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AURA-AMORE PILOT STUDY OF THE RESILIENCY OF A FORWARD AREA SIGNAL PLATOON

Maureen M. Stark

March 1986

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US ARMY BALLISTIC RESEARCH LABORATORY
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

At the request of TRADOC HQs, a pilot study was initiated in April of FY84 to apply both the Ballistic Research Laboratory (BRL) developed Army Unit Resiliency Analysis (AURA) model and Science Applications, Incorporated (SAI) developed AMORE model to the resiliency analysis of a signal unit in order to compare the models' outputs, resource requirements, applicability and ease of use. The Light Infantry Division Signal Battalion was selected as a test case for this study. The U.S. Army Signal School was responsible for developing the inputs

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required for the analysis and for exercising the AMORE methodology. BRL, using identical inputs, was responsible for applying the AURA methodology. A Forward Area Signal Platoon (FASP) was chosen as the first unit to analyze in the Signal Battalion. The results of the AURA analysis of this platoon are reported in this report. Where appropriate, comparisons between the AMORE model and the AURA model are made.

The results of the study were as follows:

- The applicability of the AURA methodology as well as its ease of use were demonstrated during this study. The modelling of the operations of the FASP was relatively easy using the structures available in AURA. These structures lent themselves well to this application.

- Although the AURA methodology was developed with the user in mind, several programs have been developed at BRL to further aide the user in developing inputs and analyzing results. In fact, most of the figures used in this report are products of these programs. These graphical aides greatly enhance the user-friendliness of the AURA code.

- The development of the input data for the study was accomplished by the USA Signal School with some interaction with the author. Once the data were developed, it took approximately two weeks to input the data into AURA, check for typographical errors, and begin production runs. The code runs very quickly, with a typical turnaround time of 10 CPU Minutes. Thus, most runs were performed within a couple of days. At that time, the outputs had to be analyzed and, in some cases, additional runs were made. This analysis of the outputs took approximately four weeks.

In addition, the following conclusions were drawn from the results of the AURA analysis.

- The AMORE-like runs overestimated unit degradation for this unit.

- The FASP was moderately resilient to small attrition levels.

- Very often, the resiliency of the unit came at the cost of supervision (i.e., the unit could not afford the luxury of having supervisor personnel in purely supervisory jobs).

- Even before any attrition was assessed, the FASP was overtaxed in its mission. That is, the FASP did not have the assets required to reach 100 percent effectiveness at initial time.

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I. BACKGROUND

At the request of TRADOC HQs, a pilot study was initiated in April of FY84 to apply both the Ballistic Research Laboratory (BRL) developed Army Unit Resiliency Analysis (AURA) model and the Science Applications, Incorporated (SAI) developed Analysis of Military Organizational Effectiveness (AMORE) model to the resiliency analysis of a signal unit in order to compare the models' outputs, resource requirements, applicability and ease of use. The Light Infantry Division Signal Battalion was selected as a test case for this study. The U.S. Army Signal School was responsible for developing the inputs required for the analysis and for exercising the AMORE methodology. BRL, using identical inputs, was responsible for applying the AURA methodology. A Forward Area Signal Platoon (FASP) was chosen as the first unit to analyze in the Signal Battalion. The results of the AURA analysis of this platoon are reported here. Where appropriate, comparisons between the AMORE model and the AURA model are made.

II. INPUTS

The ground rules of the study stated that the same inputs were to be used for the two models in all areas where practical. The USA Signal School based their inputs on the following assumptions:

a. All equipment was considered to be 100 percent operational prior to any degradation assessed by the models.

b. The unit operated with a full strength TO&E.

c. Personnel were able to perform 100 percent of the tasks to prescribed conditions and standards for their skill levels as outlined in the Soldier's Manual.

d. The unit moved in support of a brigade, and moved approximately every six hours.

e. Personnel were not deployed in Mission-Oriented Protective Posture (MOPP).

f. The unit functioned autonomously for 72 hours.

g. Times used to estimate setup and teardown times for the communications systems within the Forward Area Signal Platoon were as specified in ARTEP 11-35, AIM Div, Signal Bn (Heavy).

1. **Missions**

The Forward Area Signal Platoon was responsible for providing an Area Signal Center in the forward area of the division zone of operations (henceforth referred to as the Forward Area Signal Center (FASC)) and for providing essential communications electronics facilities terminating the division communications network at the brigade headquarters (referred to as BDE assets). Within these areas of responsibility, four missions were chosen as the basis for the AURA/AMORE analyses. These were 1) to secure the operations site and setup the unit's communications equipment; 2) to operate and maintain that equipment; 3) to tear down the equipment in preparation for the unit's relocation and, simultaneously, to send an advance party to determine the unit's new location and 4) to conduct a motor march to the new site. These missions were repeated every 6 hours when, as previously mentioned, the unit was assumed to be moving in support of the brigade. A time line was developed by the Signal School showing the approximate amount of time spent in each mission as a function of the mode of communication. This time line is included as Appendix A.

2. **Initial Strength**

A full strength level TO&E was used for this study as provided by the Signal School. A listing of personnel and major items of equipment for the Forward Area Signal Platoon is included in Appendix B.

3. **Functional Analysis**

AMORE and AURA approach the problem of how to describe unit resiliency in vastly different ways. AURA is an event sequenced, one-sided combat simulation methodology. The methodology consists of an expanding number of detailed models from the various technical communities interfaced into a large, time-dependent, event playing and optimization routine. The optimization is a dedicated, non-linear routine which models the reallocation of surviving, degraded (non-linear) assets. The optimization logic is based upon minimizing the choke point in each of the available modes of unit operation, and then selecting the optimal mode. The user specifies the modes of operation of the unit by using a flow-chart model. Items on the chart are tasks which may be performed. Tasks are linked together to complete specified missions. This flow diagram shows the relationship between the various tasks and mission accomplishment, including identification of essential, alternate, parallel and optional tasks.

The AMORE model, however, is built around a standard algorithm which solves the integer (linear) transportation problem. To use it the user must configure his unit into mission-essential teams of "equal value", i.e., groupings of personnel and equipment which add equal amounts of capability to the unit. The function of AMORE is to determine how many of these teams can be filled by the assets available, with the provision that the first team must be filled before filling the second, etc. The filling of the teams is done by the transportation algorithm.

Since these two approaches are vastly different, the functional analysis developed by the Signal School for use in AMORE was modified for use in AURA. This was done with the help of the Signal School. This functional analysis is explained in detail below.

Table 1 shows the specific tasks required for each of the four missions of the FASP. These tasks were further broken down into subtasks. Figures 1 through 4 illustrate the flow diagrams developed for each of the missions for use in AURA. These flow diagrams show the relationship between the subtasks and the personnel and equipment required to perform these subtasks (referred to in AURA as links). Figures 1 through 4 also show the specific tasks and how they interrelate. The numbers included in these figures represent the portion of capability provided to the unit during this mission by the corresponding set of subtasks. For example, in Figure 1 a "0.50" is used to indicate that during the Setup and Secure Site Mission, the subchain containing the RATT,* the RATT Team and the RATT Supervisor provides 50 percent of the unit's capability to set up the unit's equipment, with the remaining subchains contributing ten percent to the task of setting up equipment.

Take note of the subtask labelled "Intrinsic Supervision". This link is used to show that even if both the PLT LDR and the PLT SGT positions are not filled, some intrinsic supervision still exists in the unit. In other words, the unit would not lose all of its capability if it lost and did not replace both the PLT LDR and the PLT SGT.

A "link-effectiveness curve" is associated with each of these subtasks, specifying the number of assets required for maximum effectiveness (MAX IN), the maximum attainable effectiveness (MAX EFF), the minimum effectiveness for that subtask (MIN EFF) and the corresponding numbers of assets for minimum effectiveness (MIN IN). Figure 5 shows an example of the link effectiveness curve for the RATT. Note that two RATTs are required for maximum effectiveness. However, if no RATTs are available, the unit loses all of its capability to communicate via a RATT.

Two other parameters, associated with each subtask, are the maximum number of assets able to operate in that subtask (MAX INLINK) and any subtask which is directly associated with this

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* Abbreviations used in this report are included in Appendix B.

