPONS
  - INCENDIARIES
  - NUCLEAR WEAPONS
  - SURFACE-TO-SURFACE MISSILES
- LOGICAL UNIT TAPE12 - GEOGRAPHICAL DESCRIPTIONS
  - MOB DATA
  - NODES
  - SEGMENTS
  - WEATHER

Continuing in Figure 2, to the "MOB Phase" (which is shown in detail in Figure 3), the calculation consists of several stages at a fixed time interval (usually something like ten minutes). For each of these steps, subroutine EDIT is called to print a heading. This is followed by subroutines WEATHER (for calculations involving environmental considerations) and RADIO (which evaluates communications factors). Subroutine ATKMOB then directs the computation of weapon effects during air and missile attacks; the only threats which are deemed serious are from air-delivered penetrator bombs (subroutine AIRPEN), and missile-delivered Chemical-Biological-Radiological (SSMCBR) and nuclear (SSMNUC) weapons.

The nuclear attacks involve calculation of peak overpressure (NUCOPR), neutron flux (NUCNEU), and fission-fragment (NUCFFG) and secondary (NUCSCG) gamma radiation, as well as thermal deposition (NUCTHR).

Under certain conditions, a CBR attack against the WSA can leave sufficient residual agent concentrations to delay the departure of the convoy from its shelters until some cleanup is effected. If this occurs, then the time-stepping continues into the added delay period.

Next in Figure 2 is the "En Route Phase" (greater detail of which is shown in Figure 4), as the convoy makes its way down the road towards its destination. This phase is defined as the period after the selected GLCM flight leaves its shelter at the WSA. The phase includes the time at the convoy formation area which is treated as a special segment of the road segment network. As will be described in Section 5, the road network is broken down into segments, each one being typically a few kilometers in length. Travel from segment to segment can be regarded as time-stepping with unequal interval lengths, and so the subroutines in Figure 4 are repeatedly executed for segment after segment until the convoy arrives at its objective. Special time delays are introduced for the period at the convoy formation area and for flash blindness due to nuclear attack.

The subroutines involved include LOCATE (which moves the calculation to the next segment), SOFENR (for calculation of the results of unconventional warfare attacks), ATKENR (the controlling routine for air and missile attacks), and PERSIS (which accumulates persistent explosive data). The subroutines directed by ATKENR are: AIRSTR (strafing), AIRASR (air-to-surface rockets), AIRHEB (high explosive bombs), AIRCBU (cluster bomb units), AIRCBR (air delivered chemical-biological-radiological weapons), AIRCND (air delivered incendiaries), SSMCBR (missile-delivered CBR), and SSMNUC (nuclear-armed ballistic missiles). It should be noted that a serious attempt has been made to systemize the acroynms, e.g., AIR implies aircraft delivered while SSM implies Surface-to-Surface Missiles.

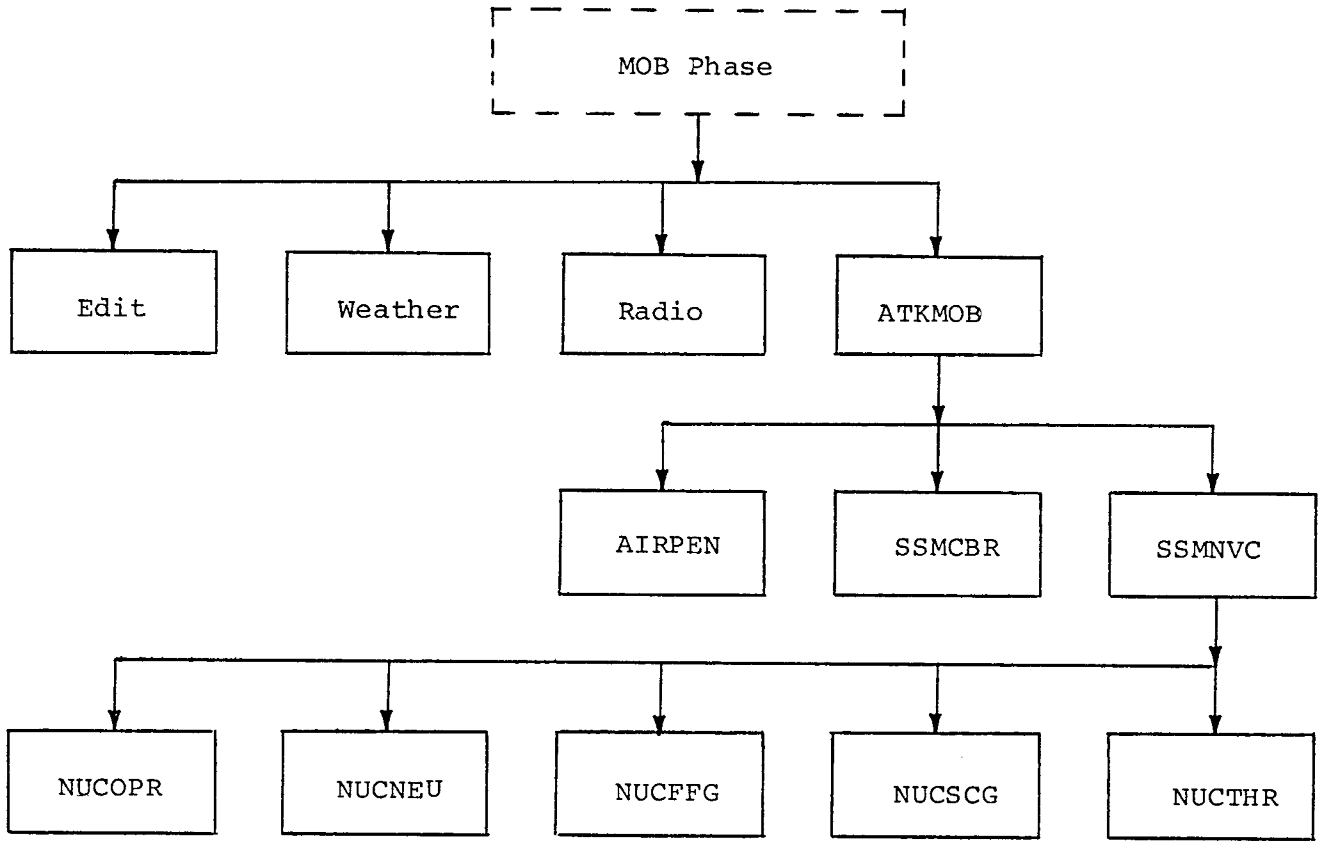

Figure 3. Detail of the MOB phase of SAVAGE.

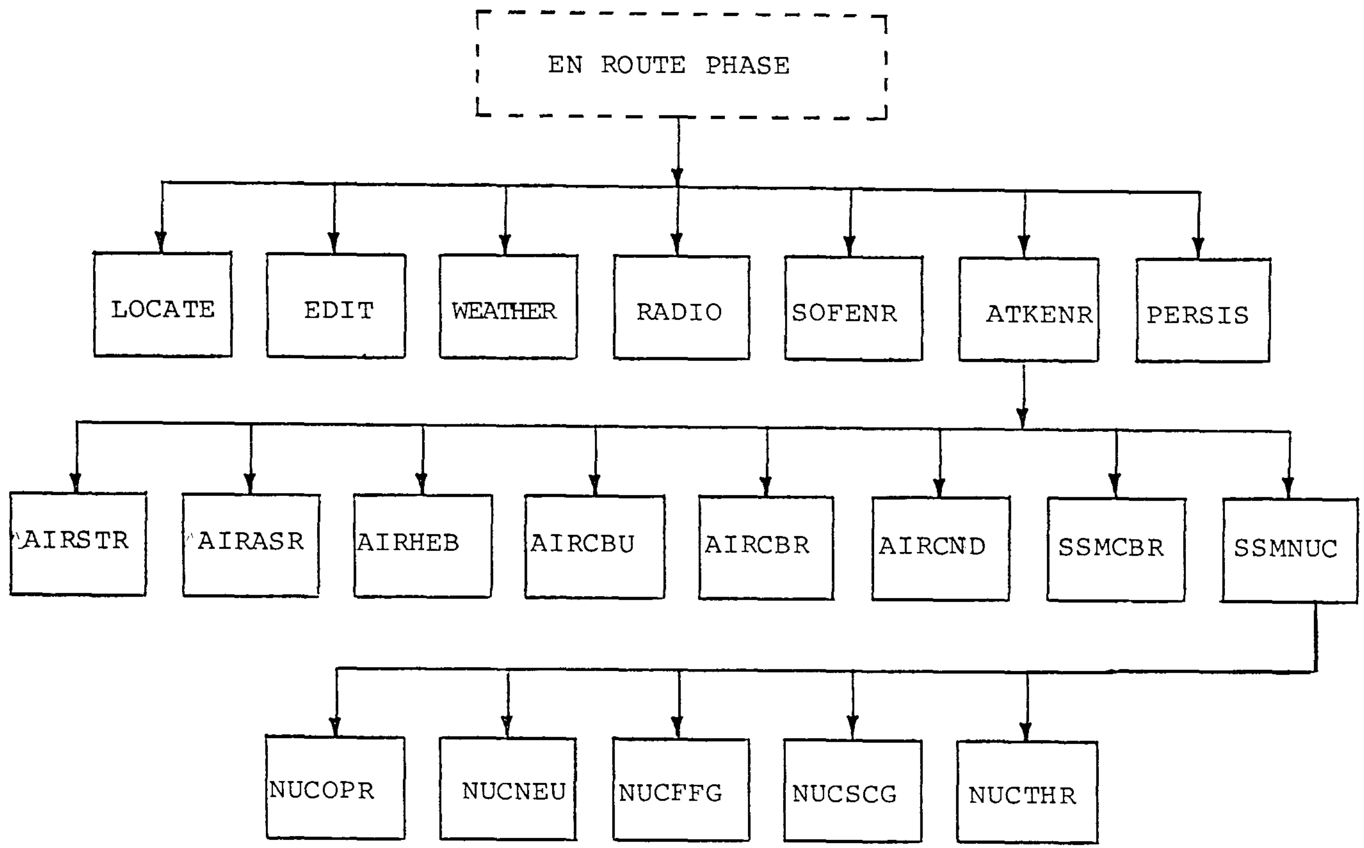

Figure 4. Detail of the en route phase of SAVAGE.

