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REPORT OF THE ARMY SCIENTIFIC ADVISORY PANEL Ad Hoc GROUP ON FIRE SUPPRESSION

JULY 1975

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J. E. Cundiff
12/2/75

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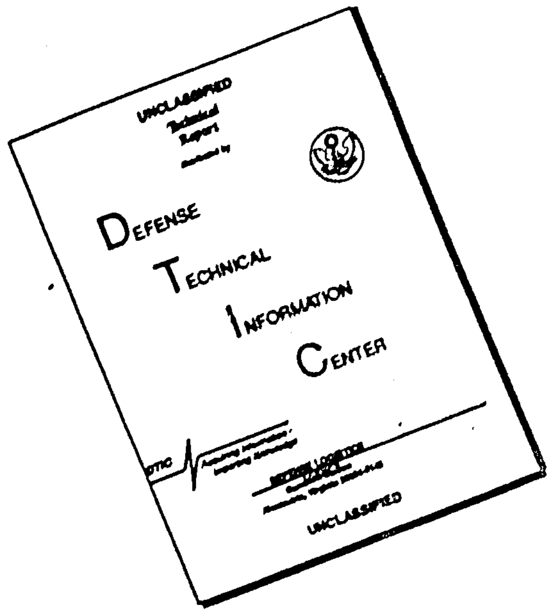

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FOREWORD

This report describes the results of an ASAP Ad Hoc Group study to provide guidance on the development and conduct of a research program on fire suppression. The report contains recommendations of immediate interest to management and technical material which we believe will be useful in conducting recommended short-term activities and in developing a potential long-term research program. Chapter 1 describes the scope of the group's efforts and presents its observations and principal recommendations. Chapter 2 describes the committee's view of the process that produces fire suppression. Chapters 3 and 4, respectively, contain material detailing technical aspects of the fire suppression process and the research program. Chapter 5 amplifies the recommended "quick fixes" to reduce suppression effects on gunners of command guided AT weapon systems.

CHAIRMAN'S NOTES

I wish to thank the following people and organizations for their work on behalf of the Ad Hoc Group on Fire Suppression --

Dr. Meredith P. Crawford, Dr. Lawrence J. Delaney, Dr. David L. Fried, and Dr. Herbert L. Ley, Members, who participated actively and indulged my forceful channeling of the discussion.

Dr. Edgar M. Johnson and Mr. Edward G. Swann, Special Consultants from the US Army Research Institute and the Naval Weapons Center, respectively, who contributed heavily to this effort, and their organizations who made them available.

LTC James R. Broome and LTC Richard K. Fickett, Military Assistants, who both contributed to the technical discussions and provided the necessary administrative support.

Dr. Marion Bryson who, although not a part of the working group, provided the field experimenter's view at one of the brainstorming sessions and contributed appendix F to the report.

The staffs at CDEC and CACDA and the instructors at CGSC, who provided valuable background information and insights into the suppression process.

SETH BONDER

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION, OBSERVATIONS, AND RECOMMENDATIONS

At the request of the TRADOC Commander, an ad hoc group on fire suppression was formed on 9 December 1974 by the Executive Committee of the Army Scientific Advisory Panel. The group was to provide guidance to the study of fire suppression by:[1,2]

(1) Briefly reviewing and assessing some of the past suppression research activities.

(2) Clarifying some of the definitions associated with the process.

(3) Defining and/or clarifying objectives of a scientific research program.

(4) Within time and resource constraints, outline the structure of a scientific research program.

Background information in the Terms of Reference (TOR) alludes to the requirement for a structured "scientific research program" (i.e., experiments, analyses, and modeling) on fire suppression leading to useful models of suppression that can be employed:

(1) In combat assessment procedures to indicate the effect of suppression on combat results (i.e., determine the value of fire suppression);

(2) To simulate suppression effects in field exercises and tests; and

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1 The term fire suppression was eventually interpreted by the group as suppression by fire; i.e., behaviors intended to lessen risk of incapacitation from firepower systems.