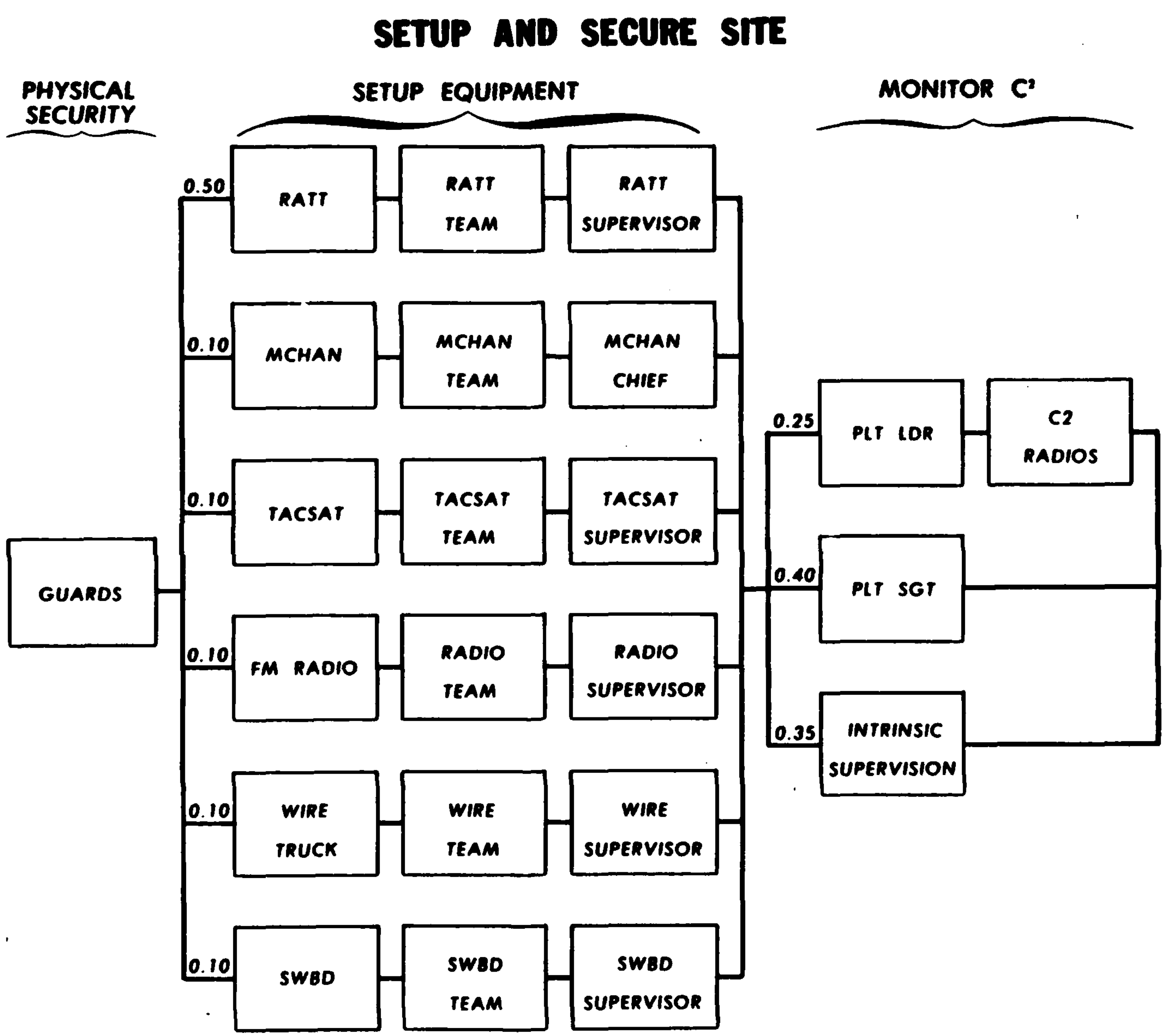

Figure 1. Functional Diagram for Mission One

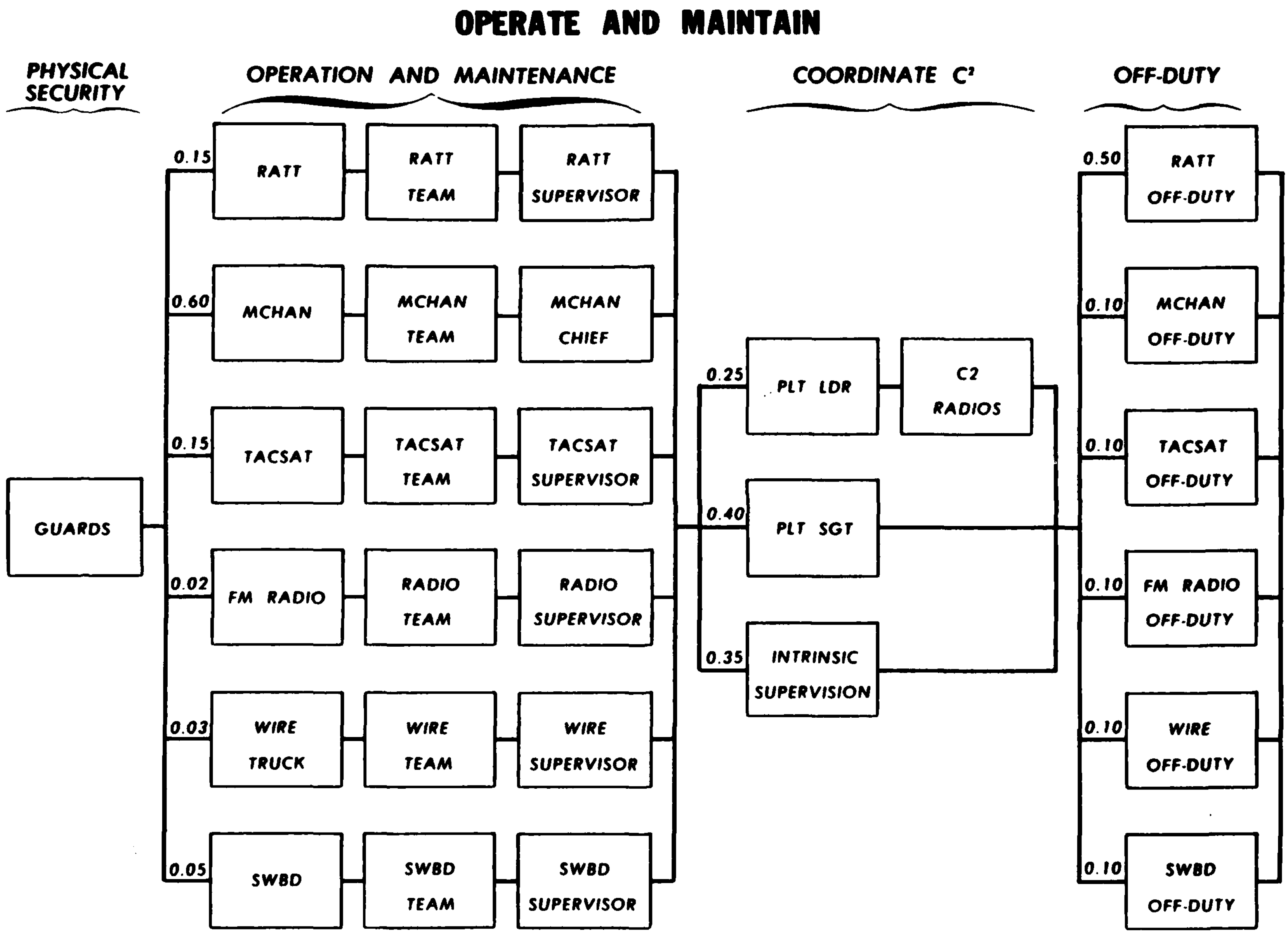

Figure 2. Functional Diagram for Mission Two

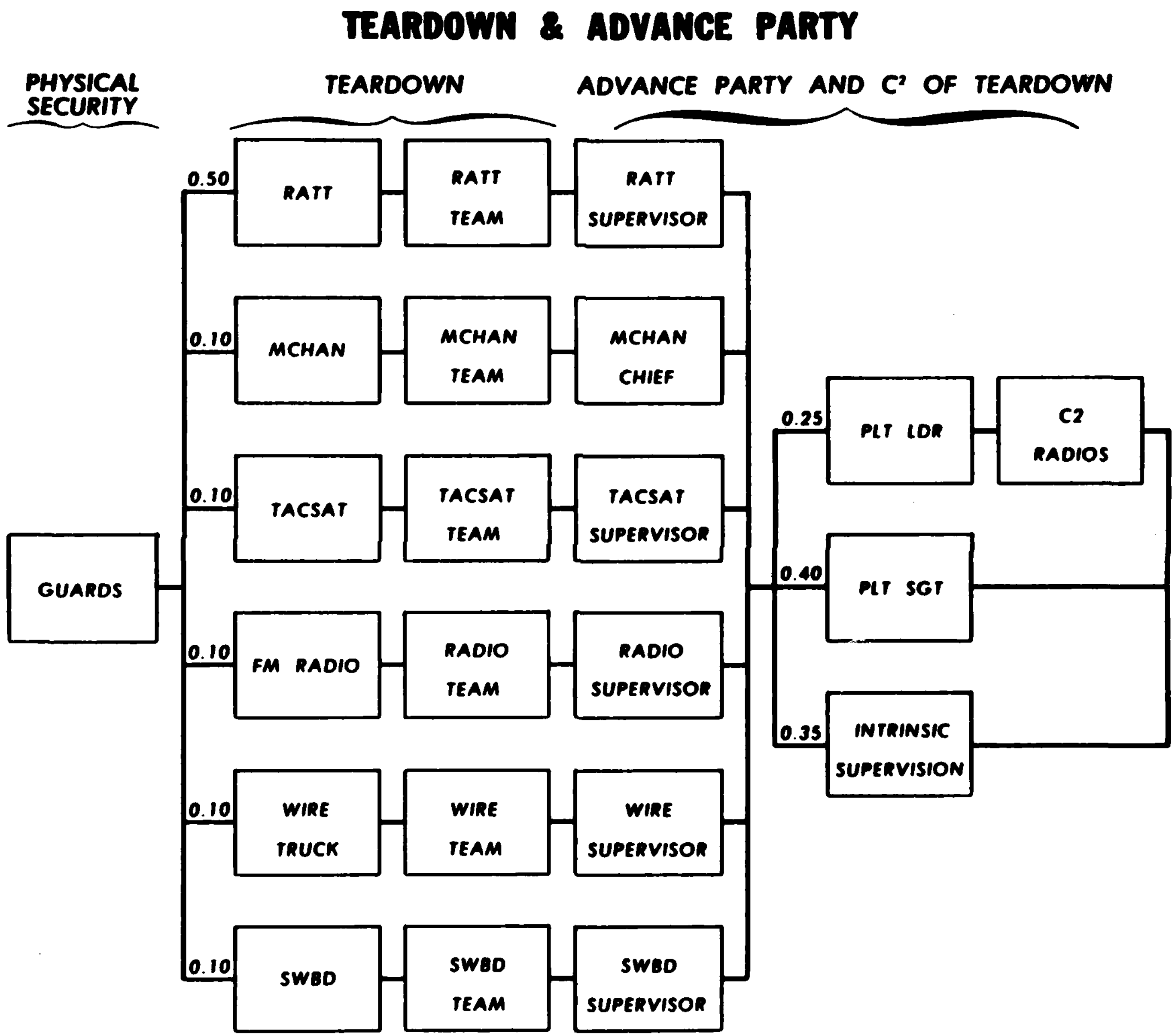

Figure 3. Functional Diagram for Mission Three

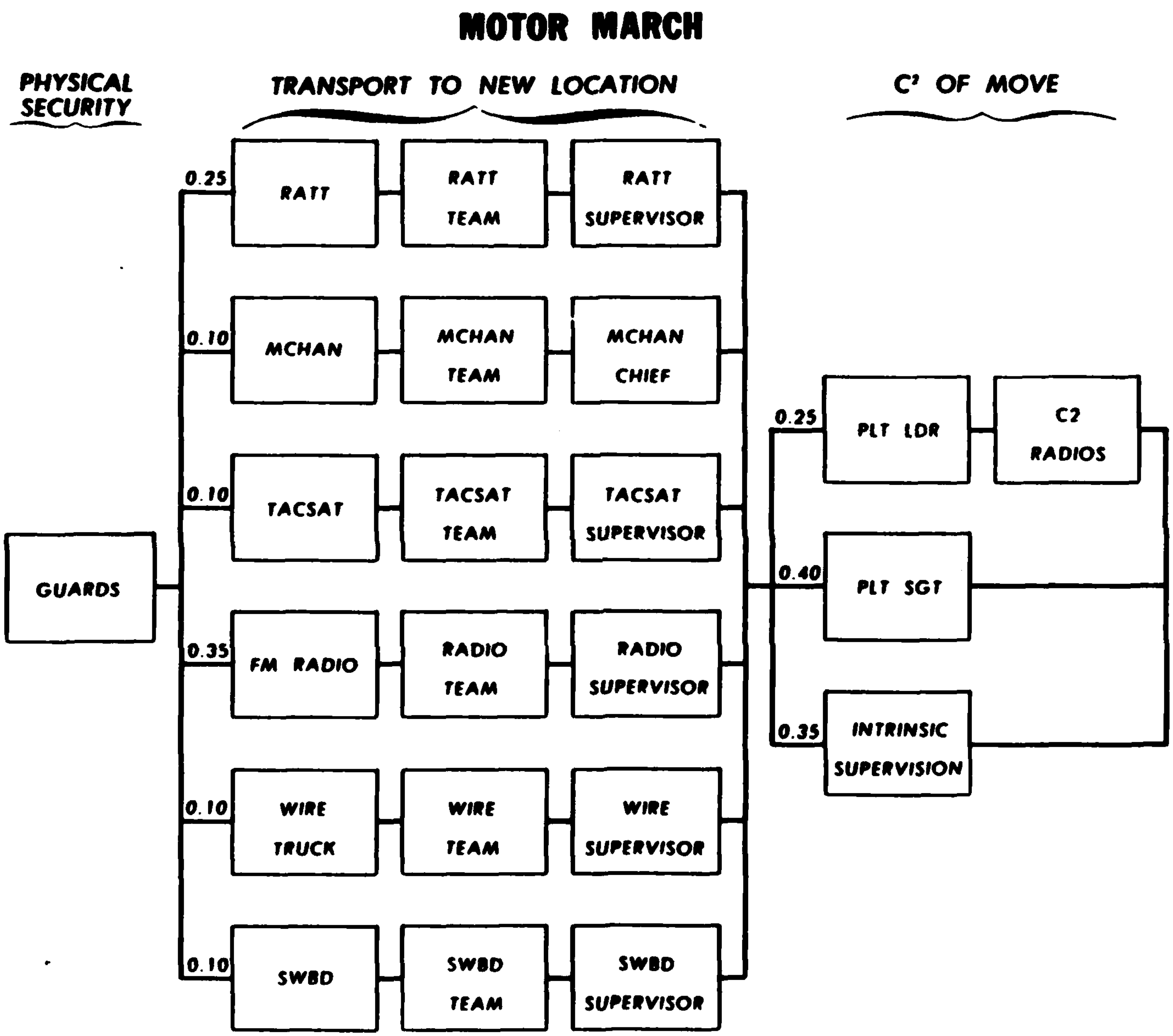

Figure 4. Functional Diagram for Mission Four

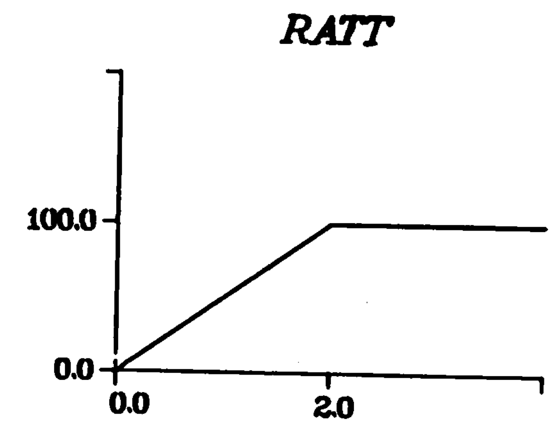

Figure 5. Link Effectiveness Curve for RATT Link

subtask (ASSOCIATED LINK). The MAX INLINK parameter is used to ensure that the AURA model does not, in trying to shore up a particular subtask, assign more assets to a subtask than is feasible. For example, whereas assigning extra guards to physical security may make sense, assigning two drivers to drive the same truck is meaningless. Use of the ASSOCIATED LINK option, has the effect of causing AURA to interpret MAX INLINK as a number relative to the items available in the associated link. For example, if all RATTs have been attrited, AURA will not continually try to assign additional RATT TEAM personnel to operate RATTs which are unavailable. Thus, the maximum number of personnel assigned to operate the RATT is directly related to the number of available RATTs. The parameters for the link-effectiveness curves associated with each subtask are listed in Table 2.

TABLE 1. SPECIFIC TASKS FOR FASP MISSIONS

Mission	Tasks
I. Setup and Secure Site	a. Physical Security b. Setup Equipment System Installation WIRE Installation SWBD Installation Supervision of Setup c. Monitoring of Command and Control (C2)
II. Operate and Maintain	a. Physical Security b. Operation and Maintenance System Operation and Maintenance WIRE Maintenance Secure Operations c. Coordination of C2 Requirements d. Provide Rest for "off-duty" personnel
III. Teardown and Advance Party	a. Physical Security b. Advance Party c. Teardown System Teardown Monitoring System Teardown d. C2 of Teardown
IV. Motor March	c. Physical Security b. Transport to new location c. C2 of move

TABLE 2. PARAMETERS FOR LINK-EFFECTIVENESS CURVES

Mission	Link	Max In	Max Eff(%)	Min In	Min Eff(%)	Max Inlink	Assoc. Link
I. Setup & Secure Site	RATT Team	6.00	100	0.00	0	6.00	RATT
	MCHAN Team	9.00	100	0.00	0	9.00	MCHAN
	TACSAT Team	3.00	100	0.00	0	3.00	TACSAT
	RADIO Team	2.00	100	0.00	0	2.00	FM RADIO
	SWBD Team	2.00	100	0.00	0	2.00	SWBD
	WIRE Team	3.00	100	0.00	0	unlmtd	NONE
	RATT Supervisor	0.50	100	0.00	80	unlmtd	NONE
	MCHAN Chief	0.50	100	0.00	60	unlmtd	NONE
	RADIO Supervisor	0.50	100	0.00	80	unlmtd	NONE
	SWBD Supervisor	0.50	100	0.00	85	unlmtd	NONE
	WIRE Supervisor	0.50	100	0.00	85	unlmtd	NONE
	RATT	2.00	100	0.00	0	unlmtd	NONE
	MCHAN	3.00	100	0.00	0	unlmtd	NONE
	FM RADIO	1.00	100	0.00	0	unlmtd	NONE
	SWBD	1.00	100	0.00	0	unlmtd	NONE
	WIRE Truck	1.00	100	0.00	0	unlmtd	NONE
	Guards	4.00	100	0.00	50	unlmtd	NONE
	PLT LDR	1.00	100	0.00	0	unlmtd	NONE
	PLT SGT	1.00	100	0.00	0	unlmtd	NONE
	C2 RADIOs	1.00	100	0.00	80	unlmtd	NONE
	Intrinsic Supervision	1.00	100	0.00	0	unlmtd	NONE
II. Operate & Maintain	RATT Team	1.00	100	0.00	0	6.00	RATT
	MCHAN Team	3.00	100	0.00	0	9.00	MCHAN
	TACSAT Team	1.00	100	0.00	0	3.00	TACSAT
	RADIO Team	1.00	100	0.00	0	2.00	FM RADIO
	SWBD Team	1.00	100	0.00	0	2.00	SWBD
	WIRE Team	1.00	100	0.00	0	unlmtd	NONE
	RATT Supervisor	0.50	100	0.00	80	unlmtd	NONE
	MCHAN Chief	0.50	100	0.00	60	unlmtd	NONE
	RADIO Supervisor	0.50	100	0.00	80	unlmtd	NONE
	SWBD Supervisor	0.50	100	0.00	85	unlmtd	NONE
	WIRE Supervisor	0.50	100	0.00	85	unlmtd	NONE
	RATT E5	0.50	100	0.00	0	unlmtd	RATT
	MCHAN E4	0.75	100	0.00	0	unlmtd	MCHAN
	TACSAT E5	0.25	100	0.00	0	unlmtd	TACSAT
	RADIO E5	0.25	100	0.00	0	unlmtd	FM RADIO
	SWBD E4	0.25	100	0.00	0	unlmtd	SWBD
	WIRE E5	0.25	100	0.00	0	unlmtd	NONE
	RATT	2.00	100	0.00	0	unlmtd	NONE
	MCHAN	3.00	100	0.00	0	unlmtd	NONE
	FM RADIO	1.00	100	0.00	0	unlmtd	NONE
	SWBD	1.00	100	0.00	0	unlmtd	NONE
	WIRE Truck	1.00	100	0.00	0	unlmtd	NONE
	Guards	4.00	100	0.00	50	unlmtd	NONE