After the completion of the En Route Phase, the convoy enters the Dispersed Launch Site Phase (Figures 2 and 5). Air and missile attacks can still occur at this time, where they are controlled subroutine ATKDLS, but the treatment of the unconventional warfare threat is more severe, and is directed by subroutine SOFDLS.

Most of the communication between subroutines in SAVAGE is done through named common blocks, with each block being devoted to a particular category of data. A list of the principal common blocks is given in Table 2. As a consequence of this design scheme, the program becomes modular in data, as well as in instructions.

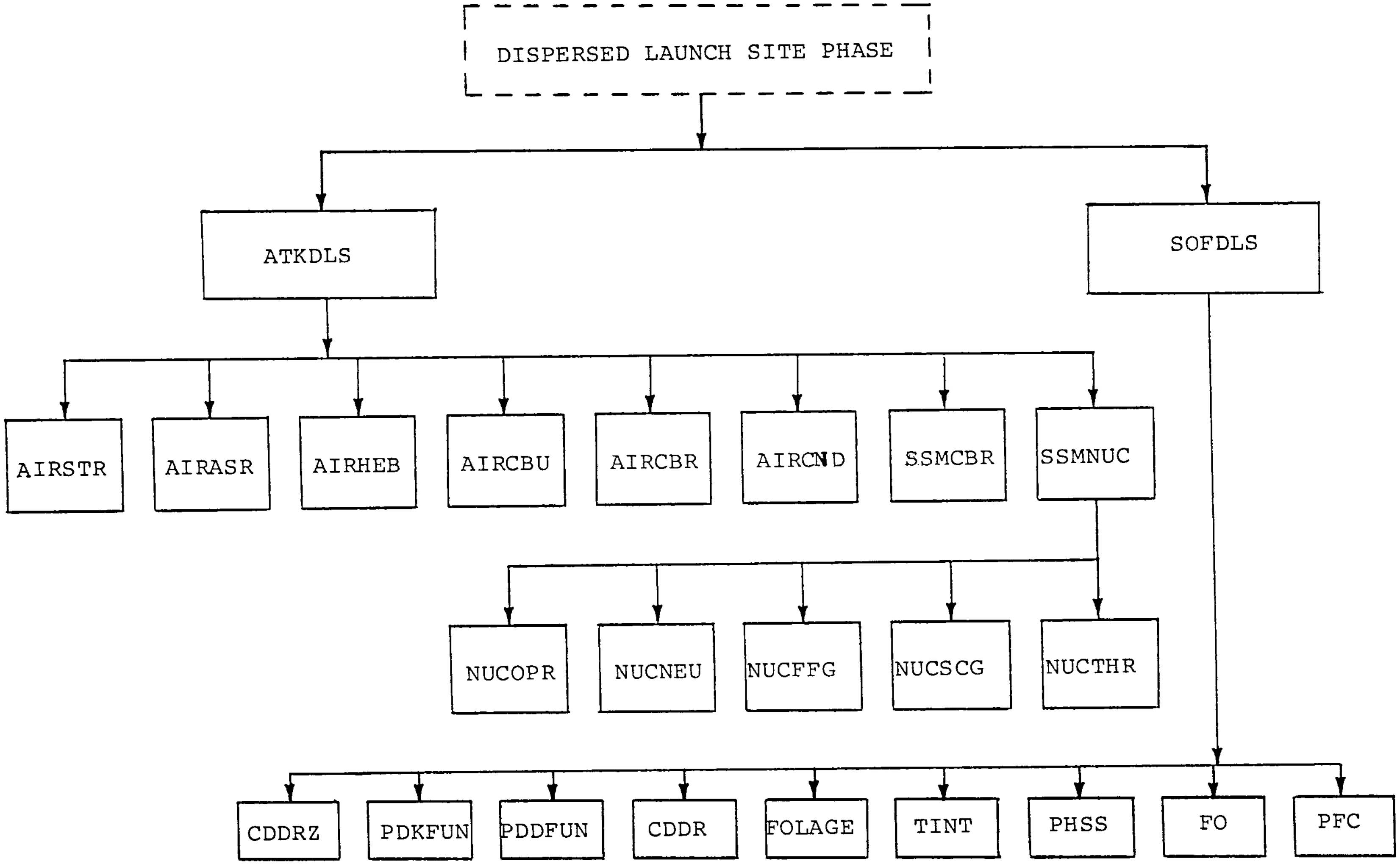

Figure 5. Detail of the Dispersed Launch Site Phase of SAVAGE.

Table 2. Principal common blocks of the SAVAGE computer program.

//	BLANK COMMON CONTAINS OVERVIEW INFORMATION
/BUF/	SCRATCH ARRAYS
/CON/	MATHEMATICAL CONSTANTS
/ENR/	ROUTE DESCRIBED BY NODES AND SEGMENTS
/FAL/	FALLOUT DATA
/MOB/	DESCRIPTION OF MAIN OPERATING BASE
/RSL/	SURVIVABILITY RESULTS
/VEH/	VEHICLE DESCRIPTIONS
/WPN/	WEAPON DESCRIPTIONS
/WTH/	WEATHER INFORMATION
/DIS/	DISPERSAL SITE INFORMATION
/OUTBACK/	EXTENDED CORE AREA

SECTION 3

TAPE 1Ø: VEHICLES

The SAVAGE program reads formatted records from Fortran logical file 1Ø, through subroutine INFILE1Ø. The CDC Operating System expects this file to have the local file name of TAPE 1Ø, as would be the case, for example, if the cataloged file VEH was assigned by the control card.

ATTACH, TAPE 1Ø, VEH, ID = ...

File 1Ø is expected to contain data describing, for each significant vehicle in the convoy, the following parameters.

LEN	length (in meters of the vehicle
WID	width
HGT	height
SPD1	maximum speed (km/hr) on highways and primary roads
SPD2	maximum speed on secondary roads
SPD3	maximum speed off road
SPD4	maximum speed on trails
TGT	target type; this is related to weapons data to be described in Section 4
HDS	coded vulnerability fractions for the side of the vehicle
HDT	" " " " " top " " "
HDF	" " " " " front " " "
HDR	" " " " " rear " " "
NAME	alphanumeric identification of the vehicle

The vulnerability fractions are compressed decimal numbers; each data word actually contains six pieces of information. Within the SAVAGE code, six types of kill are defined:

K-kill, complete loss of vehicle,
M-kill, deprivation of mobility,
F-kill, suppression of firepower,
E-kill, destruction electronics,
P-kill, death of personnel, and
I-kill, incapacitation of personnel.

A coded vulnerability parameter is composed of 12 decimal digits and, as shown in Figure 6, this can be separated into six two-digit fields. Each of those two-digit fields represents the percent probability that a particular type of kill will occur if a bullet enters through a specified side of the vehicle. These percentages can be arrived at by examining side, top, front,

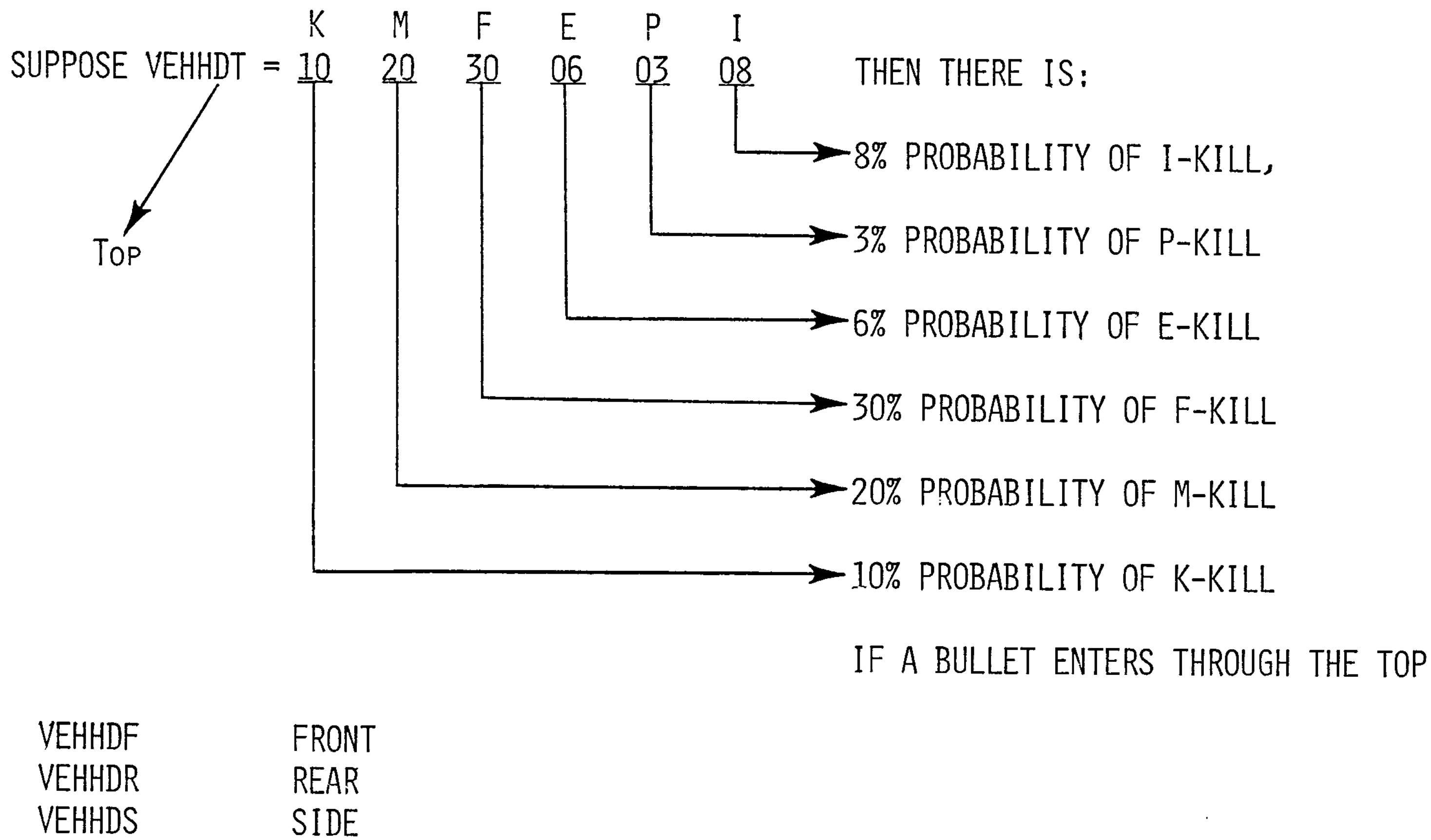

Figure 6. Coded vulnerability parameters.

and rear views of the vehicle and calculating the ratio of the vulnerable area to the total presented area.