2 Appendix A contains the specific Terms of Reference (TOR).

(3) To address the questions

What characteristics should be designed into a suppressive fire system?

How can the effects of a suppressive fire system be reduced?

The model and data results from such a research program would be used (along with other methods) in studies to address materiel requirements, tactics, and force structure problems.

The ad hoc group was structured to include expertise in the physics of weapon systems, human physiological and behavioral processes, military operations, military operations analysis, and knowledge of previous research efforts in fire suppression. Organizational affiliations and addresses of group members are given in appendix B.

In January 1975 the ad hoc group visited the Combat Developments Experimentation Center for two days to learn about past, on-going, and planned suppression experiments and about testing capabilities.[1] The Combined Arms Combat Developments Activity (CACDA) briefed the group on 12-13 February 1975 regarding the TRADOC fire suppression program and the procedures used to represent fire suppression in their spectrum of combat assessment models.[1] During this visit to Fort Leavenworth, the group met with tactics instructors of the Command and General Staff College to discuss their live fire combat experiences and their attitudes toward and behavior in response to such fire. Five days of "brainstorming" sessions were held in March and April to develop the material for this report.

The report describes some of the thoughts, observations, and results of the group's effort in response to the TOR. The remainder of this introductory

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1 The agenda for this visit is given in Appendix C.

chapter briefly describes the scope of the group's efforts and then presents the group's observations and a summary of its principal recommendations. Chapter 2 describes a conjectured structure of the process that produces fire suppression, leading to an operational definition of fire suppression effects and a statement of an overall objective of a research program. A more detailed discussion of each subprocess in this structure is given in chapter 3 to provide a basis for the ideas on a fire suppression research program which are given in chapter 4. Short term activities are discussed in section 4.1, ideas that should be considered in the formulation of a long term research program (if justified) are given in section 4.2, and section 4.3 describes the organization of a fire suppression research office. Chapter 5 contains some quick fixes for reducing fire suppression on command guided systems and some other ideas on fire suppression. As noted earlier, appendix A contains the TOR, organizational affiliations and addresses of group members may be found in appendix B, and agendas for visits to CDEC and CACDA are given in appendix C. Appendices D and E contain reviews of some of the methods used to represent fire suppression and its operational effects in small unit action models (e.g., DYNTACS, BONDER/IUA, AIDM. ASARS, etc.) and suppression due to indirect fires, respectively. A theoretical discussion of actual versus perceived threat from a suppressive weapon is given in appendix F. Appendix G contains a bibliography of past efforts on fire suppression and related topics.

Although the report contains a number of specific recommendations regarding short term activities and the content of a long term research program, it is the group's intent that its main benefit be that of stimulating future thought regarding fire suppression. Accordingly, the report contains a broad spectrum of diffuse preliminary ideas with the view that they will be pursued at greater depth by future study efforts.

1.1 *Scope of Effort*

Suppression, in its broadest sense, includes modification of a unit's performance due to (a) actual incapacitation from firepower, (b) behaviors intended to lessen risk of incapacitation from firepower systems, and (c) confusion of senses from non-firepower systems (e.g., suppression of command control activities with EW). Although the TOR specifies the assistance requested of the ad hoc group vis-a-vis a fire suppression research program, it does not delineate the scope or limits of the research program that should be considered by the ASAP group. Since actual incapacitation from firepower has been studied extensively over the past three decades, and we interpreted "fire suppression" to mean (in part) "suppression by fire," we assumed that mechanism (b) was the one intended as the group's charge. However, the scope of the effort was still large if one considers the many possible dimensions of the types of fire suppression, the combat functions suppressed, the suppressing system suppressor, and suppressed system (suppressee). These dimensions are discussed in general below and the (limited) scope of the group's deliberations noted thereafter.