TABLE 2. PARAMETERS FOR LINK-EFFECTIVENESS CURVES (continued)

Mission	Link	Max In	Max Eff(%)	Min In	Min Eff(%)	Max Inlink	Assoc. Link
	PLT LDR	1.00	100	0.00	0	unlmtd	NONE
	PLT SGT	1.00	100	0.00	0	unlmtd	NONE
	C2 RADIOs	1.00	100	0.00	80	unlmtd	NONE
	MCHAN Off-Duty	4.75	100	0.00	0	unlmtd	NONE
	RATT Off-Duty	3.50	100	0.00	0	unlmtd	NONE
	TACSAT Off-Duty	1.75	100	0.00	0	unlmtd	NONE
	FM RADIO Off-Duty	.75	100	0.00	0	unlmtd	NONE
	SWBD Off-Duty	.75	100	0.00	0	unlmtd	NONE
	WIRE Off-Duty	.75	100	0.00	0	unlmtd	NONE
	Intrinsic Supervision	1.00	100	0.00	0	unlmtd	NONE
III. Teardown & Advance Party	RATT Team	4.00	100	0.00	0	6.00	RATT
	MCHAN Team	9.00	100	0.00	0	9.00	MCHAN
	TACSAT Team	3.00	100	0.00	0	3.00	TACSAT
	RADIO Team	2.00	100	0.00	0	2.00	FM RADIO
	SWBD Team	2.00	100	0.00	0	2.00	SWBD
	WIRE Team	3.00	100	0.00	0	unlmtd	NONE
	RATT Supervisor	0.50	100	0.00	80	unlmtd	NONE
	MCHAN Chief	0.50	100	0.00	80	unlmtd	NONE
	RADIO Supervisor	0.50	100	0.00	80	unlmtd	NONE
	SWBD Supervisor	0.50	100	0.00	85	unlmtd	NONE
	WIRE Supervisor	0.50	100	0.00	85	unlmtd	NONE
	RATT	2.00	100	0.00	0	unlmtd	NONE
	MCHAN	3.00	100	0.00	0	unlmtd	NONE
	FM RADIO	1.00	100	0.00	0	unlmtd	NONE
	SWBD	1.00	100	0.00	0	unlmtd	NONE
	WIRE Truck	1.00	100	0.00	0	unlmtd	NONE
	Guards	4.00	100	0.00	50	unlmtd	NONE
	PLT LDR	1.00	100	0.00	0	unlmtd	NONE
	PLT SGT	1.00	100	0.00	0	unlmtd	NONE
	C2 RADIOs	1.00	100	0.00	80	unlmtd	NONE
	Intrinsic Supervision	1.00	100	0.00	0	unlmtd	NONE
IV. Motor March	RATT Team	2.00	100	0.00	0	2.00	RATT
	MCHAN Team	3.00	100	0.00	0	3.00	MCHAN
	TACSAT Team	2.00	100	0.00	0	2.00	TACSAT
	RADIO Team	1.00	100	0.00	0	1.00	FM RADIO
	SWBD Team	1.00	100	0.00	0	1.00	SWBD
	WIRE Team	1.00	100	0.00	0	unlmtd	NONE
	RATT Supervisor	0.50	100	0.00	80	unlmtd	NONE
	MCHAN Chief	0.50	100	0.00	80	unlmtd	NONE
	RADIO Supervisor	0.50	100	0.00	80	unlmtd	NONE

TABLE 2. PARAMETERS FOR LINK-EFFECTIVENESS CURVES (continued)

Mission	Link	Max In	Max Eff(%)	Min In	Min Eff(%)	Max Inlink	Assoc. Link
	SWBD Supervisor	0.50	100	0.00	85	unlmtd	NONE
	WIRE Supervisor	0.50	100	0.00	85	unlmtd	NONE
	RATT	2.00	100	0.00	0	unlmtd	NONE
	MCHAN	3.00	100	0.00	0	unlmtd	NONE
	FM RADIO	1.00	100	0.00	0	unlmtd	NONE
	SWBD	1.00	100	0.00	0	unlmtd	NONE
	WIRE Truck	1.00	100	0.00	0	unlmtd	NONE
	Guards	4.00	100	0.00	50	unlmtd	NONE
	PLT LDR	1.00	100	0.00	0	unlmtd	NONE
	PLT SGT	1.00	100	0.00	0	unlmtd	NONE
	C2 RADIOs	1.00	100	0.00	80	unlmtd	NONE
	Intrinsic Supervision	1.00	100	0.00	0	unlmtd	NONE

The modelling of the "off-duty" assets merits some discussion. In order for the personnel in the FASP to be able to operate throughout a 72-hour period, it was mandatory that they get some rest (when possible). The only time in which this was feasible was during mission two - Operate and Maintain. During this time, a skeleton crew can handle the equipment with occasional supervision. This was represented by the parameters used for the off-duty links. Note the FM RADIO off-duty link required 0.75 people for maximum effectiveness. In this example, this meant that one person was required to operate/supervise approximately 25 percent of the time during mission two. This left approximately 75 percent of that time for rest. A similar logic applied to the other off-duty personnel.

Also, take note of how these off-duty assets were structured (shown in Figure 2). Once again, the numbers shown represent the portion of capability provided to the unit during this mission by each of the groups of off-duty personnel. An important point is illustrated here. Note that the structure of the Off-duty segment parallels the structure of the Setup segment. In this case, however, the factors used for each part of the segment (ie., RATT Off-duty, MCHAN Off-duty, etc.) represent the relative importance of each of these personnel getting rest. It was more important for RATT personnel to get rest during this time because they were the assets needed most in the other missions.

4. **Substitution Matrix**

The Signal School developed a substitution/transfer matrix for use in AMORE. This matrix specified which personnel and equipment could substitute for attrited personnel. Zeros indicate that the substitution was effective immediately, and dots indicate that no substitution was allowed. A 30-minute transfer time was assumed from the FASC to the BDE Command Post. The personnel and equipment matrices, along with the assumptions used in developing these matrices, are included in Appendix C.

A requirement of the algorithm used in AMORE is that the teams be made up of integer assets. As a result, any substitute is assumed to function in his new position as well as the original occupant of the position, given only that enough time has elapsed for the substitution to be made. This limitation is unrealistic in the case of individuals moving "up the ladder" in a time interval of interest in a combat scenario. The effect of this limitation is to force the user to decide, on a 'go-no go' basis, whether to allow a particular substitution. Unfortunately, it is only with preknowledge of the correct result that the user can determine whether or not the choices were correct, since any independent measure of the substitutability of an actual individual who is working "up the ladder" is not a 'go-no go', but a fraction of the required performance.

The AURA model allows the user to specify both a time for substitution and an effectiveness for that substitute. Thus, the Signal School expanded the substitution matrix for use in AURA, which included effectiveness values for each substitute in each job he was capable of substituting. This matrix, along with the assumptions used in it's development, is also included in Appendix C. Note: Had the AURA substitution matrix been done first, this "go-no go" process would have been avoided. Thus, sub-optimal substitutes, which had to be ignored for AMORE, could have been considered. The effect of applying the "go-no go" in this study is reflected in the resulting effectiveness matrix in which all allowed substitutes are at greater than 50 percent effectiveness.

The times developed for AMORE represent the time required for a substitute to travel to his new job, become acclimated to that job AND to perform at maximum (100 percent) capability. Since AURA allows non-optimal substitutions to be made, the substitution times used for the AMORE analysis were inappropriate in that they included time for the substitute to reach maximum capability in his new job. Thus, for this study, AURA used the substitution time to represent time required for the substitute to travel to his new job. The 30-minute transfer time between the FASC and the BDE Command Post was retained, but it was assumed that anyone substituting in a job within the FASC or within the BDE Command Post would be able to substitute in jobs within the same area within 2 minutes. Personnel in the direct vicinity of the job requiring substitutes were given a transfer time of 0 minutes.

5. **Deployment**

To conduct an AMORE run, the user must input kill probabilities (Pks) for the various assets. During execution, the code then draws random numbers against these Pk values to determine the pool of assets for that replication. The transportation algorithm then attempts to map as many team positions onto the assets as it can, always assuring that all lower numbered teams are included. AMORE does not include, and in fact has no use for, the physical deployment of the unit.

In contrast to AMORE, the AURA user usually specifies the attacks to be aimed at the unit, the reinforcements to arrive, etc. The AURA methodology includes extensive data bases containing such diverse factors as lethal footprints for conventional munitions, log normal kill probabilities for nuclear effects, toxic chemical dispersion and evaporations, MOPP degradation, reliability and target acquisition probabilities. The methodology automatically selects the appropriate weapon effects routines and internally calculates the effects of individual weapons against individual items within the unit. In order to do this type of laydown, a unit deployment is essential (although AURA can be made to run similarly to AMORE by deploying all items at a single X, Y coordinate and using AURA's PREFAIL option).

Although it was not necessary to do a unit deployment for the baseline study (the comparison of AURA results with AMORE results), unit deployment was included in the AURA analysis in order to allow additional runs to be made using more of AURA's capability than the baseline required. The unit deployment was done by BRL with guidance from the Signal School. Figures 6 through 8 show the deployment of the unit's major items of equipment. Table 3 contains a complete listing of the unit's deployment. The listing includes 1) the X and Y coordinates for each asset, 2) the number of assets deployed at each coordinate, 3) kill criteria for conventional, nuclear and toxic threats and 4) initial posture codes (conventional, nuclear, and MOPP). The defaults for kill criteria and initial postures were used for this analysis.