The code echoes the data which it reads to the printer; a sample is shown in Figure 7.

VEHICLE DESCRIPTIONS

I	LEN	WID	HGT	SPD1	SPD2	SPD3	SPD4	IGT	HDS	HDI	HDF	HDR	NAME
1	16.80	2.40	2.60	46.00	32.20	14.80	20.90	6	1030200510	1030300308	0850052030	0820500507	T
2	16.80	2.40	2.60	46.00	32.20	14.80	20.90	7	1030000510	1030300409	0850002030	0820000810	L
3	16.80	2.40	2.60	46.00	32.20	14.80	20.90	6	1030200510	1030300308	0850052030	0820500507	T
4	16.80	2.40	2.60	46.00	32.20	14.80	20.90	6	1030200510	1030300308	0850052030	0820500507	T
5	16.80	2.40	2.60	46.00	32.20	14.80	20.90	7	1030000510	1030300409	0850002030	0820000810	L
6	16.80	2.40	2.60	46.00	32.20	14.80	20.90	6	1030200510	1030300308	0850052030	0820500507	T

Figure 7. Contents of file TAPE 1Ø, as echoed by SAVAGE.

SECTION 4

TAPE 11: WEAPONS

The Fortran logical file 11 is expected by SAVAGE to contain formatted data describing the weapons available to the hostile forces, and the delivery methods.

There are eight basic weapons types defined in SAVAGE. They are:

a. Strafing,
b. Air-to-surface rockets,
c. High explosive bombs,
d. Penetrator bombs,
e. Cluster bomb units,
f. CBR agents
g. Incendiaries,
h. Nuclear weapons.

As a matter of nomenclature, the word "weapon" is often used in SAVAGE to denote a group of munitions which are dispensed simultaneously. Thus, a stick of bombs is a weapon, rather than a single bomb, and a burst of gunfire is regarded as a weapon, instead of an individual bullet.

Each weapon is defined by a set of parameters, including weapon class, label, reliability, group quantity, and effectiveness rating against various target types.

The weapons class is a number which tells the code which algorithm to use in calculating the effects of an attack. Strafing attacks fall into class 100, rocket pods in class 200, HE bombs class 300, and so forth, in the same order as the list which was given above. The last two digits of the weapons class can be varied to provide a means of distinguishing subclasses. For example, class 600 refers to air-delivered CBR agents, while class 601 designates agents which are delivered by surface-to-surface ballistic missile.

Each weapon is also assigned a label known as LWPN. This can be thought of as being similar to a part number: it has no significance other than as a way of pointing to a particular piece of hardware. The use of this parameter will be described later in this section.

A reliability value, between 0 and 1 is also specified in the data file. Every weapon has an alphanumeric name, which can be used as a memory aid.

The code echoes the weapons data that it finds on TAPE 11: Figure 8 is an example, showing four kinds of HE bombs, "Habit," "Headline," "Hinge," and "Horde". As can be seen from the CLS column, they are all of class 300

HIGH EXPLOSIVE BOMBS

IC	I	CLS	LWPN	REL	QI	CEPV	CEPR	TGT	GK	GM	GF	GP	GI	NAME
1	2	300	310	.950	10.0	20.0	40.0	1	0.00000	0.00000	0.00000	0.00000	0.00000	HABIT
								2	0.00000	0.00000	0.00000	0.00000	0.00000	
								3	0.00000	0.00000	0.00000	0.00000	0.00000	
								4	0.00000	0.00000	0.00000	0.00000	0.00000	
								5	0.00000	0.00000	0.00000	0.00000	0.00000	
								6	.17830	.06613	.06613	.17830	.06613	
								7	.17830	.06614	0.00000	.17830	.06613	
								8	0.00000	0.00000	0.00000	0.00000	0.00000	
								9	0.00000	0.00000	0.00000	0.00000	0.00000	
								10	0.00000	0.00000	0.00000	0.00000	0.00000	
2	3	300	320	.950	10.0	20.0	40.0	1	0.00000	0.00000	0.00000	0.00000	0.00000	HEADLINE
								2	0.00000	0.00000	0.00000	0.00000	0.00000	
								3	0.00000	0.00000	0.00000	0.00000	0.00000	
								4	0.00000	0.00000	0.00000	0.00000	0.00000	
								5	0.00000	0.00000	0.00000	0.00000	0.00000	
								6	.14154	.05755	.05755	.14154	.05755	
								7	.14154	.05755	0.00000	.14154	.05747	
								8	0.00000	0.00000	0.00000	0.00000	0.00000	
								9	0.00000	0.00000	0.00000	0.00000	0.00000	
								10	0.00000	0.00000	0.00000	0.00000	0.00000	
3	4	300	330	.900	6.0	20.0	40.0	1	0.00000	0.00000	0.00000	0.00000	0.00000	HINGE
								2	0.00000	0.00000	0.00000	0.00000	0.00000	
								3	0.00000	0.00000	0.00000	0.00000	0.00000	
								4	0.00000	0.00000	0.00000	0.00000	0.00000	
								5	0.00000	0.00000	0.00000	0.00000	0.00000	
								6	.10628	.04164	.04164	.10628	.04164	
								7	.10628	.04164	0.00000	.10628	.04164	
								8	0.00000	0.00000	0.00000	0.00000	0.00000	
								9	0.00000	0.00000	0.00000	0.00000	0.00000	
								10	0.00000	0.00000	0.00000	0.00000	0.00000	
4	5	300	340	.900	3.0	20.0	40.0	1	0.00000	0.00000	0.00000	0.00000	0.00000	HORDE
								2	0.00000	0.00000	0.00000	0.00000	0.00000	
								3	0.00000	0.00000	0.00000	0.00000	0.00000	
								4	0.00000	0.00000	0.00000	0.00000	0.00000	
								5	0.00000	0.00000	0.00000	0.00000	0.00000	
								6	.09708	.03388	.03388	.09708	.03388	
								7	.09708	.03388	0.00000	.09708	.03388	
								8	0.00000	0.00000	0.00000	0.00000	0.00000	
								9	0.00000	0.00000	0.00000	0.00000	0.00000	
								10	0.00000	0.00000	0.00000	0.00000	0.00000	

Figure 8. Sample data for HE bombs, as extracted from the data base by SAVAGE.

but they have unique LWFN labels. They have reliability (REL) factors of 90% and 95%, and the QI column displays the quantity of individual munitions in the stick.

Each HE bomb has 60 γ-values associated with it, in the form of a matrix of six kill types (k, M, F, E, P and I) and ten target (TGT) types. The γ-values are used to parameterize the probability of kill versus distance curve,

$$P_k(r) = \exp(-\gamma^2 r^2) \tag{1}$$

which is assumed when a bomb lands a distance r away from a target element. As can be seen, there are nonzero γ-values only for target types 6 and 7; it will be recalled that the vehicles which were shown in Figure 7 had these target type numbers. Thus, to calculate, for example, K-kills against the first vehicle (which was TGT=7), the code will use Equation (1) with γ=0.17830.

Air-to-surface rockets, CBUs, and Incendaries use a similar logical structure.

A pair of Concrete Penetrators are shown in Figure 9, as repeated by the code, after being read from TAPE 11. Penetrators are of class 400, and they are used here in sticks of QI=4 or 2. In this case, a penetration factor (FAC) is all that is needed, one for each target type. The target types TGT=1 and 2 will be used to represent, respectively, a standard GLCM Protective Shelter, and a QRA Shelter. The penetration factor is used by the code as the probability of kill, given a hit. As can be seen, "Parasol" is given a 10% chance of knocking out a standard shelter.

Nuclear weapons are defined by their design type (which is put in the least significant two digits of the weapons class), and by yield and fission fraction. Figure 10 list two such devices. "Nereid" is a 250-kt, 50% fission weapon of design type 8.

Two types of chemical weapons are shown in Figure 11. "Katydid" is of weapon class 600, and contains 300 kg (QØ) of an agent whose Median Lethal Dose (LD5Ø) for inhalation is 75 mg-min/m^3, with a Median Incapacitation Dose (ID5Ø) of 3 mg-min/m^3. It is an air-delivered stick of two bombs, which are intended to be dropped 100 meters upwind (UPW), with a crosswind spacing (DY) of 25 meters. It has a diffusivity (D) of 1 m^2/sec, and forms a layer with vertical thickness (H) of 10 meters. The parameter G does not apply to air-delivered bombs.

CBR weapon "Keitloa," in Figure 11 is of class 601. This is distinct from class 600, in that Keitloa is a ballistic missile warhead filled with liquid agent and intended for an air burst. Following the burst, the 350 kg of agent in this weapon falls to earth as "rain". Under these circimstances,

PENETRATOR BOMBS

IC	I	CLS	LWPN	REL	QI	CEPV	CEPR	TGT	FAC	NAME
1	6	400	410	.900	4.0	20.0	40.0	1	.10000	PARASOL
								2	.08000	
								3	0.00000	
								4	0.00000	
								5	0.00000	
								6	0.00000	
								7	0.00000	
								8	0.00000	
								9	0.00000	
								10	0.00000	
2	7	400	420	.800	2.0	20.0	40.0	1	.20000	PENNANT
								2	.17000	
								3	1.00000	
								4	0.00000	
								5	0.00000	
								6	0.00000	
								7	0.00000	
								8	0.00000	
								9	0.00000	
								10	0.00000	

Figure 9. Concrete penetrator bombs.

IC	I	CLS	LWPN	REL	YIELD	FF	NAME
1	12	808	810	.980	250.000	.5000	NEREID
2	13	809	820	.980	1500.000	.1000	NEWSPEAK

Figure 10. Nuclear weapons.

CHEMICAL-BIOLOGICAL-RADIOLOGICAL WEAPONS

ID	I	CLS	LWPN	REL	QI	QD	LD50	ID50	UPW	DY	D	H	G	NAME
1	9	601	510	.900	2.0	1000.00	100.00	25.00	100.00	25.00	1.00	10.00	0.00	KATYDID
1	10	601	520	.950	1.0	1000.00	100.00	25.00	100.00	25.00	1.00	10.00	0.00	KEITLOA

Figure 11. Chemical-Biological-Radiological weapons.

area deposition density is the best measure of effectiveness, and so LD5Ø and ID5Ø are in units of mg/m^2. The factor G in this case is the particulate size distribution parameter, γ, which was used in the mathematical treatment of this problem in Section 2, Volume II.

Following the descriptions of weapons, TAPE 11 is expected to have definitions of aircraft and missiles. Sample aircraft data can be seen in Figure 12. Each type of airplane is given its own unique label, LACF (which is used by the user to request an attack by a particular model of aircraft), and each has an alphanumeric name.

The third column of the Aircraft Descriptions is LWPNP; this is a pointer which indicates what type of ordnance is carried by the airplane. For example. the LACF=30 "Agate" carries weapon type LWPNP = 320; from Figure 8, it is possible to see that LWPN = 320 is the HE bomb stick known as "Headline". Since, in Figure 12, QWPN = 2, it is possible to tell that "Agate" is loaded with two sticks of ten bombs each.

It is assumed that when aircraft are sent out on armed reconnaissance, they will have to search for their targets. They will be able to examine a strip of Search Width SW = 6 km, at Search Speed SS = 500 km/hr. If they locate a target, they will attack from altitude HGT = 2500 ft (in the case of "Agate",) and will dispense their ordnance at a dive angle of DIV = 30 degrees. The Circular Error Probable during visual deliveries is CEPV, and during radar deliveried it is CEPR.

Figure 13 shows three types of hostile ballistic missiles. Each is known by its label, LSSM, while the value LWHDP is a warhead pointer which should be equal to the LWPN value for either a chemical or nuclear bomb. QWHD is the number of warheads carried on the missile: clearly only "Minaret" has been MIRVID. If QWHD is greater than one, then RWHD is the radius of the impact footprint in kilometers. The multiple warheads are treated as though they land at equally-spaced intervals around a circle of this size.

The arrangement by which the weapon pointer LWPNP (or warhead pointer LWHDP) matches the label LWPN of a previously-defined weapon is a part of an elaborate data access scheme which is symbolically summarized in Figure 14. In it, the LWPNP points to the LWPN, and the user in turn will be able to ask for a particular aircraft type by using the input variable LACFP to point to the LACF which comes from TAPE 11. The variables which are shown in dashed boxes (IACFP, IACF, IWPNP, IWPN) are not normally visible or accessable to the user but are maintained for internal program purposes. This organization, which is basically an indirect addressing system, will be discussed further in Section 6.

AIRCRAFT DESCRIPTIONS

I	LACF	LWPNP	QWPN	SW	SS	NAME
1	10	110	3.00	6.00	500.00	ABSINTHE
2	30	320	2.00	6.00	500.00	AGATE
3	40	410	1.00	6.00	500.00	ADYTUM
4	50	510	5.00	6.00	500.00	AUK
5	60	610	2.00	6.00	500.00	ARCANE
6	70	710	2.00	6.00	500.00	APPIAN

Figure 12. Aircraft descriptions.

MISSILE DESCRIPTIONS

I	LSSM	LWHDP	NAME
1	61	620	MUSKET
2	80	810	MINARET
3	81	820	MIMOSA

Figure 13. Missile descriptions.

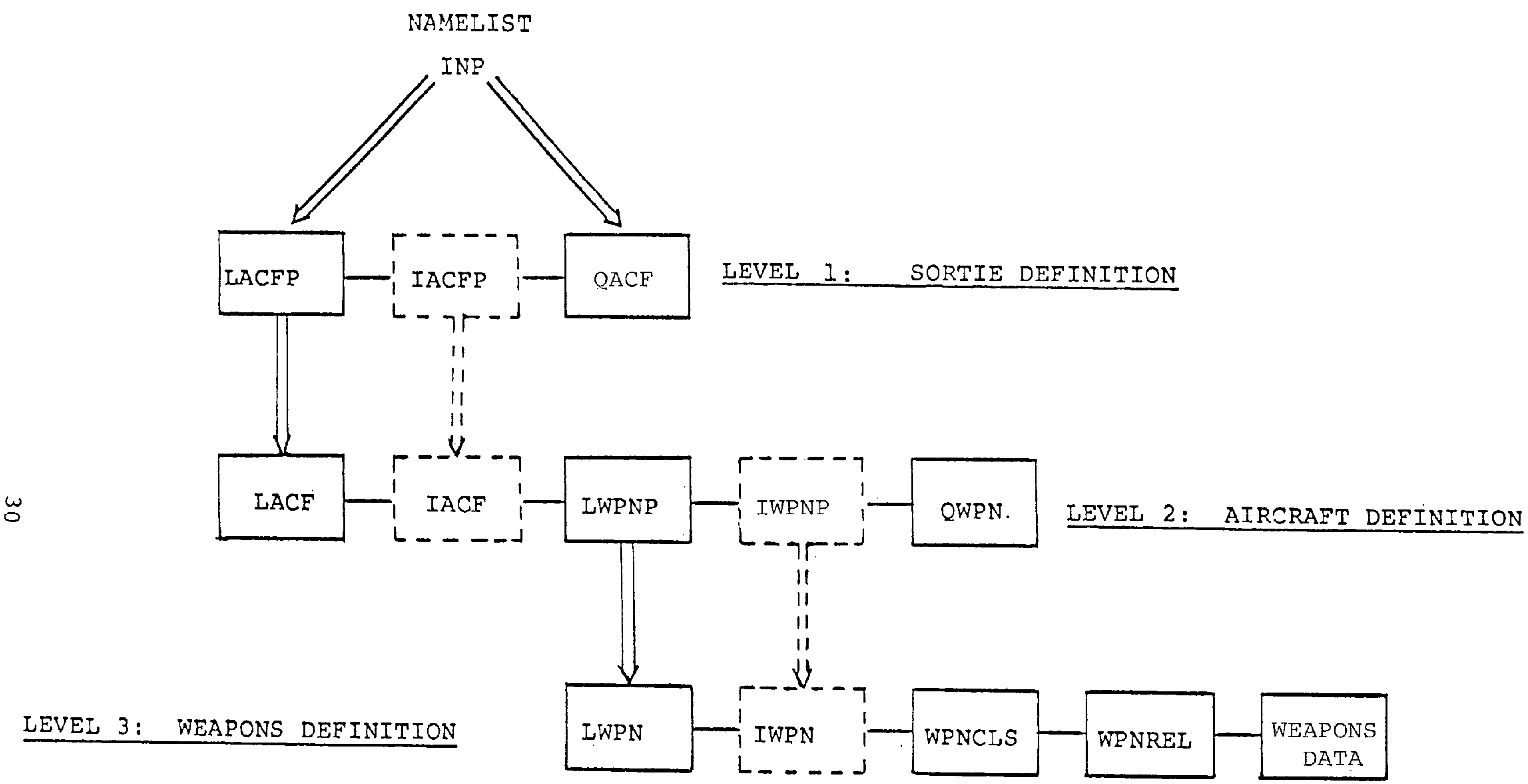

Figure 14. Indirect-addressing total retrieval system employed by SAVAGE for weapons description.

SECTION 5

TAPE 12: GEOGRAPHY

The Fortran logical file 12 contains information which is geographical in nature. The first section of the file contains data which describes the size, location, and orientation of the shelters in the WSA. Figure 15 is a sample of such data; for each of the eight buildings XBLG and YBLG are the coordinates of the buildings centroid, BLGANG is the angle which its longest side makes with North, and BLGLEN and BLGWID are its length and width. BLGTGT is the target type for the building; this is linked to the target types which were listed in Figure 9 for concrete penetrators.

After the shelter data, TAPE 12 has the xy-coordinates of a few points which define the corners of the peripheral fence. Given the information about the shelters, and the fence, it is possible to draw a picture of the WSA. SAVAGE does this automatically using a printer plot, and a sample is demonstrated in Figure 16.

Following the WSA data, TAPE 12 has two very large blocks of information which describes the route from WSA to Launch Site. This description is organized structurally in terms of nodes and segments.

As used by SAVAGE, a node is merely a point in space. Its only properties are its map coordinates, its altitude, an identifying number, and perhaps a name. Nodes are generally located at cross roads, or at places where a road changes direction or character.

Segments represent portions of the road system. A segment is anchored in space by specifying the identifying numbers of two nodes, one at either end of the segment. A number of parameters are associated with each segment, and these values form a description of the local characteristics, including potential threats and choke points, and the ease with which the segment can be degraded by such things as rain and snow. Each segment also has a surface type, which is used in the code to select which of the four vehicle speeds (from TAPE1Ø) is appropriate, depending on the degree of paving.

Figure 17 is a typical node-and-segment network. Most nodes have names, and all nodes have identifying four-digit numbers. Certain pairs of nodes are connected by road segments, each of which has a three-digit label number.

As an example, the route from Rose Canyon (node 1200) to Flynn Springs (node 2220) can be described as

-105, 101, 104, 201, 223, 224,

if segments are assumed to run from west to east, and south to north.