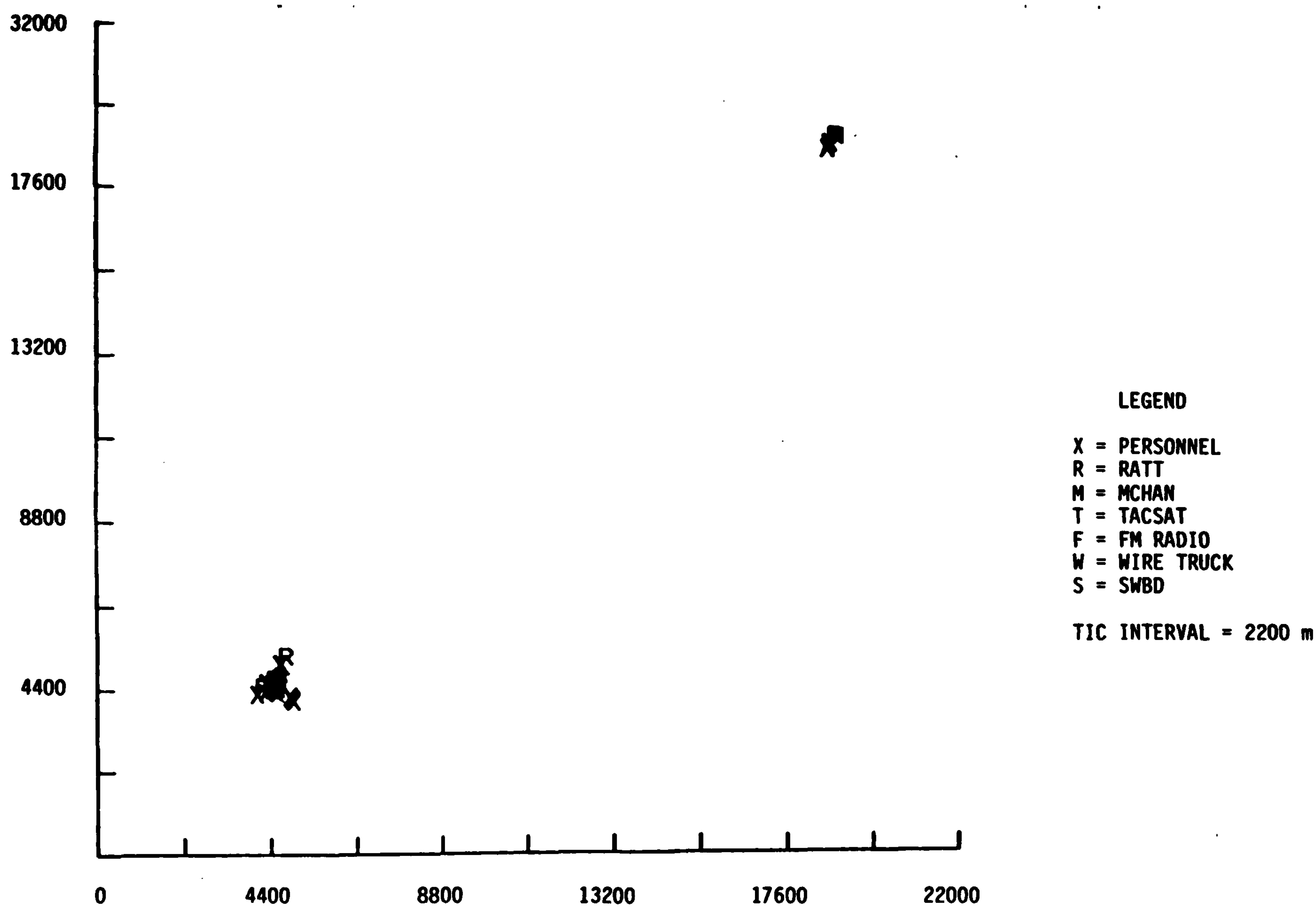

Figure 6. FASP Deployment

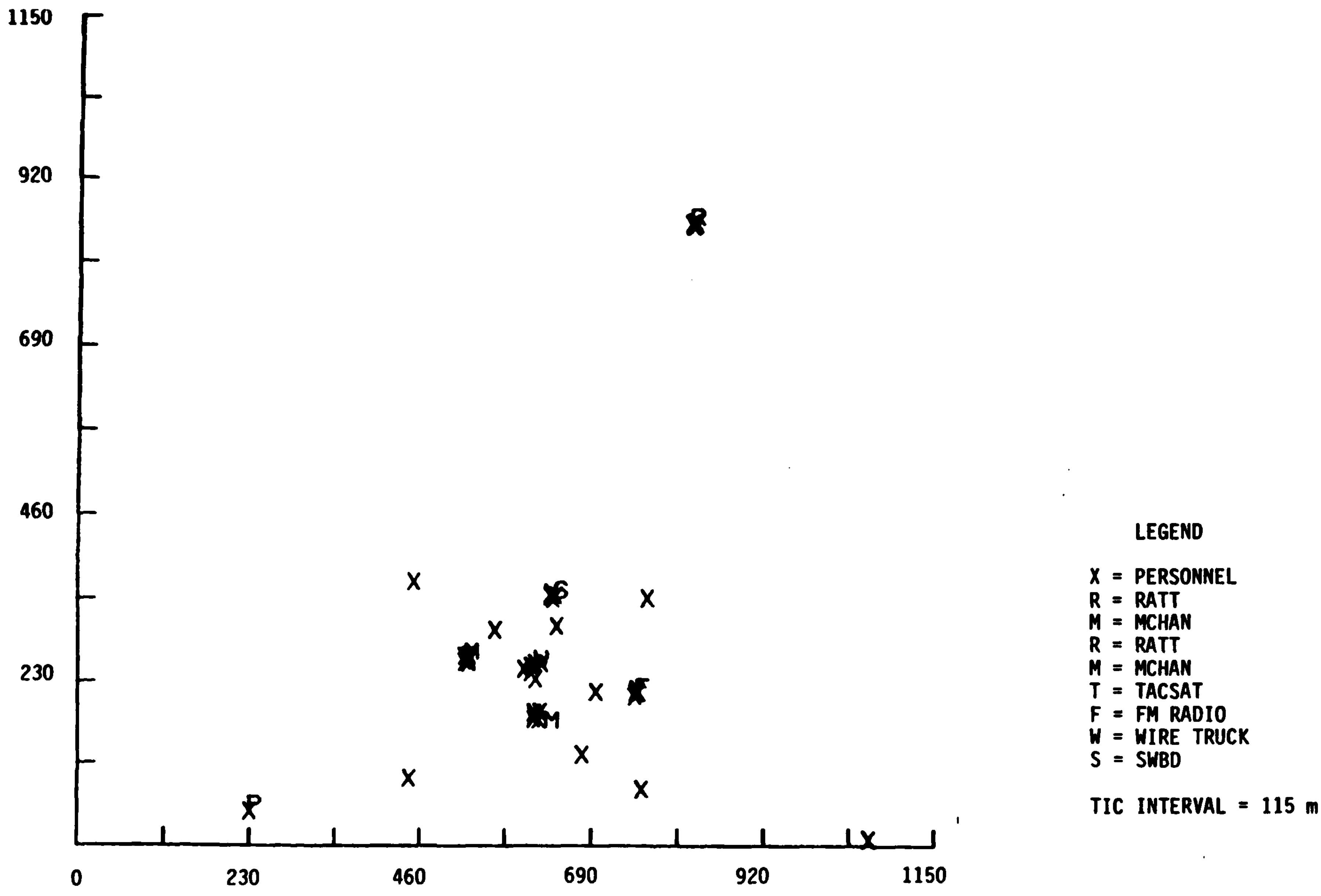

Figure 7. FASC Deployment

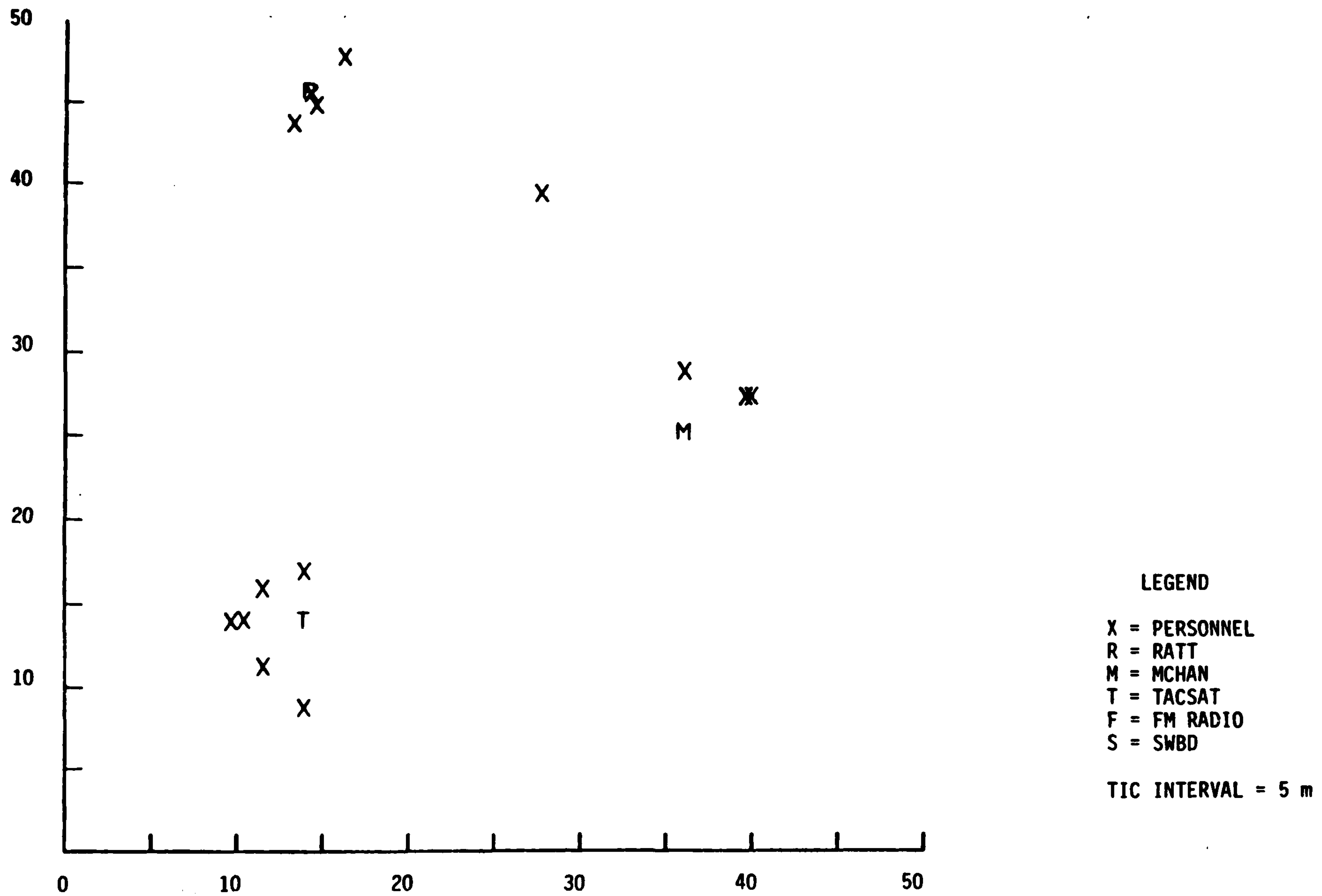

Figure 8. FASP Deployment (at BDE)

TABLE 3. DEPLOYMENT OF ASSETS

Area	Asset(s)	X	Y	Number	Kill Criteria					
FASC	PLT LDR Truck	85.5	301.0	1.00	1	1	1	1	1	0
	GRC-106	85.5	301.0	1.00	1	1	1	1	1	0
	C2 VRC-46	85.5	301.0	1.00	1	1	1	1	1	0
	PLT LDR	85.5	301.0	1.00	1	1	1	1	1	0
	MCHAN	483.2	419.8	1.00	1	1	1	1	1	0
	31ME3	466.3	431.0	1.00	1	1	1	1	1	0
	31ME4	466.3	440.3	2.00	1	1	1	1	1	0
	FM RADIO	604.2	466.0	1.00	1	1	1	1	1	0
	31KE3	600.5	463.2	1.00	1	1	1	1	1	0
	31KE4	603.1	467.3	1.00	1	1	1	1	1	0
	31KE5	603.1	473.1	1.00	1	1	1	1	1	0
	WIRE Truck	469.0	505.5	1.00	1	1	1	1	1	0
	36CE3	469.0	487.5	1.00	1	1	1	1	1	0
	36CE4	453.4	501.2	2.00	1	1	1	1	1	0
	36CE5	462.2	505.5	1.00	1	1	1	1	1	0
	MCHAN	378.4	515.3	1.00	1	1	1	1	1	0
	31ME3	373.1	511.4	1.00	1	1	1	1	1	0
	31ME4	373.1	519.9	2.00	1	1	1	1	1	0
	31ME6	378.5	511.4	1.00	1	1	1	1	1	0
	PLT SGT	414.1	555.2	1.00	1	1	1	1	1	0
	SWBD	494.3	600.3	1.00	1	1	1	1	1	0
	36ME3	488.3	601.5	1.00	1	1	1	1	1	0
	36ME4	491.2	598.3	2.00	1	1	1	1	1	0
	36ME6	489.0	606.0	1.00	1	1	1	1	1	0
	RATT	674.4	1109.8	1.00	1	1	1	1	1	0
	31CE3	675.6	1108.0	1.00	1	1	1	1	1	0
	31CE4	673.5	1108.3	1.00	1	1	1	1	1	0
	31CE5	673.0	1109.8	1.00	1	1	1	1	1	0
	31CE6	676.9	1111.8	1.00	1	1	1	1	1	0
BDE	TACSAT	14722.0	14653.0	1.00	1	1	1	1	1	0
	BDE 26QE3	14722.0	14656.0	1.00	1	1	1	1	1	0
	BDE 26QE4	14722.0	14647.0	1.00	1	1	1	1	1	0
	BDE 26QE5	14718.0	14653.0	1.00	1	1	1	1	1	0
	MCHAN	14746.0	14664.0	1.00	1	1	1	1	1	0
	BDE 31ME3	14750.0	14667.0	1.00	1	1	1	1	1	0
	BDE 31ME4	14746.0	14668.0	2.00	1	1	1	1	1	0
	RATT	14723.0	14686.0	1.00	1	1	1	1	1	0
	BDE 31CE3	14721.0	14684.0	1.00	1	1	1	1	1	0
	BDE 31CE4	14725.0	14689.0	1.00	1	1	1	1	1	0
	BDE 31CE5	14723.0	14686.0	1.00	1	1	1	1	1	0

AURA makes a distinction between the asset required to do a job and the job itself. Very often, this distinction can be ignored by giving the asset and the job the same name. This was done with the equipment in the FASP. For example, the name "MCHAN" represented both the multichannel unit and the job done by the multichannel. There are times, however, when this distinction between the job and the asset required to do the job is an important one. For example, consider the GUARD job. Guards were required for physical security but there were no military occupational specialties (MOS) for guards included in the FASP TO&E. Here, the assets available to perform the guard job substituted in that job. In this analysis, maximum use was made of the ability to give assets and jobs different names in order to vary the parameters associated with the different jobs. The jobs were then deployed along with the unit assets. This was done so that when assets substituting in certain jobs (as with the guard job) are exposed to incoming threats, they take casualties in the vicinity of that job. For example, a RATT operator may be doing the guard job when an incoming volley strikes the RATT. This operator should not be assessed as a casualty because he is currently located far away from the incoming round. The job deployment is included in Table 4.

TABLE 4. DEPLOYMENT OF JOBS

Mission	Area	Job	X	Y	Kill Criteria					
I.	FASC	RATT Team	676.0	1112.0	1	1	1	1	1	0
		MCHAN Team	474.2	441.0	1	1	1	1	1	0
		RADIO Team	605.2	468.8	1	1	1	1	1	0
		SWBD Team	495.2	602.5	1	1	1	1	1	0
		WIRE Team	496.1	561.0	1	1	1	1	1	0
		RATT Supervisor	679.1	1109.2	1	1	1	1	1	0
		MCHAN Chief	378.4	510.4	1	1	1	1	1	0
		RADIO Supervisor	603.1	470.2	1	1	1	1	1	0
		SWBD Supervisor	489.0	606.0	1	1	1	1	1	0
		WIRE Supervisor	476.4	509.1	1	1	1	1	1	0
		Guards	610.6	331.9	1	1	1	1	1	0
		Guards	299.6	347.8	1	1	1	1	1	0
		Guards	617.3	599.1	1	1	1	1	1	0
		Guards	305.3	620.7	1	1	1	1	1	0
		C2 RADIOs	85.5	301.0	1	1	1	1	1	0
	BDE	RATT Team	676.9	1112.0	1	1	1	1	1	0
		MCHAN Team	14750.2	14667.3	1	1	1	1	1	0
		TACSAT Team	14718.1	14653.0	1	1	1	1	1	0
		TACSAT Supervision	14720.1	14653.0	1	1	1	1	1	0
II.	FASC	RATT Team	676.0	1112.0	1	1	1	1	1	0
		MCHAN Team	474.2	441.0	1	1	1	1	1	0
		RADIO Team	605.2	468.8	1	1	1	1	1	0
		SWBD Team	495.2	602.5	1	1	1	1	1	0
		WIRE Team	496.1	561.0	1	1	1	1	1	0
		RATT Supervisor	679.1	1109.2	1	1	1	1	1	0
		MCHAN Chief	378.4	510.4	1	1	1	1	1	0
		RADIO Supervisor	603.1	470.2	1	1	1	1	1	0
		SWBD Supervisor	489.0	606.0	1	1	1	1	1	0
		WIRE Supervisor	476.4	509.1	1	1	1	1	1	0
		Guards	610.6	331.9	1	1	1	1	1	0
		Guards	299.6	347.8	1	1	1	1	1	0
		Guards	617.3	599.1	1	1	1	1	1	0
		Guards	305.3	620.7	1	1	1	1	1	0
		C2 RADIOs	85.5	301.0	1	1	1	1	1	0
		Off-Duty	530.7	380.8	1	1	1	1	1	0
	BDE	RATT Team	676.9	1112.0	1	1	1	1	1	0
		MCHAN Team	14750.2	14667.3	1	1	1	1	1	0
		TACSAT Team	14718.1	14653.0	1	1	1	1	1	0
		TACSAT Supervision	14720.1	14653.0	1	1	1	1	1	0
		Off-Duty	14737.5	14680.3	1	1	1	1	1	0

TABLE 4. DEPLOYMENT OF JOBS (continued)