MAIN OPERATING BASE DESCRIPTION

I	XBLG	YBLG	BLGANG	BLGLEN	BLGWID	BLGTGT	NAMBLG
1	55.00	-40.00	300.00	48.78	26.22	1	S1
2	220.00	5.00	107.00	48.78	26.22	1	S2
3	150.00	65.00	63.00	48.78	26.22	1	S3
4	50.00	180.00	39.00	48.78	26.22	1	S4
5	-35.00	275.00	307.00	48.78	26.22	1	S5
6	-146.00	250.00	309.00	48.78	26.22	1	S6
7	-160.00	150.00	270.00	48.78	26.22	1	S7
8	-130.00	75.00	268.00	48.78	26.22	2	Q

Figure 15. Description of WSA, as echoed by SAVAGE.

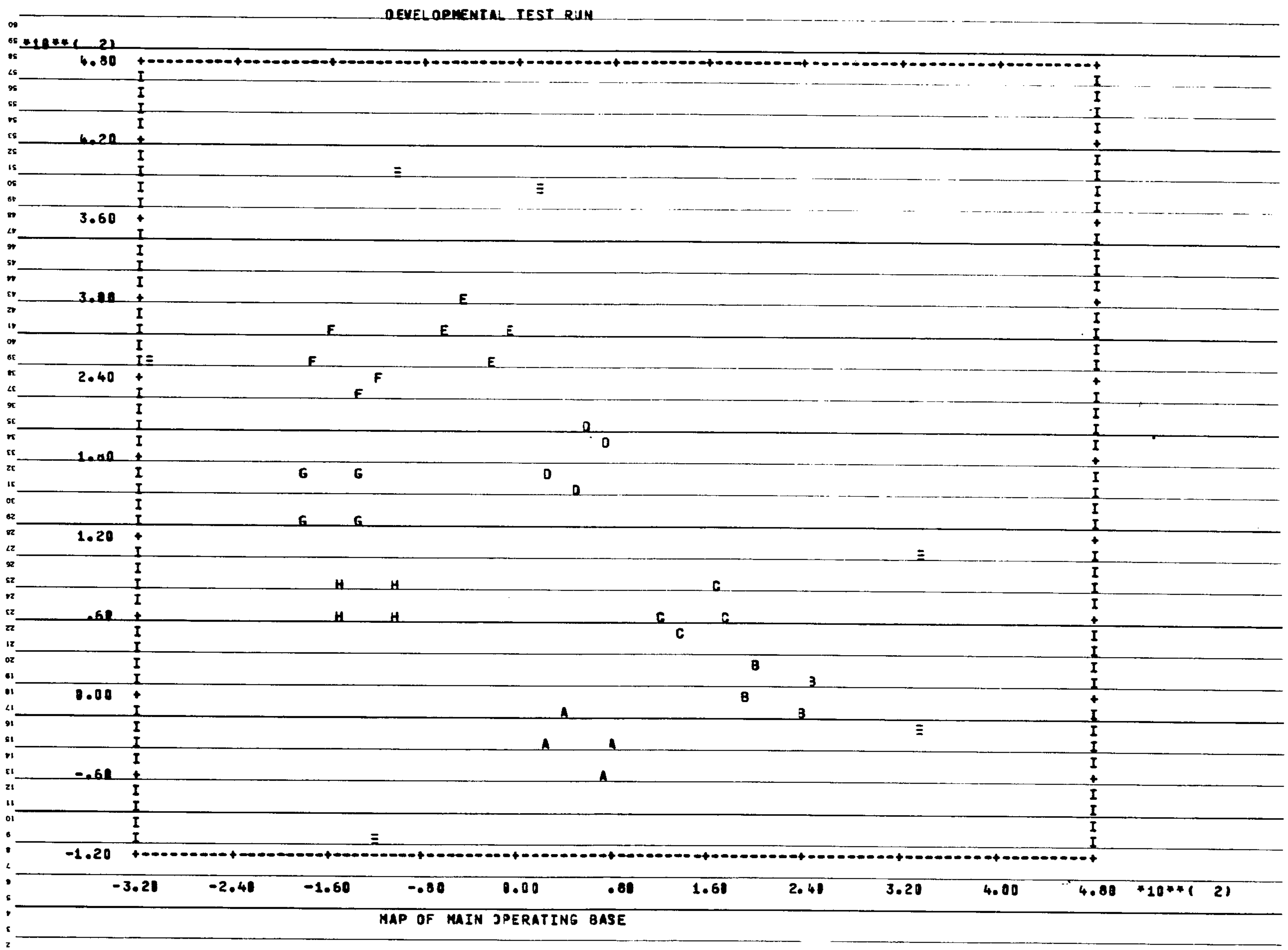

Figure 16. Map of main operating base.

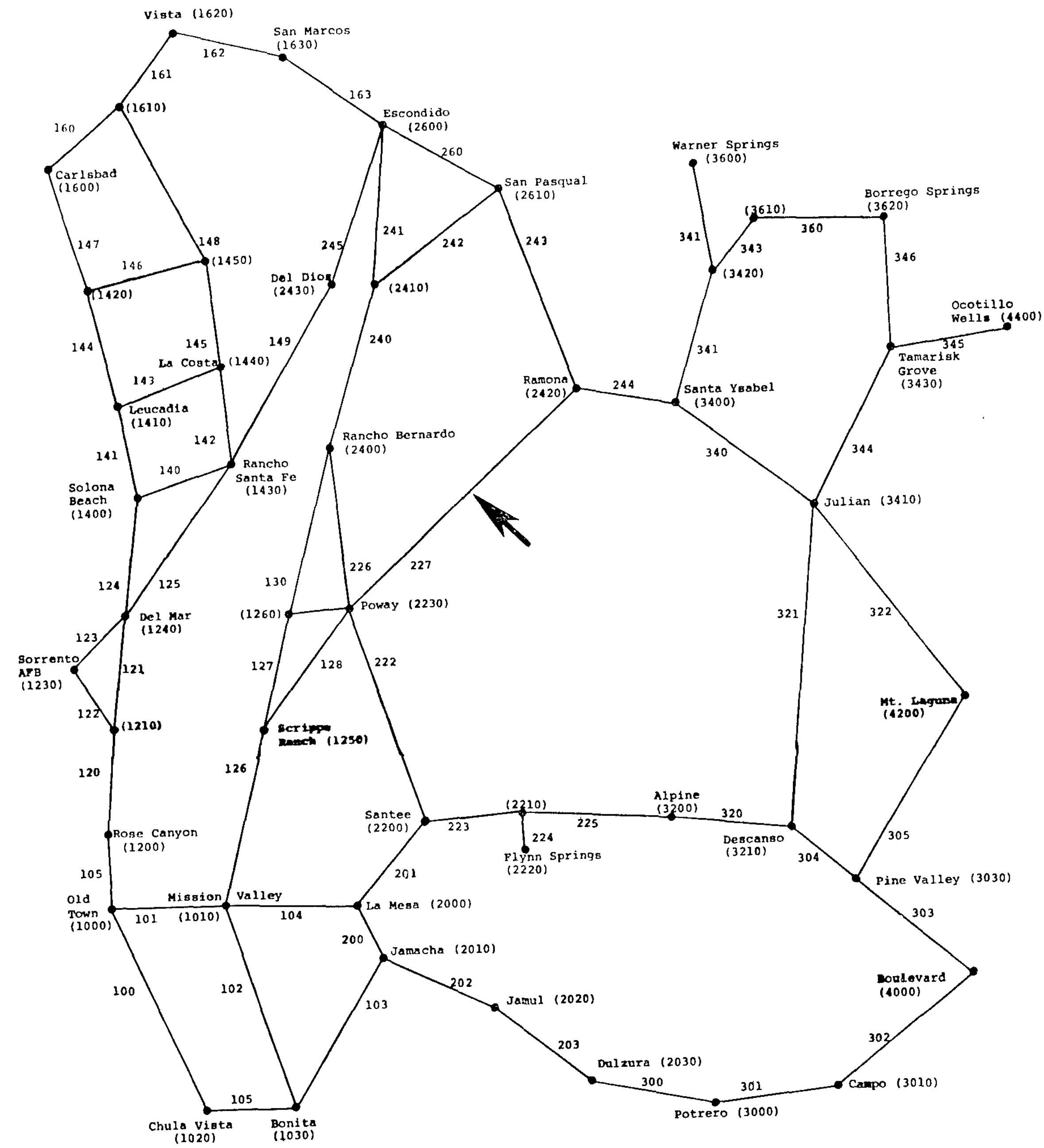

Figure 17. Sample node-and-segment geographical network. Node numbers are shown with parenthesis, segment number without. Segments are assumed to run from South to North and West to East; thus segment 227 runs from Poway to Ramona, but - 227 runs from Ramona to Poway. (This segment is indicated by an arrow.)

SECTION 6
USER-SPECIFIED INPUT

SAVAGE reads a relatively small amount of data from the standard input device - the card reader, or its queue file equivalent. Except for one title card of Hollerith information, all input uses the Fortran Namelist form, which allows the greatest ease of data entry.

As stated, the first card is used for a title. Any information can be put on this card, or it can be left blank, but one card image must be at this point in the input stream.

Following the title card, the program will expect the Namelist group INP; this will provide SAVAGE with its basic data requirements and also signal whether or not additional Namelist groups follow.

Table 3 lists the variables in Namelist INP, along with their properties and definitions. It must be noted that the arrays LFLT, LACFP, QACF, FLTTØ, and FLTT1 are isomorphic to each other. That is, the code expects the first element of LACFP to be associated with the first element of QACF, and the first of FLTTØ and FLTT1; they describe different factors of the same attack. Likewise, the second elements all go together, and the third ones, etc. The array LFLT is not used internally, but exists solely to allow the user to label the flights so that they can be more easily referred to.

There is no requirement that the attacks be in any chronological order; in other words, it is not an error to have FLTTØ(3) > FLTTØ(4). It is, however, necessary for FLTTØ(i) < FLTT1(i), for all values of i, or else the i^{th} attack will never take place.

Returning to Figure 14, it can be seen that the Namelist INP input provides a description of the attacking aircraft and weapons in an indirect way: the user-provided pointer LACFP indicates an aircraft type LACF, which is linked to a weapons pointer LWPNP, which in turn indicates a weapon type. The user need only provide the uppermost stratus of data, and the remainder is obtained by the program automatically.

The missile-attack arrays, LMSL, LSSMP, XYMSL, ZMSL, and TMSL have a similar relationship to each other as do the aircraft attack arrays. The variable XYMSL has been declared to be complex; this means that the x and y coordinates should appear together in parenthesis, separated by a comma.

All absolute times which are input to INP should be in military-style format, with four digits representing hours and minutes in a 24-hour clock. No decimal point or colon may be used. This rule applies to the variables TIME, FLTTØ, FLTT1, and TMSL, all of which are expected by the program to be integers.

Table 3. Variables in Namelist INP.

Variable Name	Variable Type	Dimension if array	Default Value	Definition
TIME	INTEGER	-	0	Starting time of simulation - military style (hhmm)
DATE	INTEGER	-	0	Date that simulation is to be for (mmdd)
ALAT	REAL	-	0	North latitude of geographical area (use negative for South)
LPATH	INTEGER	200	0	Ordered sequence of segment numbers from MOB to launch site.
NPMOB	INTEGER	-	0	Number of time steps to take on MOB (in WSA)
DTMOB	REAL	-	0	Size (minutes) of time steps to take on MOB
LSTP	INTEGER	10	0	Labels of segment on which convoy is to make scheduled stops
NPSTP	INTEGER	10	0	Number of steps to take on each of the stops
DTSTP	REAL	10	0	Size (minutes) of time steps to take on the stops
NPPLS	INTEGER	-	0	Number of steps to take at the Dispersed Launch Site
DTDLS	REAL	-	0	Time step at Launch Site
LFLT	INTEGER	10	0	Arbitrary numeric label for a flight of aircraft (optional)
LACFP	INTEGER	10	0	Pointer to aircraft type in attack; must refer to an LACF in TAPE 11.
QACF	REAL	10	0	Quantity of aircraft in the attack
FLTTØ	INTEGER	10	0	Starting time of attack aircraft over the Operational Area (military style)
FLTT1	INTEGER	10	0	Ending time of attack (military time)
LMSL	INTEGER	10	0	Arbitrary numeric label for a missile attack (optional)
LSSMP	INTEGER	10	0	Pointer to missile type; must refer to a SSM in TAPE 11.
ZMSL	REAL	10	0	Height of burst (meters) of missile attack
TMSL	INTEGER	10	0	Time of missile attack (military style)

Table 3. Variables in Namelist INP (Continued)

Variable Name	Variable Type	Dimension if array	Default Value	Definition
KBLG	INTEGER	-	1	Building number in WSA from which GLCM emerges
DLDR	REAL	30	0	Distance (meters) of each vehicle in convoy behind the leader
OA	REAL	-	10,000	Size (km^2) of GLCM operational area
WNDØØ	REAL	-	0	Wind speed (km/hr) at surface
WND1Ø	REAL	-	0	Wind speed (km/hr) at 10,000 feet altitude
WNDDIR	REAL	-	0	Wind direction (degees clockwise from North)
INCP	INTEGER	-	0	Flag: set $\neq$ 0 if radio data to be read (Namelist INPCQ)
INDSE	INTEGER	-	0	Flag: set $\neq$ 0 if protection factors to be read (Namelist INPDSE)
INSOF	INTEGER	-	0	Flag: set $\neq$ 0 if LRRP data to be read (Namelist INPSOF)

All relative times (DTMOB, DTSTP, and DTDLS) are expected to be real numbers, in units of minutes.

At the end of INP are three flags: ICQ, IPSE, and ISOF. These flags are normally zero by default, but if one or more is reset to one during the INP read, then that is a signal that SAVAGE should read one or more additional Namelist groups.

If ICQ≠0, then the program will attempt to read the Namelist group CQ immediately following INP. Table 4 lists the variable in CQ, all of which are related to communications factors.

If the flag IDSE≠0 after the reading of INP, then the program will attempt to read the Namelist group PSE, which will modify some of the factors associated with CBR and nuclear doseages. The variables are listed in Table 5. This Namelist group should follow CQ if the latter is present, or INP if not.

The flag ISOF, if set to be nonzero, will cause Namelist group SOF to be read. SOF contains variables which are involved in the calculation of the results of infiltration by hostile Special Operations Forces into the GLCM Dispersal Site. If this Namelist is present, it should follow DSE, or CQ (if DSE is not being supplied), or INP (if neither DSE or CQ are input). The variables in SOF are shown in Table 6. It should be noted that the variables DAFI, DBFI, NRI, NTHEAI, DELRI, NSI, and LSI are arrays whose subscripts indicate the angular region of the problem, and that equal subscripts on different arrays must go together.

Table 4. Variables in Namelist CQ.

Variable Name	Variable Type	Dimension if array	Default Value	Definition
XYVHF	COMPLEX	10	XYVHF(1) at MOB; others are zero	(x,y) coordinates of friendly VHF transmitters from which order can be received
WVHF	REAL	10	NVHF(1) = 10,000 others = 0	Power (watts) of VHF transmitters
XY HJ	COMPLEX	10	XYVHJ(1) is 100 km East of MOB; others are zero	(x,y) coordinates of hostile VHF jammers
WVHJ	REAL	10	WVHJ(1) = 10,000 others = 0	Power (watts) of VHF jammers
ZVHJ	REAL	10	0	Altitude (feet) of VHF jammers
QRN	REAL	-	1.E-7	Atmospheric background noise (volts/m)

Table 5. Variables in Namelist DSE.

Variable Name	Default Value	Definition
PTNCBR	10	Personnel protection factor against CBR agents
PTNOPR	10	" " " " " overpressure
PTNRAD	10	" " " " " direct ionizing radiation
PTNTHM	10	" " " " " thermal radiation
VEHOPRK	7	Overpressure (psi) necessary to give 50% chance of K-kill on a vehicle
VEHOPRM	5	" " " " " " " " " M-kill " " "
VEHOBRF	5	" " " " " " " " " F-kill " " "
VEHOPRE	5	" " " " " " " " " E-Kill " " "
VEHRADK	10,000	Ionizing radiation (rads) necessary to give 50% chance of K-kill on a vehicle
VEHRADM	10,000	" " " " " " " " " " M-kill " " "
VEHRADF	8,000	" " " " " " " " " " F-kill " " "
VEHRADE	4,000	" " " " " " " " " " E-kill " " "
VEHTHMK	1,000	Thermal radiation (cal/cm^2) " " " " " " K-kill " " "
VEHTHMM	100	" " " " " " " " " " M-kill " " "
VEHTHMF	100	" " " " " " " " " " F-kill " " "
VEHTHME	100	" " " " " " " " " " E-kill " " "

Table 6. Variables in Namelist SOF.

Variable Name	Variable Type	Dimension if array	Default Value	Definition
NOFT	INTEGER	-	1	Offense type (1 => RPG - 7, 2 => Satchel charge)
NODEG	INTEGER	-	10	Gaussian quadrature integration parameter
NDUT	INTEGER	-	1	Defense unit type (1 => Sentry, 2 => M60, 3 => HMMWV)
NAR	INTEGER	-	5	Number of angular boundaries
DTAU	REAL	-	1.0	Sentry scan time (seconds)
DAFI(I)	REAL	10	0.0	Degradation exponential constant for length scales in angular region I
DBFI(I)	REAL	10	1.0	Degradation exponential constant for length scales; modulates sun angle in angular region I
NRI(I)	INTEGER	10	5.0	Number of differential radii (meters) in angular region I
NTHEAI(I)	INTEGER	10	10	Number of differential angles in angular region I
DELRI(I)	REAL	10	20	Differential radius (meters) in angular region I
NSI(I)	INTEGER	10	50	Number of sensors in angular region I
LSI(I)	INTEGER	10	20	Length of sensors (meters) in angular region I
RDD(ND	REAL	10	1000	Maximum detection distance (meter) of defense unit ND
RDK(ND)	REAL	10	170 if NPUT=1 280 otherwise	Maximum hazardous range (meters) of defense unit ND
TOTSH(NF)	REAL	10	1	Total shots by offensive type NF
BURST(NF)	REAL	10	1	Burst length of shot by offensive type NF
ROD(NF)	REAL	10	100	Minimum distance (meters) for shooting by offensive type NF
ROB(NF)	REAL	10	500	Maximum distance (meters) for shooting by offensive type NF
VONF(NF)	REAL	10	0.2235	Average rate of advance (m/sec) of offensive type NF in grass field

SECTION 7

DISPERSAL SITE ANALYSIS

A representation used by SAVAGE of a generic dispersal site is shown in Figure 18. A description of the associate model may be found in Section 5, Volume I and the algorithms in Sections 1 and 2 of Volume II. Stored information regarding Figure 18 may be found in the common block/DIS/. As shown, SAVAGE partitions the generic site into five (NAR) principal angular regions (I). Forest and sensor boundaries are modeled by straight-line segments between end points (XFA, XFB for forests; XSA, XSB for sensors). Each angular regions (ATHETA) has an assigned foliage type (FOL) which affects the detectability (PDD) and kill probabilities (PDK), plus the rate of advance (VONF) of the attacking Special Operations Forces (SOF). Each angular region has: defenses (NDUT) of a specific type (NDUT, 1 = sentry, 2 = M60 post, 3 = High Mobility Miltipurpose Wheeled Vehicle (HMMWV)) and number (ND); 2) targets which are designated either TELs or LCCs have a specific number (NT), and assigned locations (TELX, TELY, LCCX, LCCY), 3) sensors, which have specific numbers (NSI) and lengths (LSI), 4) a distance degradation factor (RDM) to account for local effects (DAFI) (alertness, weather, etc.) and time of day (DBFI and ZETA), plus 5) a prescribed number of offensive types and weapons (NOFT).