Mission	Area	Job	X	Y	Kill Criteria					
III.	FASC	RATT Team	676.0	1112.0	1	1	1	1	1	0
		MCHAN Team	474.2	441.0	1	1	1	1	1	0
		RADIO Team	605.2	468.8	1	1	1	1	1	0
		SWBD Team	495.2	602.5	1	1	1	1	1	0
		WIRE Team	496.1	561.0	1	1	1	1	1	0
		RATT Supervisor	678.1	1109.2	1	1	1	1	1	0
		MCHAN Chief	378.4	510.4	1	1	1	1	1	0
		RADIO Supervisor	603.1	470.2	1	1	1	1	1	0
		SWBD Supervisor	489.0	606.0	1	1	1	1	1	0
		WIRE Supervisor	476.4	509.1	1	1	1	1	1	0
		Guards	610.6	331.9	1	1	1	1	1	0
		Guards	299.6	347.8	1	1	1	1	1	0
		Guards	617.3	599.1	1	1	1	1	1	0
		Guards	305.3	620.7	1	1	1	1	1	0
		C2 RADIOs	85.5	301.0	1	1	1	1	1	0
	BDE	RATT Team	676.9	1112.0	1	1	1	1	1	0
		MCHAN Team	14750.2	14667.3	1	1	1	1	1	0
		TACSAT Team	14718.1	14653.0	1	1	1	1	1	0
		TACSAT Supervision	14720.1	14653.0	1	1	1	1	1	0
IV.	FASC	RATT Team	676.0	1112.0	1	1	1	1	1	0
		MCHAN Team	474.2	441.0	1	1	1	1	1	0
		RADIO Team	605.2	468.8	1	1	1	1	1	0
		SWBD Team	495.2	602.5	1	1	1	1	1	0
		WIRE Team	496.1	561.0	1	1	1	1	1	0
		RATT Supervisor	678.1	1109.2	1	1	1	1	1	0
		MCHAN Chief	378.4	510.4	1	1	1	1	1	0
		RADIO Supervisor	603.1	470.2	1	1	1	1	1	0
		SWBD Supervisor	489.0	606.0	1	1	1	1	1	0
		WIRE Supervisor	476.4	509.1	1	1	1	1	1	0
		Guards	610.6	331.9	1	1	1	1	1	0
		Guards	299.6	347.8	1	1	1	1	1	0
		Guards	617.3	599.1	1	1	1	1	1	0
		Guards	305.3	620.7	1	1	1	1	1	0
		C2 RADIOs	85.5	301.0	1	1	1	1	1	0
	BDE	RATT Team	676.9	1112.0	1	1	1	1	1	0
		MCHAN Team	14750.2	14667.3	1	1	1	1	1	0
		TACSAT Team	14718.1	14653.0	1	1	1	1	1	0
		TACSAT Supervision	14720.1	14653.0	1	1	1	1	1	0

6. Unit Attrition

As previously mentioned, AMORE uses probabilities to determine unit attrition and the result of that attrition on the unit's ability to operate. AURA can imitate AMORE by using the AURA "prefail" option. Three attrition levels were assumed for the baseline analyses: 10, 20 and 30 percent. The same level of attrition was used for both equipment and personnel.

7. Results

The results of the baseline analyses are illustrated in Figure 9 and Table 5. Figure 9 shows the effectiveness of the unit during each of its designated missions as a function of time. Only one time point is shown for missions II, III and IV since unit effectiveness remained constant during these missions.

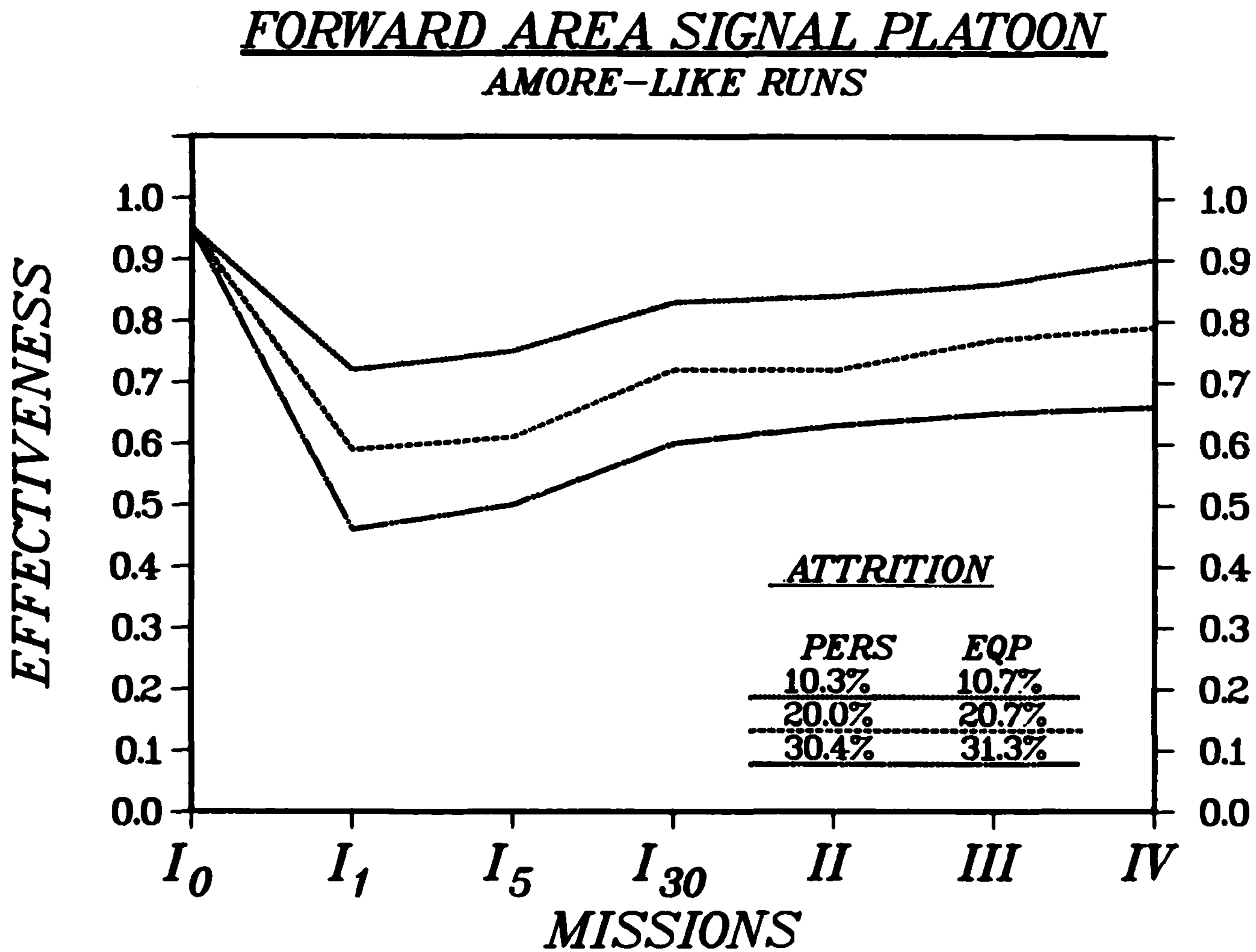

Figure 9. Effectiveness Results for Baseline Analysis

TABLE 5. LIMITING SEGMENTS FOR FASP (FOR 10 PERCENT ATTRITION CASE)

Mission	Segment	Percent of Time Limiting Effectiveness
I.	Physical Security	10
	Setup Equipment	78
	Monitor C2	12
II.	Physical Security	2
	System Operation & Maintenance	84
	Coordinate C2 Reqt.	6
	Provide rest for off-duty pers.	8
III.	Physical Security	2
	System Teardown	76
	C2 of Teardown	22
IV.	Physical Security	0
	Transport to new location	54
	C2 of move	22

Note that at time 0 in mission I (denote by I_0) the unit was not able to reach full effectiveness (100 percent). In fact, the unit was only able to do approximately 95 percent of its setup mission. In this case, that means it took the unit approximately 5 percent longer to setup the unit equipment. The reason for this initial limitation was that the unit did not have sufficient personnel to perform all the setup functions AND to provide physical security and thus was not able to perform up to 100 percent capability.

Continuous curves are used to illustrate the effectiveness results in Figure 9 and the remaining figures in this report. The reader is cautioned, however, not to interpret anything about the unit's capability at time points not plotted. For example, although it is correct to interpret the effectiveness of the unit at time 0 as being 95 percent, it is not correct to interpret the effectiveness of the unit between time 0 and time 1 as being some value between 95 percent and the value at time 0. The curves are used strictly to aid the reader.

The effects of the three different levels of attrition were evident in the drop in effectiveness during mission I. Three time points are after time 0. The value plotted at I_1 represents the effectiveness of the unit in mission I prior to any substitution taking place. The value plotted at I_5 represents the effectiveness of the unit in mission I after local substitution has taken place (ie., substitution within the FASC and within the BDE, but not between the two). The value plotted at I_{30} represents the effectiveness of the unit after substitution throughout the unit (FASC and BDE) has been completed. As mentioned previously, only one time point is shown for missions II, III and IV.

Note that the unit effectiveness dropped to approximately 70 percent in mission one with attrition assessed at 10 percent for both equipment and personnel. Given time for substitutions to take place, the unit was able to reconstitute itself for a residual effectiveness of 80 percent by 30 minutes into the mission. With 20 percent attrition, the unit effectiveness dropped to 60 percent and returned to 70 percent after substitution. A similar trend was seen when assessing the effect of 30 percent attrition on the unit.

The failure of items in AURA is modeled using a Monte Carlo technique: random numbers are drawn against (exponentially distributed) failure probabilities. It is necessary, therefore, to run a number of interactions in order to draw a sufficient number of random numbers to accurately reflect the failure distribution. This need for replications applies to all AURA runs involving Monte Carlo modeled phenomena, especially those involving the arrival of threat warheads. Thus, the effectiveness values output by AURA (and plotted in Figure 9) are actually an average of the values in each of many replications (in this case 50).

AURA provides, in addition to the unit effectiveness outputs, an audit trail throughout the scenario which details the capabilities most often limiting the unit in its effectiveness. Table 5 includes a summary of this information for the 10 percent attrition example. Shown are what are referred to as segments (ie. blocks of capability as denoted in Figures 1 through 4) and the percentage of time these segments were limiting the unit. By this we mean, the percentage of times during the 50 replications run that improvement in these segments (by increasing the number of available assets, substituting cross-trained personnel, etc.) would have resulted in an increase in unit effectiveness.

Although it is obvious, from the results shown in Table 5, that unit effectiveness was most often limited by some combination of the communications equipment and personnel setting up the equipment, it is not immediately clear (from the information given in Table 5) whether or not the "weak link" was the equipment, the personnel or some combination of both. Examination of other AURA outputs showed that improving any of several different capabilities in mission one would have improved unit effectiveness. These were: the WIRE Supervisor, the SWBD Supervisor, the TACSAT Setup Team, the RADIO Supervisor, the MCHAN Setup Team and less often, the RATT and MCHAN. Most often, it was the lack of supervisory personnel that limited effectiveness. An examination of the casualty outputs showed that the supervisors did not necessarily limit unit effectiveness because they had been attrited but that, in fact, these supervisors were needed in other jobs in which personnel had been attrited. The unit could not afford the luxury of having personnel function in strictly supervisory roles. This was reflected in the link inputs (shown in Table 2); ie., operating without a supervisor was estimated to result in only a 15 to 20 percent loss in capability (except in the case of the MCHAN Chief estimated at a 40 percent loss). So, in this case, it was a combination of both equipment and personnel that limited the unit's effectiveness.

The preceeding discussion identifies the unit's limitations. However the remaining question to be answered was why did the unit suffer an initial loss of 25 percent capability with only a 10 percent attrition rate when analyzed in the random (AMORE) mode. The answer to this question highlights one of AMORE's limitations.

AMORE calculates attrition of personnel and equipment randomly throughout the unit. In AMORE, there is no correlation between personnel and equipment and their collocation within the unit. In one AMORE replication, a RATT may be attrited, in another, a RATT Team member, in yet another, a RATT Supervisor. Although there is some probability that two of these items may be lost concurrently, the chance is quite small. Consider, for example, the RATT capability as shown for mission one in Figure 1 which includes the RATT, the RATT Team, and the RATT Supervisor. If each is independently lost approximately 10 percent of the time, it is evident that one of the three, and hence the RATT capability, will be lost approximately 30 percent of the time (the sum of the number of times some element in that subchain is limiting). This same reasoning applies to the runs assessing 20 and 30 percent unit attrition.

The casualties that would result from an actual attack are not independent of each other. Rather, individuals and equipment in a unit are correlated with each other through their deployment, function, posture, etc. Thus, for example, in the case of a volley of fire aimed at the RATT, the most likely casualties are the RATT and those personnel collocated near the RATT. It is not likely that some piece of equipment or personnel located far away from the RATT will be attrited. Therefore, it is more likely that personnel and equipment contributing to the same capability within the FASP will become casualties together. The AMORE model has no practical way to play this correlation.

In order to make this point, and by doing so highlight one of the major differences in the AMORE and AURA methodologies, sensitivity runs were made (called excursions) with AURA to explore the effect of this correlation on the unit effectiveness.

8. **AURA Excursions**

The AURA model is designed so as to make it easy to run excursions on the initial set of inputs (defined as the baseline). Two sets of excursions were completed for this study.

a. Excursion set 1. The first set of excursions examined the effects of different levels of attrition resulting from incoming enemy fire aimed at the FASP. In this first set of excursions, it was assumed that each incoming volley had an equal probability of landing anywhere in the unit. This was done in order to show the relationship between attrition and collocation of assets.

Lethality data for the personnel and equipment in the unit was developed for these excursions. The lethality data used for this analysis will not be included in the body of this report in order to keep this report unclassified. This should not be a problem to the reader, since the purpose in running these excursions was not to provide data on a realistic scenario, the type of warhead, delivery system, etc.

Figure 10 shows the results of one replication in which artillery rounds were aimed at the unit using uniformly distributed volleys of rounds. This illustration shows the actual ground zeroes (designated by the asterisks) and the lethal footprints against personnel for the rounds (designated by the circles surrounding the asterisks). Note that uniformly distributed volleys does not mean that the volleys are uniformly distributed across the unit, but that the mean point of impact of each volley has an equal probability of landing anywhere within the unit.

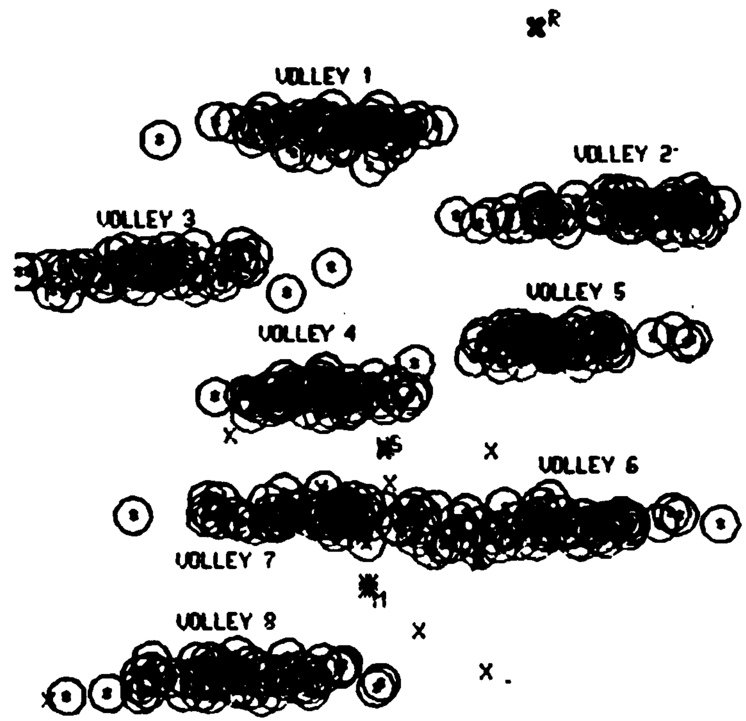

Figure 10. Example of Weapon Pattern Resulting from Delivery Errors Drawn from a Uniform Distribution

Figure 11 shows the results of this set of excursions. Shown in Figure 11 is the effectiveness of the unit after one attack (between time 0 and time 1). Notice that, in these runs, the attrition level for personnel was not the same as that for equipment. This was not surprising since personnel are more vulnerable than equipment to the selected threat munitions and thus, are more likely to be attrited. In order to make a fair comparison between this set of runs and AMORE-like runs, several AMORE-like runs (using the AURA PREFAIL option) were completed with personnel and equipment attrition levels identical to those seen in Figure 11. The results of these excursions are shown in Figure 12, labelled AMORE-Like Runs (Set 2).

Note that in all cases, the AMORE-like runs resulted in a lower effectiveness for the same attrition levels. This is seen most clearly in the runs with 18.7 percent personnel attrition immediately after the attack. This was due to the fact that when losses are caused by incoming threat munitions there is a high probability that personnel and equipment performing the same task will become casualties together. Thus, loss of a piece of equipment and associated personnel is likely to affect only one portion of the unit mission. However, an equal number of randomly selected losses will likely affect several portions of the same unit mission. Thus, these results show that the AMORE-like runs tended to overestimate unit degradation.

b. Excursion set 2. The second set of excursions completed for this analysis involved employing threats against specific areas within the FASP and included consideration of the delivery errors and weapon patterns associated with the threats. In each case, a different aimpoint or set of aimpoints was chosen and various numbers of rounds employed to achieve different levels of personnel and equipment degradation. The purpose in this set of excursions was twofold: first, these excursions further illustrate the correlation between collocation of assets and unit resiliency and secondly, they illustrate the impacts of losing various related assets within the unit.

Figure 13 illustrates the type of weapon employment used in this set of excursions. Delivery errors (both independent and correlated) were taken from a normal distribution. Thus, the result was a cluster of warhead impacts about an actual ground zero. This is the type of weapon effects likely to be seen on the battlefield. Figure 13 shows one volley of rounds impacting within the unit.

Figures 14 through 17 show the results of various excursions of this type. Notice in all cases except one, the unit resiliency remained high. Figure 17 shows the results of choosing an aimpoint within the BDE area. A dramatic drop in unit effectiveness was seen during mission one when 22 percent personnel

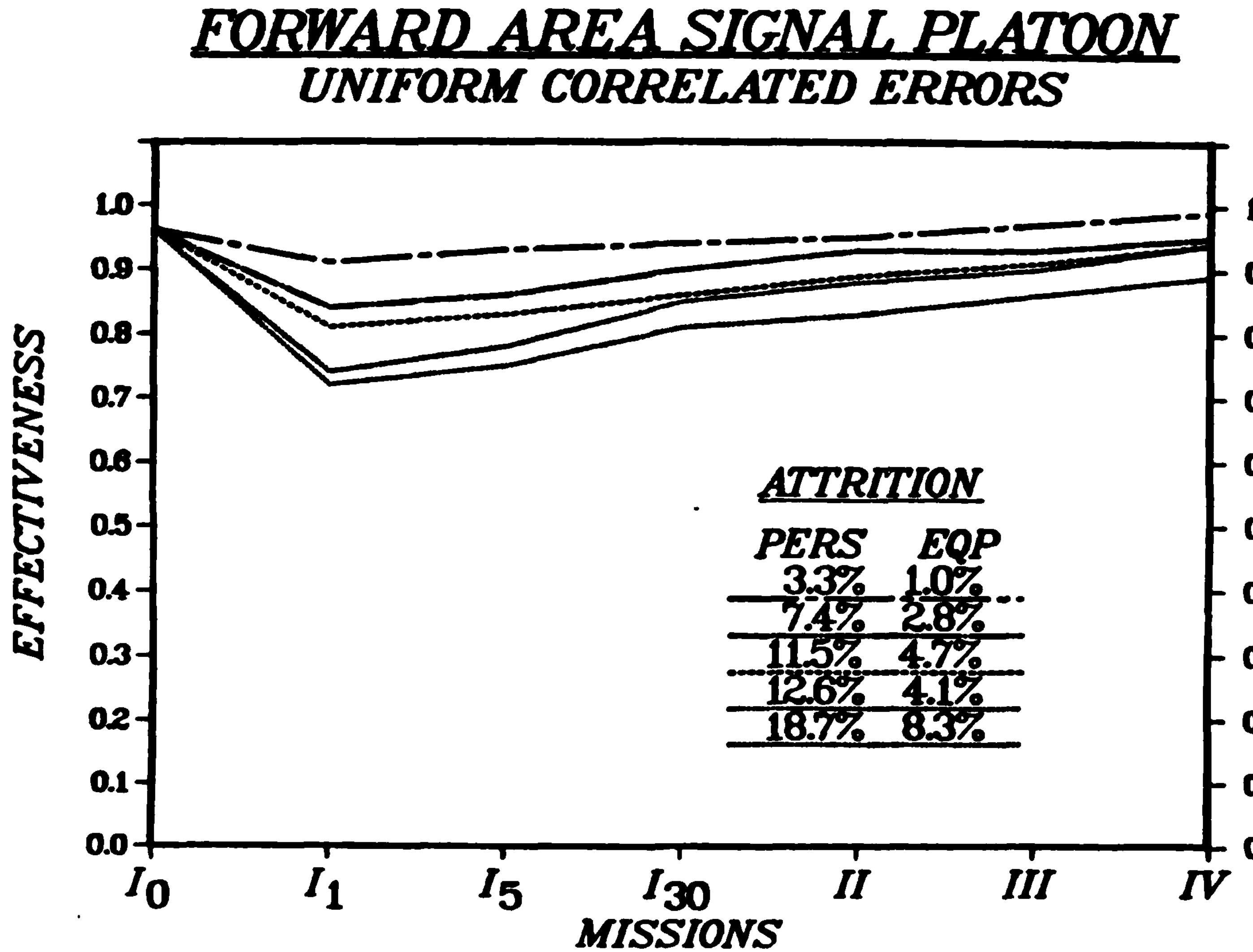

Figure 11. Excursion Set One Results

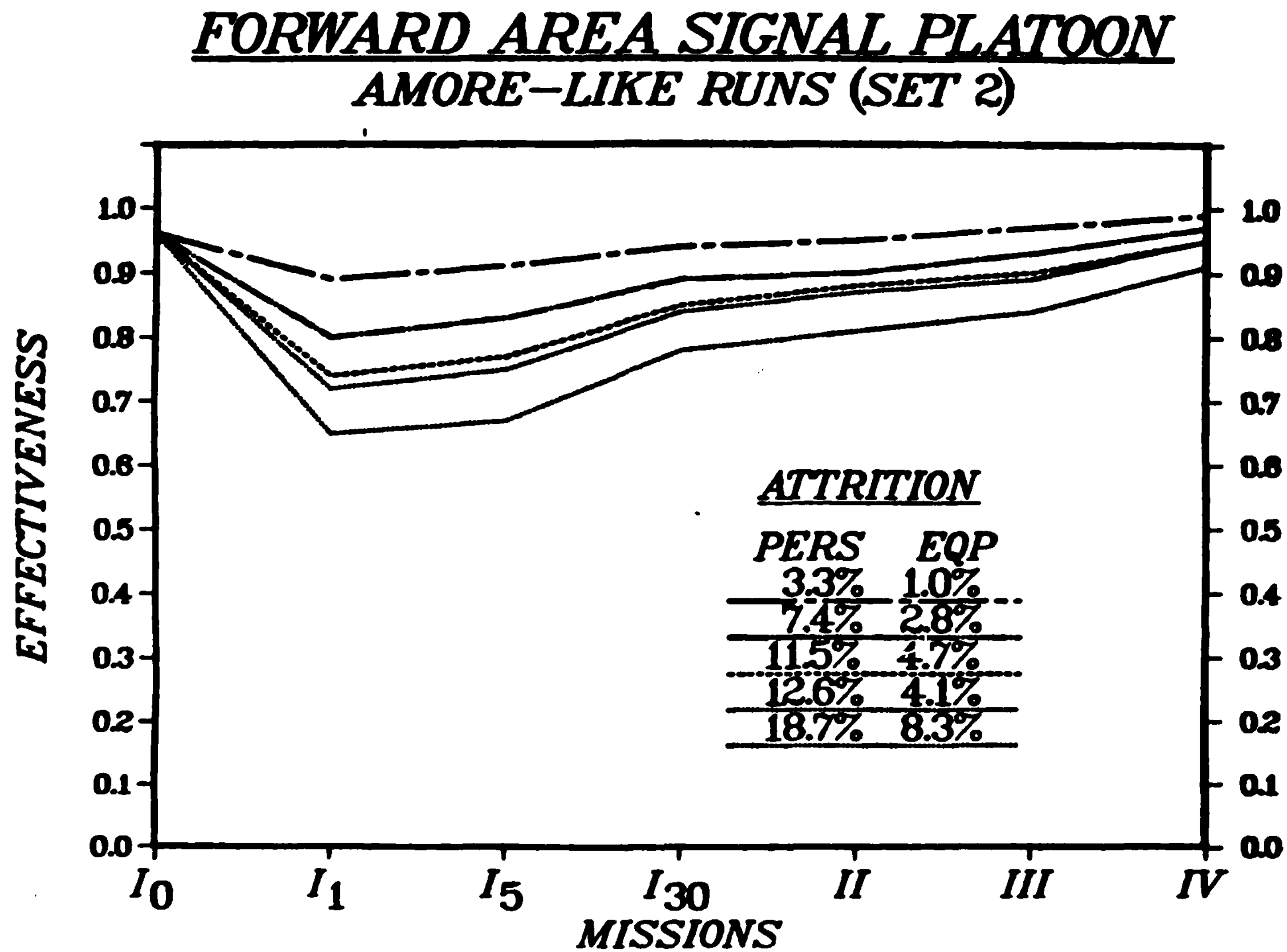

Figure 12. AMORE - Like Runs (Set 2)

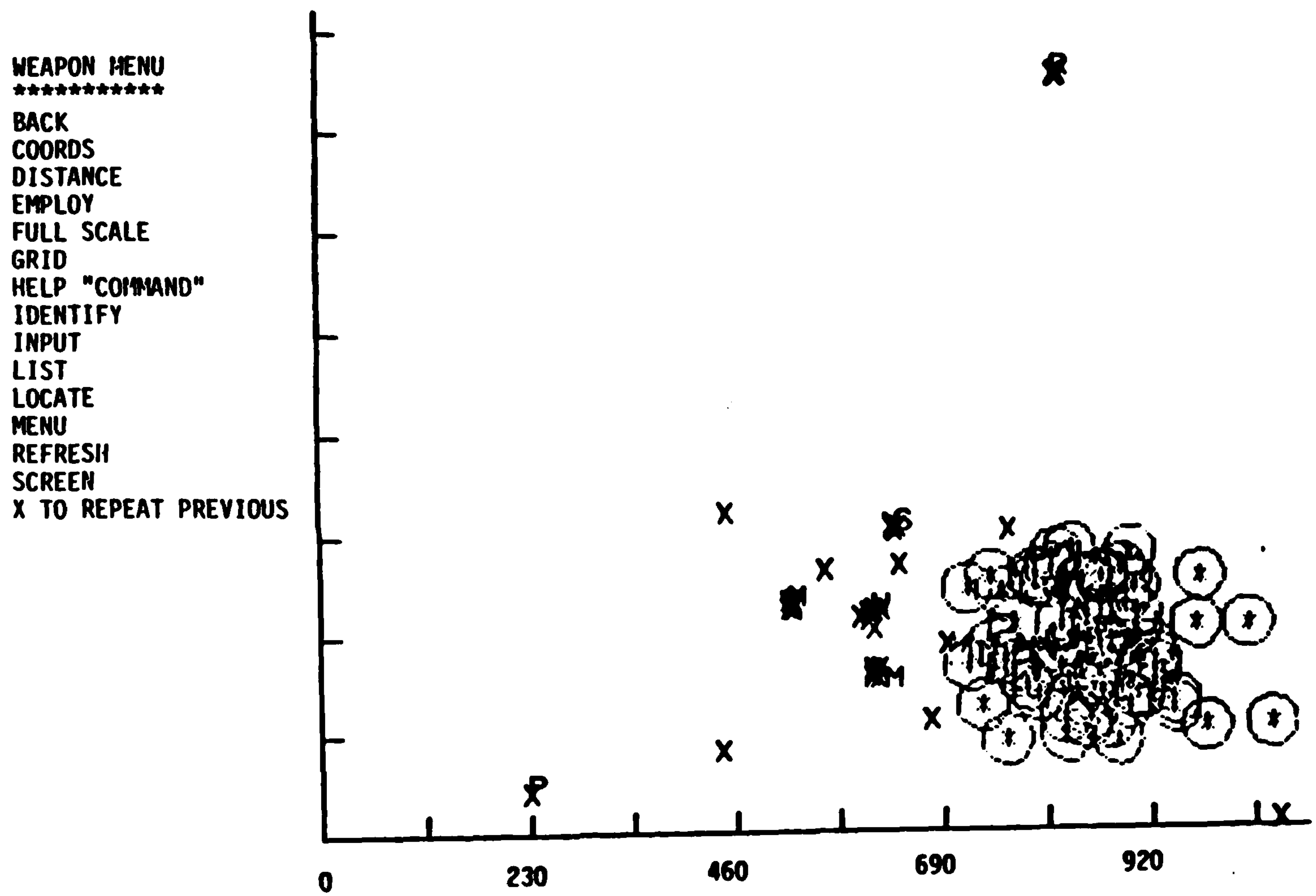

Figure 13. Example of Weapon Pattern Resulting from Delivery Errors Drawn from a Normal Distribution