Numerically, the user divides the angular region into sub angular regions (NTHEAI), and integrates along the distance R to the attacker in steps (NR). Each defense post has a probability of detecting (PDDFUN) and killing (PDKFUN) the offense. Along each ray, the offense has a certain probability to penetrate (PENT). (For satchel charge, and at the TEL or LCC's coordinates, this probability is equivalent to the probability of survival (PLSTEL, PLSLCC). At each step, the offense has a probability of killing a target (PHSS) utilizing a firing distribution (OFD). The product of PENT * PHSS * OFD is made and integrated along each step of the ray. This provides PLS TEL and PLSLCC as a function of a distance and angle grid. Integrating (TINT) over the grid provides an average PLS TEL and PLS LCC to an attack in the angular region.

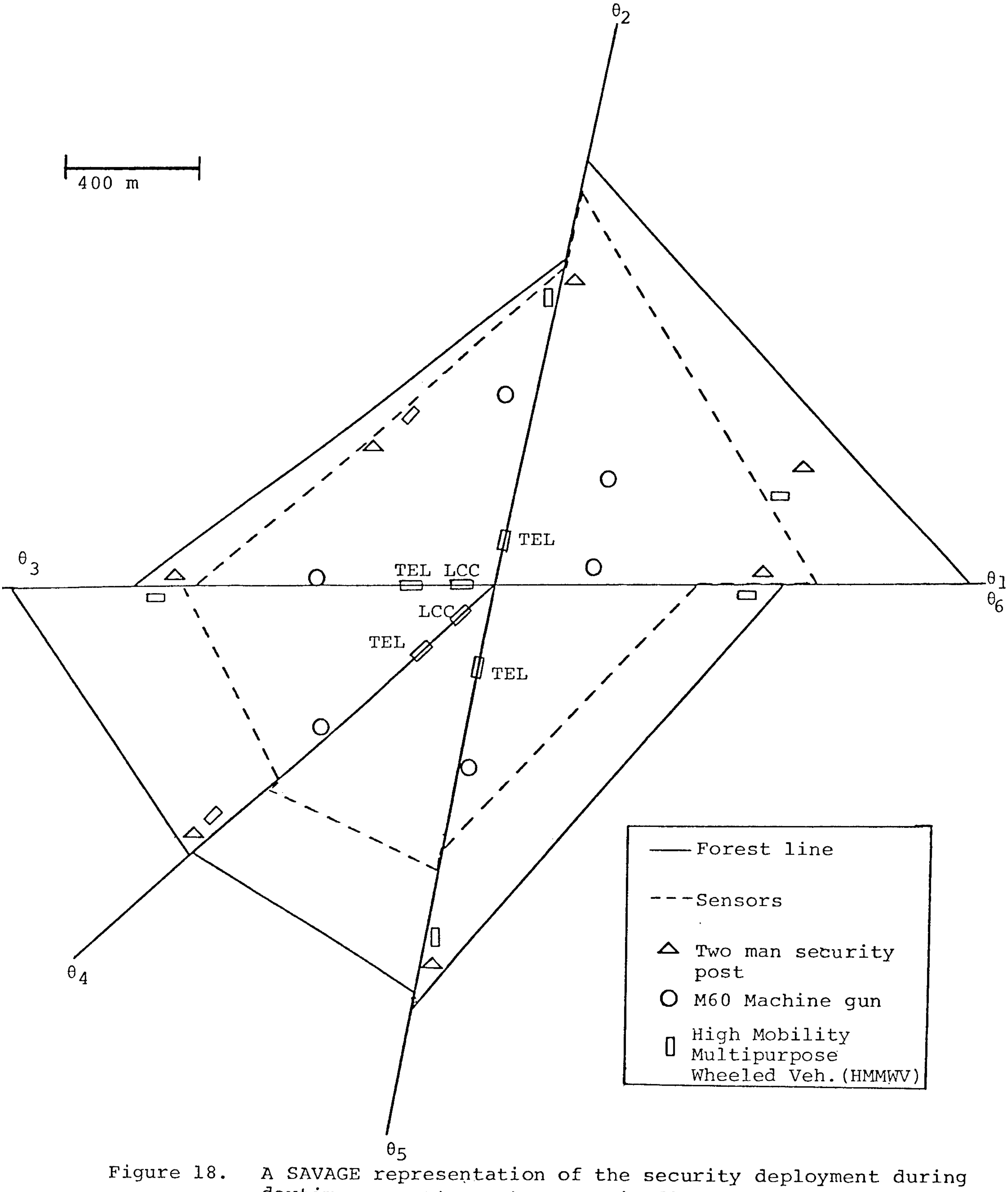

Figure 18. A SAVAGE representation of the security deployment during daytime operations at a generic dispersal site.

SECTION 8

SUPPORTIVE SAVAGE GRAPHICS

The SAVAGE graphics utilizes the integrated software plotting package called DISPLA which is at most large computer facilities. The actual plotting device may vary from facility to facility so a system consultant might be necessary to set up the required control cards at the beginning of the program. The DISSPLA package itself is device independent, but the SAVAGE graphics program MAP, which plots the dispersal route nodes and segments, must be used with a device that can plot over 30" in the horizontal direction. The device used in the development of the program was a Gould Electrostatic. If this device is available, it is recommended. The SAVAGE graphics program WSARD automatically scales the plot to fit within 8½ by 11 page borders, so almost any device will work. Because of the special device requirements of the graphic program MAP, it was thought best to keep MAP and WSARD as separate programs.

WSARD is designed to take the available data base from the main SAVAGE program and from it produce a high resolution graphic display to scale of the WSA buildings and perimeter fence. The WSARD program is self scaling, self labeling and adjusted to fit on an 8½ by 11 inch page. See Figure 19.

In addition to the data base of the SAVAGE program, a separate data file must be created for WSARD. This separate file contains the nodes and coordinates for the road networks on the WSA, since this information is not given in the SAVAGE data base. If this information is not necessary, a file simply containing two end-of-file statements is all that is required.

Using WSARD two files must be attached locally when running WSARD. The first file is the geographical data from the SAVAGE program. This must be attached locally as TAPE 3. These files are named WAXWORKS and UROADS if the United Kingdom data is being used or BITTER and NOROADS if the supplied West German data is used. (Note: NOROADS is a dummy file that enables WSARD to run without road network data. NOROADS can also be used with WAXWORKS if that version is desired without a road network.) In the program WSARD the line: CALL META: This is a specific system plot command and must be changed or removed as other computer facilities require.

MAP: MAP is the SAVAGE high resolution graphic program which produces a full length scale node and segment map of the dispersal route. When connected to the SAVAGE geographical data, MAP automatically adjusts the coordinate system so that the origin is located at the WSA and distances are measured in kilometers relative to the WSA. MAP is also self labeling, self scaling,

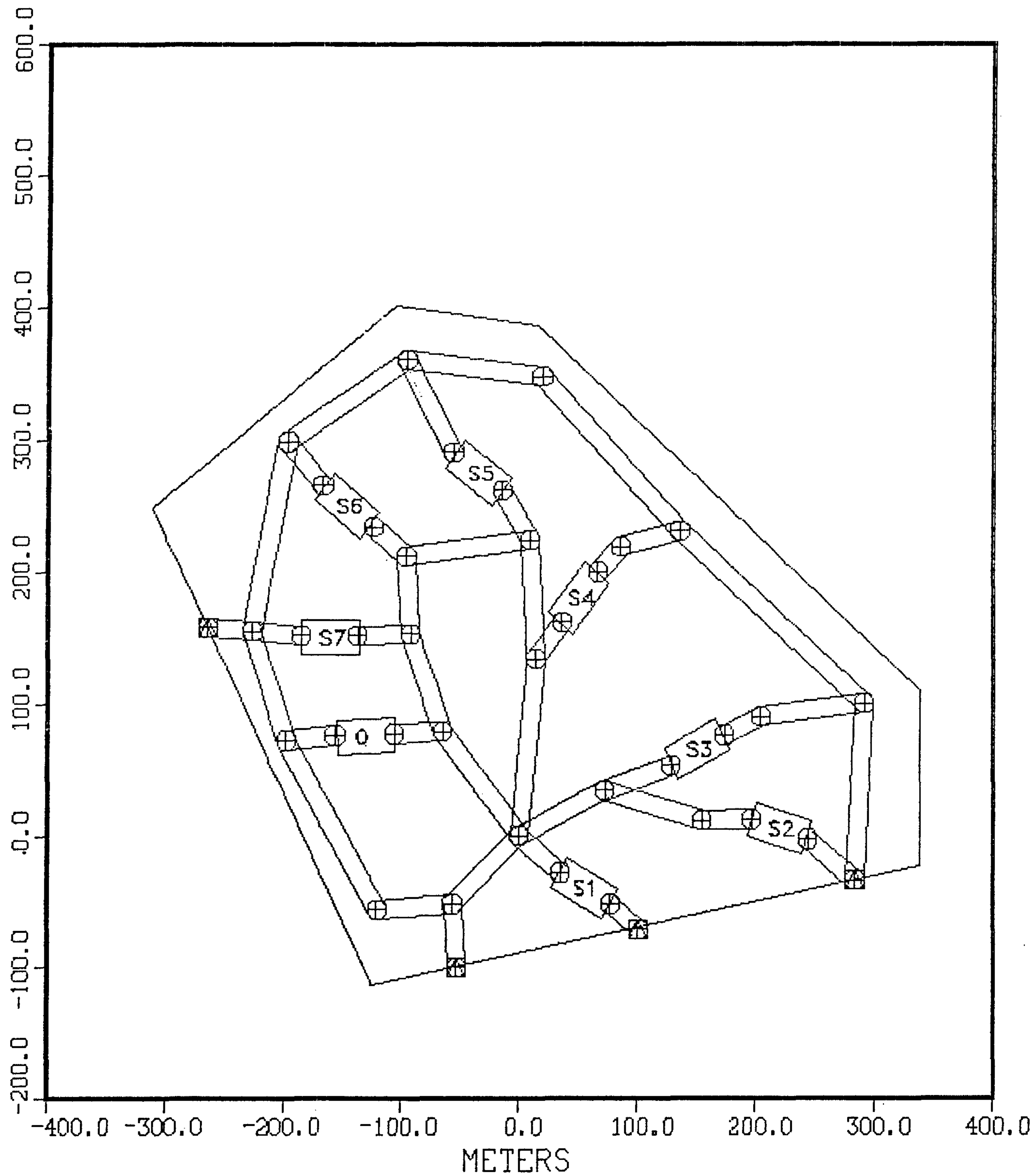

Figure 19. High resolution graphics from the program WSARD (actual size) result of files WAXWORKS and UROADS.

and has the ability to rotate the entire coordinate system to maximize the area covered by the plot within the page area available when a Gould electrostatic plotter, or a device with similar capabilities is used (Figure 20).