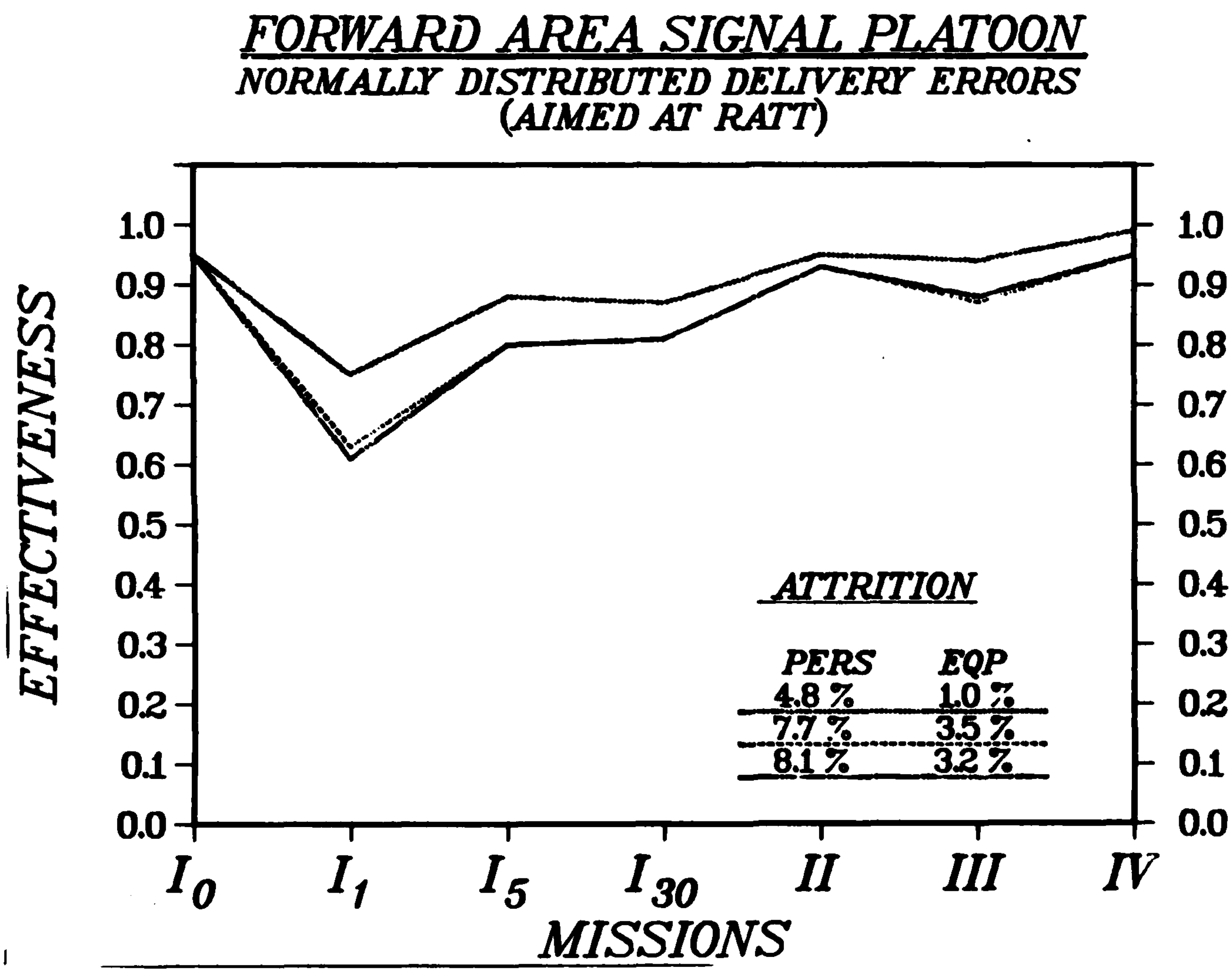

Figure 14. Excursion Set Two Results - (Incoming Fire Aimed at RATT)

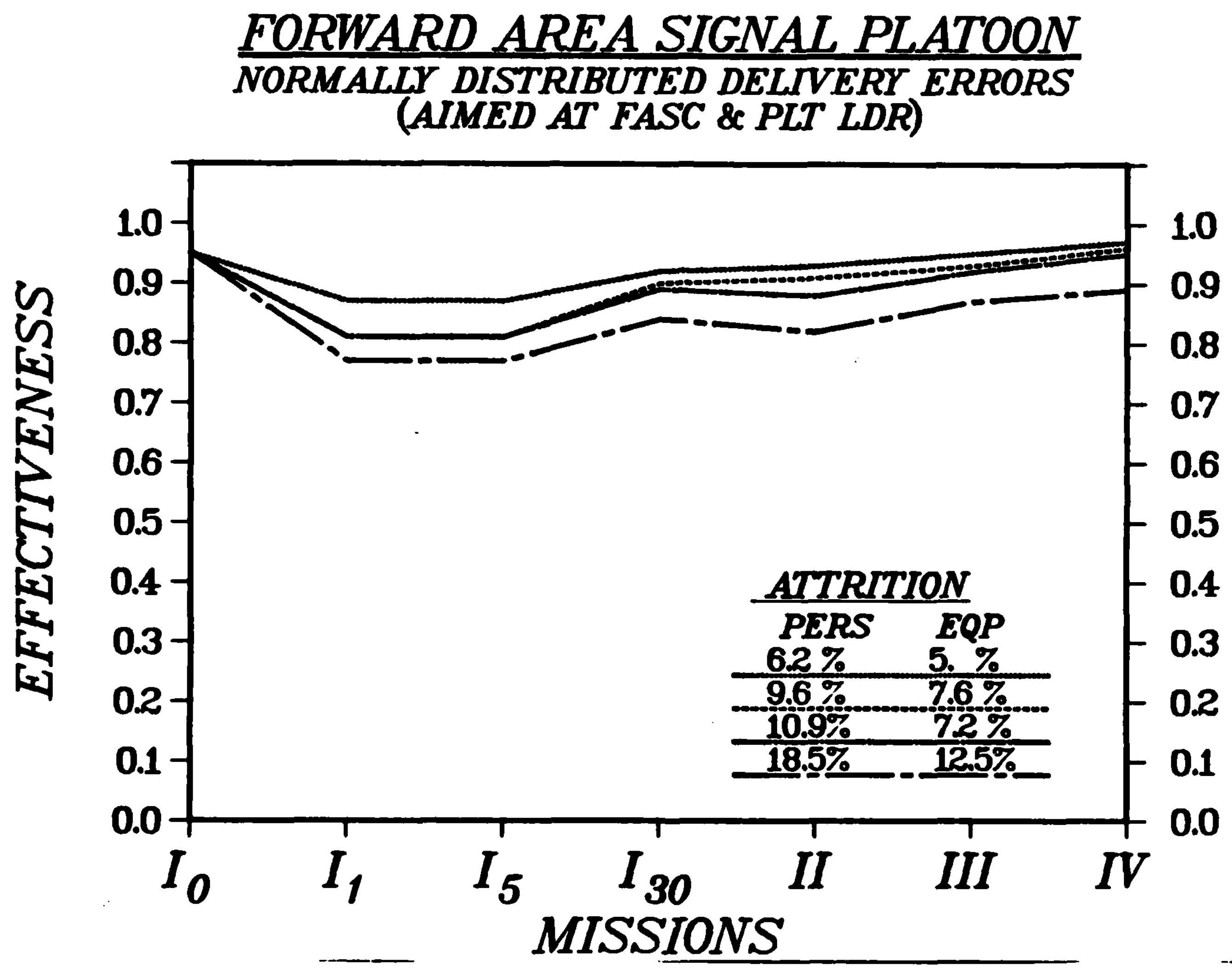

Figure 15. Excursion Set Two Results (Incoming Fire Aimed at FASC and PLT LDR)

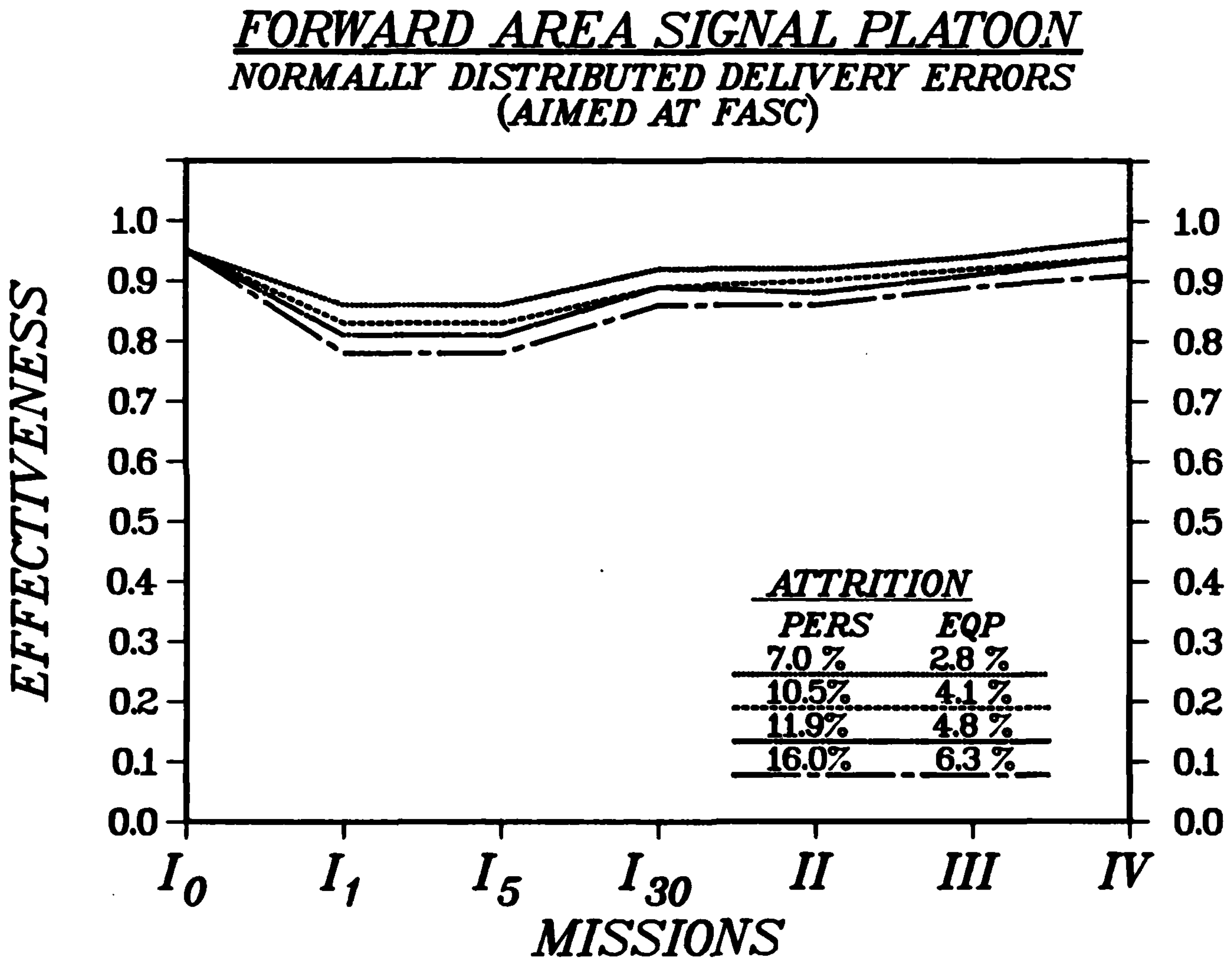

Figure 16. Excursion Set Two Results (Incoming Fire Aimed at FASC)

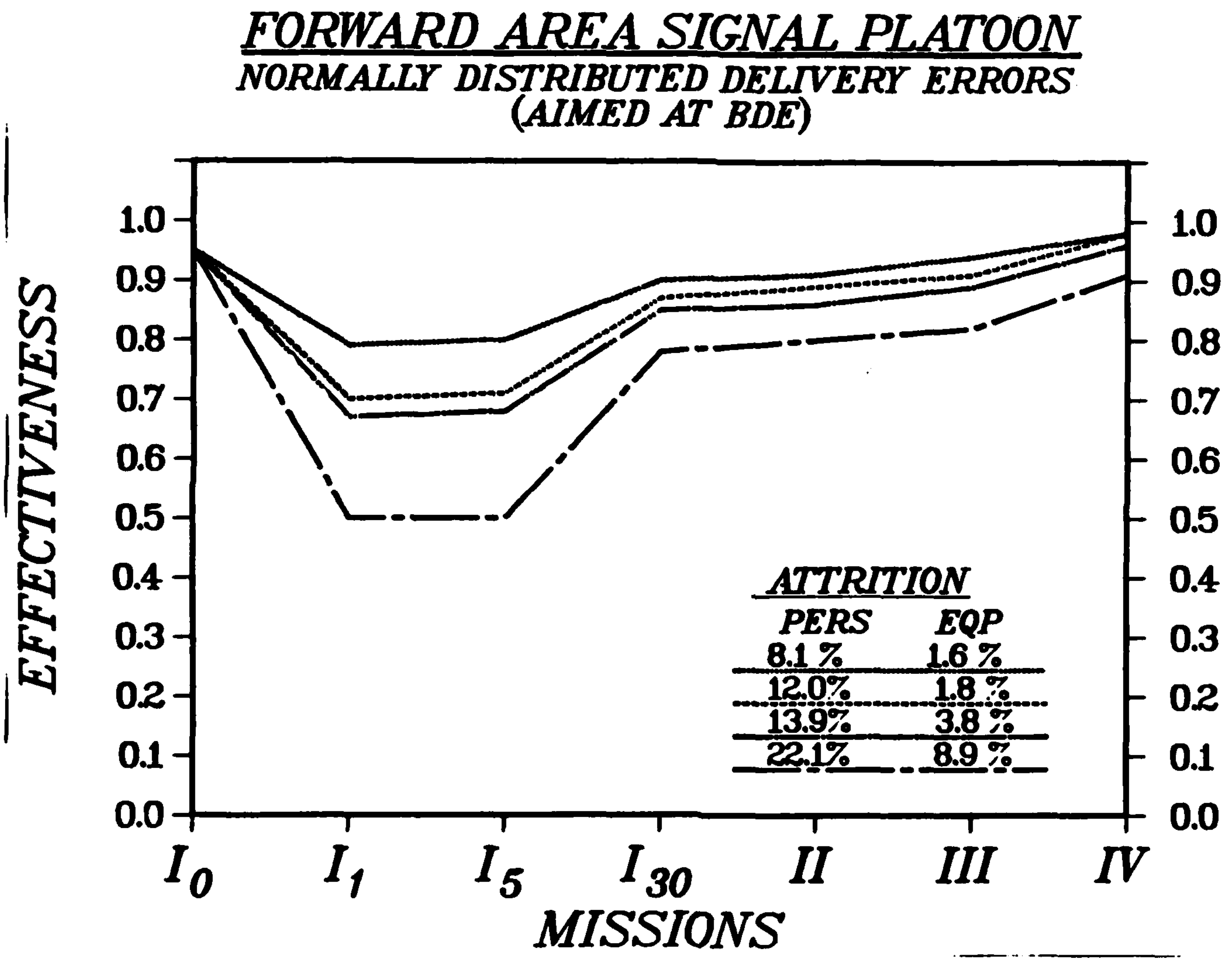

Figure 17. Excursion Set Two Results (Incoming Fire Aimed at BDE Assets)

attrition was achieved. It was determined that the personnel attrited were those operating the RATT, MCHAN and TACSAT and required substitutions were not available from the FASC until 30 minutes after the attack, at which point the effectiveness in mission one climbed back up to approximately 70 percent.

9. Conclusions

The analyses performed for the AMORE-AURA pilot study were limited in scope. This study by no means represents an in-depth, comprehensive study of a signal unit and its resiliency. A detailed analysis of the resiliency of a Mobile Subscriber Equipment platoon was completed in March of 1985 and represents a more thorough analysis of a signal unit.[1]

Recall, the purpose of this study was to compare the methodologies in terms of resource requirements, outputs, applicability and ease of use. Of note is the fact that the author has used the AURA code extensively for other studies and thus, any comments about the ease of use and applicability are bound to be somewhat subjective. With that caveat in mind, the following comments are presented on these two aspects of the study:

- The applicability of the AURA methodology as well as its ease of use were demonstrated during this study. The modelling of the operations of the FASP was relatively easy using the structures available in AURA. These structures lent themselves well to this application.

- Although the AURA methodology was developed with the user in mind, several programs have been developed at BRL to further aide the user in developing inputs and analyzing results. In fact, most of the figures used in this report are products of these programs. These graphical aies greatly enhance the user-friendliness of the AURA code.

- The development of the input data for the study was accomplished by the US Army Signal School with some interaction with the author. Once the data were developed, it took approximately one and half to two weeks to input the data into AURA, check for typographical errors, and begin production runs. The code runs very quickly, with a typical turnaround time of 10 CPU minutes. Thus, most runs were performed within a couple of days. At that time, the outputs had to be analyzed and, in some cases, additional runs were made. This analysis of the outputs took approximately four weeks.

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1. "Tactical Communications Mission Area Analysis Resiliency Study," M.M. Stark, MAJ R. Stark and M.A. Tatum, USABRL, April 1985, draft report.

The following conclusions address the results of the AURA analysis, itself.

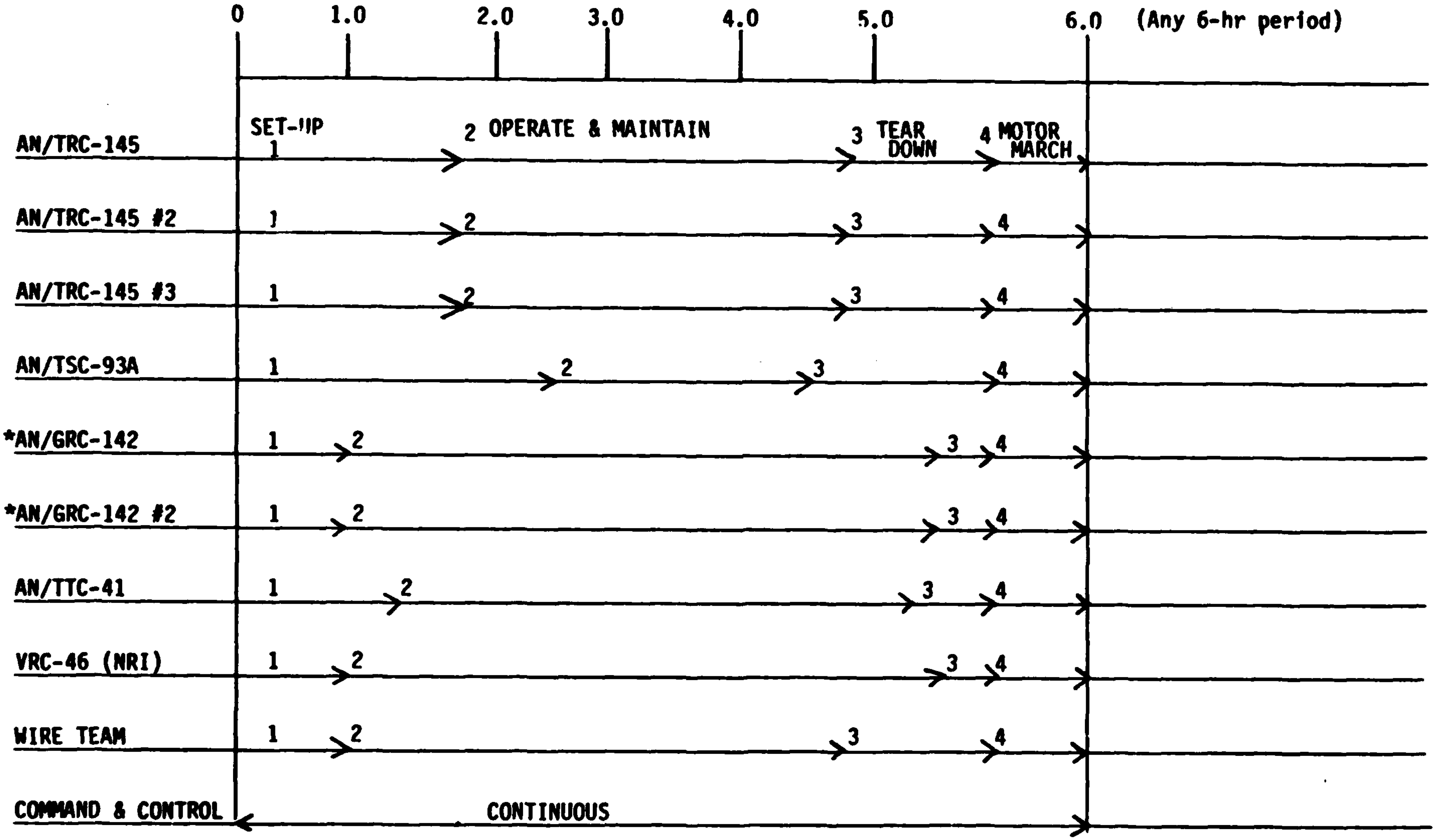
- The AMORE-like runs overestimated unit degradation for this unit.
- The FASP was moderately resilient to small attrition levels.
- Very often, the resiliency of the unit came at the cost of supervision (ie., the unit could not afford the luxury of having supervisor personnel in purely supervisory jobs).
- Even before any attrition was assessed, the FASP was overtaxed in its mission. That is, the FASP did not have the assets required to reach 100 percent effectiveness at initial time.

APPENDIX A

FASP TIME LINE

Appendix A contains a time line for the operations in the Forward Area Signal Platoon (FASP). This time line was based on the assumption that the FASP would move in support of a brigade every 6 hours during a 72-hour scenario.

FORWARD AREA SIGNAL PLATOON



* CAPABLE OF OPERATION DURING MOVEMENT

Appendix A: FASP Time Line

APPENDIX B

ORGANIZATION AND EQUIPMENT

Appendix B contains the table of organization and equipment (TO&E) for the Forward Area Signal Platoon (FASP).

TABLE B-1. ORGANIZATION AND EQUIPMENT FOR FASP

Location	Personnel	MOS	Initial Strength
FASC	PLT LDR	----	1
	PLT SGT	----	1
	MCHAN CH E6	31ME6	1
	MCHAN OP E4	31ME4	4
	MCHAN OP E3	31ME3	2
	RADIO SEC CH E6	31CE6	1
	SR RDO OP E5	31CE5	1
	RDO TTY OP E4	31CE4	1
	RDO TTY OP E3	31CE3	1
	CBT RDO CH E5	31KE5	1
	RDO OP E4	31KE4	1
	RDO OP E3	31KE3	1
	SWBD SUPV E6	36ME6	1
	SWBD OP E4	36ME4	2
	SWBD OP E3	36ME3	1
	WIRE INST CH E5	36CE5	1
	WIRE INST E4	36CE4	2
	WIRE INST E4	36CE3	1
BDE	TACSAT OP E5	26QE5	1
	TACSAT OP E4	26QE4	1
	TACSAT OP E3	26QE3	1
	MCHAN OP E4	31ME4	2
	MCHAN OP E3	31ME3	1
	SR RDO OP E5	31CE5	1
	RDO TTY OP E4	31CE4	1

Equipment	AURA name	Description	Initial Strength
TTC-41 (V) 2	SWBD	Switchboard	1
GRC-142	RATT	Radio Teletype Unit	2
TRC-145 (V) 1	MCHAN	Multichannel Unit	3
VRC-46	FM RADIO	Radio	1
	C2 VRC-46		1
GRC-106	C2 RADIO	PLT LDR's radio	1
CARGO TRUCK	PLT LDR TRUCK	2-1/2 ton truck	1
	WIRE TRUCK		1
TSC-93A	TACSAT	Tactical Satellite unit	1

APPENDIX C

SUBSTITUTION MATRICES

Appendix C contains the substitution matrices developed for the analysis of the Forward Area Signal Platoon (FASP). Included are both the substitution time and effectiveness matrices. For example, the PLT SGT can substitute for the PLT LDR within 30 minutes, in his own job and in the jobs of the MCHAN CH E6, RADIO SEC CH E6 and the SWBM SUPV E6 with no time delay. Recall, these substitution times were developed for use with AMORE and thus, do not allow non-optimal substitutions.

The AURA analysis used a modified version of this substitution time matrix along with the second table in this appendix which includes substitution effectiveness. For example, the PLT SGT can substitute for the PLT LDR and will be able to perform at 90 percent effectiveness in that job. The PLT SGT can function at 100 percent effectiveness when substituting for the MCHAN CH E6, RADIO SEC CH E6, or the SWBD SUPV E6.

PERSONNEL

SUBSTITUTION TIMES FOR THE
FORWARD AREA SIGNAL PLATOON

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1 PLT LDR	0	30																								
2 PLT SGT	30	0	0			0							0													
3 MCHAN CH E6	120	60	0	0	0														60	60	60	30	30			
4 MCHAN OP E4			240	0	0											60	30	30	90	60	60	30	30			
5 MCHAN OP E3				15	0												45	30		75	60	45	30			
6 RADIO SEC CH E6	180	120				0	0	0	0	0	0	0												30	30	30
7 SR RDO OP E5						60	0	0	0	0	0	0				30	30	30						30	30	30
8 RDO TTY OP E4						240	30	0	0	30	0	0				60	30	30						60	30	30
9 RDO TTY OP E3								15	0		15	0					45	30							45	30
10 CBT RDO CH E5						240	180	180	180	0	0	0				30	30	30						210	210	210
11 RDO OP E4							210	180	180	30	0	0				60	30	30						240	210	210
12 RDO OP E3								195	180		15	0					45	30							225	210
13 SWBD SUPV E6	150	90											0	0	0	0	0	0								
14 SWBD OP E4													240	0	0	60	30	30								
15 SWBD OP E3														15	0		45	30								
16 WIRE INST CH E5													120	60	60	0	0	0								
17 WIRE INST E4														60	60	30	0	0								
18 WIRE INST E3														75	60		15	0								
19 TACSAT OP E5			120	60	60											60	60	60	0	0	0	30	30			
20 TACSAT OP E4				60	60											90	60	60	30	0	0	30	30			
21 TACSAT OP E3				75	60												75	60		15	0	45	30			
22 MCHAN OP E4			270	30	30											90	60	60	60	30	30	0	0			
23 MCHAN OP E3				45	30												75	60		45	30	15	0			
24 SR RDO OP E5						30	30	30	30	30	30	30				60	60	60						0	0	0
25 RDO TTY OP E4						20	60	30	30	60	30	30				90	60	60						30	0	0
26 RDO TTY OP E3								45	30		45	30					75	60							15	0

SUBSTITUTION EFFECTIVENESS

PERSONNEL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1 PLT LDR	100	85																								
2 PLT SGT	90	100	100			100							100													
3 MCHAN CH E6	80	85	100	100	100														85	85	85	100	100			
4 MCHAN OP E4			75	100	100											90	90	90	80	85	85	100	100			
5 MCHAN OP E3				100	100												90	90		85	85	100	100			
6 RADIO SEC CH E6	70	75				100	100	100	100	100	100	100												100	100	100
7 SR RDO OP E5						90	100	100	100	95	95	95				90	90	90						100	100	100
8 RDO TTY OP E4						75	90	100	100	90	95	95				85	90	90						90	100	100
9 RDO TTY OP E3								100	100		95	95					90	90							100	100
10 CBT RDO CH E5						75	65	65	65	100	100	100				90	90	90						65	65	65
11 RDO OP E4							60	65	65	90	100	100				85	90	90						60	65	65
12 RDO OP E3								65	65								90	90							65	65
13 SWBD SUPV E6	75	80																								
14 SWBD OP E4													75	100	100	85	90	90								
15 SWBD OP E3																	90	90								
16 WIRE INST CH E5													85	90	90											
17 WIRE INST E4														90	90	90	100	100								
18 WIRE INST E3														90	90		100	100								
19 TACSAT OP E5			85	85	85											90	90	90	100	100	100	85	85			
20 TACSAT OP E4				85	85											85	90	90	90	100	100	85	85			
21 TACSAT OP E3				85	85												90	90		100	100	85	85			
22 MCHAN OP E4			75	100	100											85	90	90	80	85	85	100	100			
23 MCHAN OP E3				100	100												90	90		85	85	100	100			
24 SR RDO OP E5						90	100	100	100	95	95	95				90	90	90						100	100	100
25 RDO TTY OP E4						75	90	100	100	90	95	95				85	90	90						90	100	100
26 RDO TTY OP E3								100	100		95	95					90	90							100	100

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