USING MAP: The only file requirements is to attach locally the geographical data when running map. This is known as either WAXWORKS or BITTERS if the United Kingdom or the West German route is being run, respectively. As with WSARD the line:

CALL META:

This must be removed or changed when running on facilities other than at the U.S. Air Force Weapons Laboratory (AFWL).

Attention must also be given to the capabilities of the plotter used. Typical plots produced by the program MAP are in the neighborhood of 9 inches in the vertical and 40 inches in the horizontal (Figure 21). The Gould electrostatic is recommended.

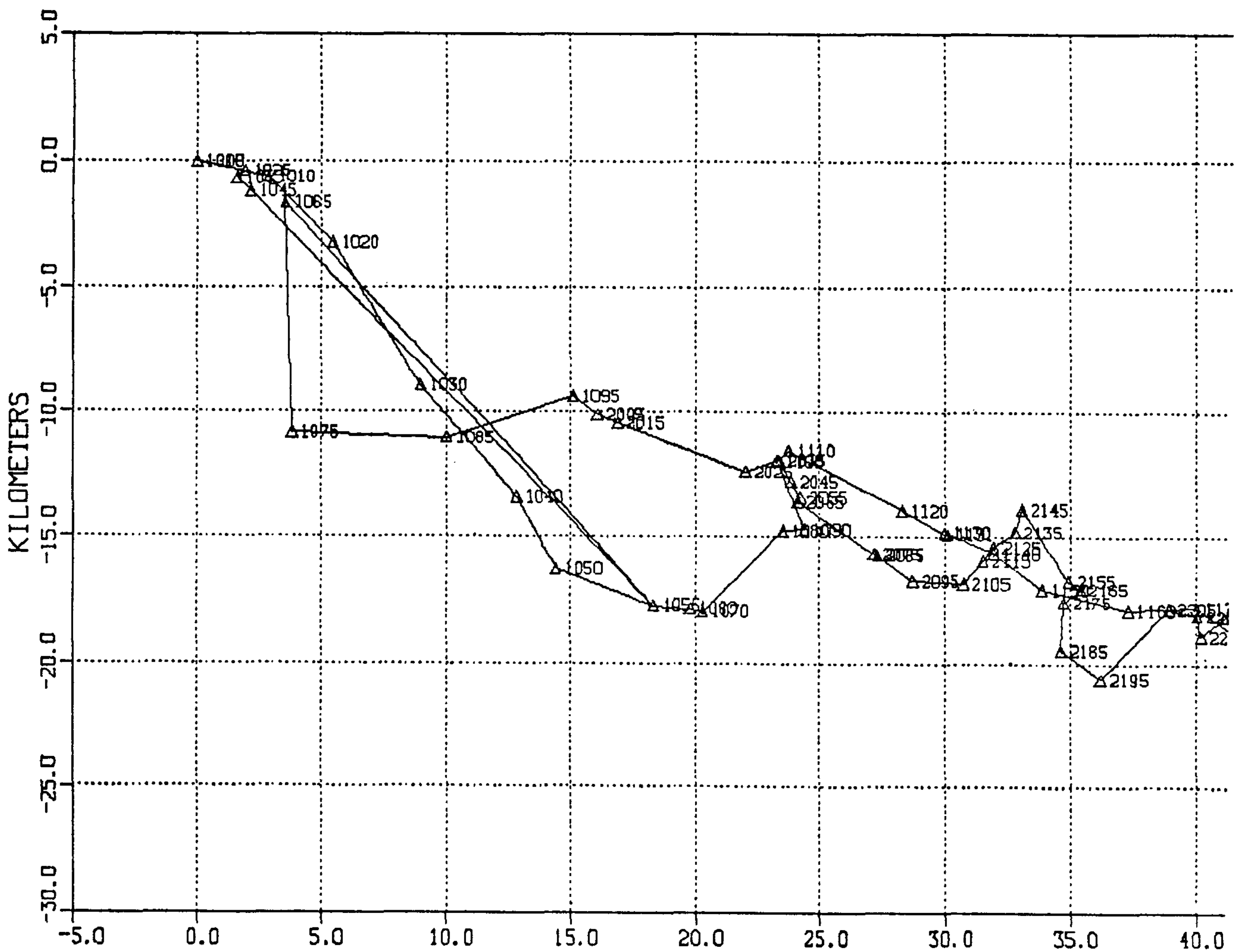

Figure 20. High resolution graphics from program map attached to file BITTERS. Figure shows nodes and segments. Note WSA at coordinate 0.0,0.0.

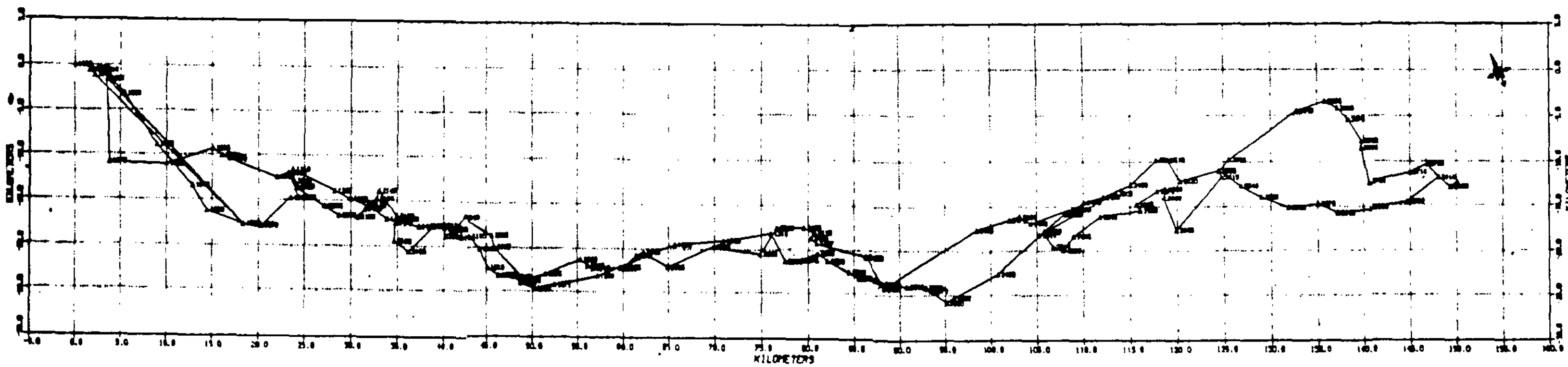

Figure 21. High resolution graphics from program map attached to BITTERS. Figure is reduced 4 times. Figure illustrates typical dimensions of plots generated from program map.

APPENDIX A

FORTRAN NAMELIST INPUT/OUTPUT

Fortran, in most of its implementations, allows a program to have a statement similar to

```
NAMELIST/SSI/KEN, PHIL, GARY JAKE, SECTY, CONSLT
```

which informs the compiler that the variables KEN,. . ., CONSLT can be referred to in later input/output (i/o) operations by the groupname SSI. This type of statement is nonexecutable.

After the groupname has been declared, the statement

```
READ SSI
```

will cause the computer to attempt to read from the card reader (or its logical equivalent), the values of the variables which are contained in the Namelist group SSI. The input must have an appearance similiar to the following:

```
Δ $SSI
Δ PHIL = 23.7,
Δ JAKE = 4
Δ GARY = -145.333,
Δ KEN  = (5.3, 173E9)
Δ SECTY = 1.2, Ø.3
Δ CONSLT= (Ø.1, 5.2), (11.7, 93.85),
Δ $END
```

The use of the symbol "Δ" above indicates that column 1 of each card should be blank.

As shown above, the first card must begin with a dollar sign, followed by the Namelist groupname. After that, variables can be specified by simply stating

variablename = value,

until the last card, which should be $END. Note that the variables in the sample input are not in the same order as they were in the NAMELIST declaration; the data cards can be in any order, since the constant values are associated in the input with the proper variable names.

In the example, PHIL and GARY are floating-point variables, and so are given floating-point constants in the input data. JAKE is an integer, and is given an integer value. Assuming that KEN has been declared to be complex in the program, its data card supplies the real and imaginary parts within parenthesis, separated by a comma.

SECTY is a floating point array, and CONSLT is a complex array. Conservative locations in an array are filled by simply supplying several constants, separated by commas.

Not only do input data cards not need to be in any particular order, but they do not all have to be present. If a variable does not appear in the data cards, then its value is unchanged by the READ operation. For example,

```
Δ $SSI
Δ JAKE = -17,
Δ $END
```

will change only the value of JAKE, leaving all the others the same. In fact,

```
Δ $SSI
Δ $END
```

will satisfy the READ operation, without changing anything.

It is also unnecessary to specify all of the elements of arrays. For example, SECTY could be dimensioned with 100 elements, but

```
Δ SECTY = 1.2, Ø.3,
```

will only change the values of the first two. It is also proper to set

```
Δ SECTY (25) = 1.8, 2.3, 7.1,
```

in which case only SECTY(25), SECTY (26), and SECTY (27) are given new values. A repeat count factor can also be used for arrays:

```
Δ SECTY = 12 + 18.2, 1.5, 7 * Ø.1,
```

will put 18.2 into the first twelve locations, followed by one location containing 1.5, and then seven containers Ø.1.

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