*Types of Fire Suppression

Fire suppression may be categorized into two classes -- reactive and threat. Reactive fire suppression is defined as suppression *caused by the delivery* of firepower (e.g., a Dragon gunner stops tracking a target upon sensing the receipt of a pattern of fire around his area). Suppression *caused by the threat* of delivery of firepower is referred to as threat fire suppression (e.g., a Dragon gunner no longer exposes himself in order to fire on a unit of tanks after deducing from the pattern of incoming rounds that he has been pinpointed, or because of the possibility of being pinpointed; and ADA battery may not fire at an airborne FAC for fear of disclosing its position and eventually being engaged). Note that threat suppression may or may not be activated by stimuli from incoming rounds, but can result from other information. The distinction between reactive and threat fire suppression is discussed further in Chapter 2.

*Suppression of Combat[1] Activity

Suppression by fire can suppress a number of combat activities individually or in combinations, including firing, search for and observation of targets (acquisition), movement of an element or elements within a small unit engagement (maneuver), movement of a unit to different locations between engagements[2] (mobility), and command-control.

*Suppressing System (Suppressor or Generating Mechanism)

-Weapon System Type

(1) Indirect Fire (LOS not required between the system and the target and thus cannot be affected directly by the suppressee)

-artillery
-mortars
-grenades
-fixed wing aircraft
-attack helicopters
-
-
-

1 Includes communications.

2 The commonly referred to area denial suppression might be more usefully thought of as suppression of the mobility function.

(2) Direct Fire (LOS required between system and target)

-tanks
-AT system
-machine guns
-rifles
-tactical aircraft
-attack helicopters
-air defense guns
-artillery (laser designated)
-
-
-

-Munition Type

(1) Delivery
-projectiles
-missiles
-grenades
-bombs
-rockets
-
-
-

(2) Warhead
-area lethality
HE
Napalm
Nuclear
Chemical
-
-
-

-impact lethality
APDS
HEAT
Bullets
-
-
-

-Mission

-Attack
-Defend
-Delay
-Withdraw
-
-
-

- Task
  - Base of Fire (fixed overwatch)
  - Bounding Overwatch
  - Assault
    -
    -
    -
- Activity
  - Firing
  - Maneuvering
  - Search and Observation (acquisition)
    -
    -
    -

*Suppressed System (Suppressee)

- Force Size
  - An Individual
  - Weapon Crew
  - Squad
  - Platoon
  - Company
  - Battalion
  - Brigade
    -
    -
    -
- Type
  - Dismounted Infantry
  - Mounted Infantry
  - Mortar Crew
  - A.T. Crew
  - Tank Crew
  - Field Artillery Crew
  - ADA Crew
  - Attack Helicopter Crew
  - Tactical Aircraft Crew
    -
    -
    -

-Protection Level

- -Exposed
  - Standing
  - Prone
- -Terrain Shielded
- -Armor Shielded
- -Vehicles
  - Unarmored
  - Armored
  - -
  - -
  - -

-Mission

- -Attack
- -Defend
- -Delay
- -Withdraw
  - -
  - -
  - -

-Task

- -Base of Fire (fixed overwatch)
- -Bounding Overwatch
- -Assault
  - -
  - -
  - -

-Activity

- -Firing
- -Maneuvering
- -Search and Observation (acquisition)
  - -
  - -
  - -

*Environmental Conditions

- -Day/Night
- -Terrain
- -Weather
- -Climate
  - -
  - -
  - -

Clearly, research programs to study fire suppression processes for all possible combinations of the above dimensions would take many generations to complete. Although ideas eventually developed by the group are believed applicable to the study of most of the fire suppression processes noted above, the group's deliberations were focused around (and it is recommended that an eventual research program initially consider) the following dimensions:

*Reactive and that threat fire suppression which may follow the reactive one[1]

*Fire suppression that occurs within tactical company level combined arms engagements

*Suppressing systems
- -All ground and air launched weapon system types
- -Munition types
    - -all delivery types
    - -impact and fragmentation warheads only

*Suppressee systems
- -Force size
    - -the individual
    - -weapon systems crew
- -Type -- in order of priority
    - -those that fire command guided munitions
        - -anti-tank systems
        - -designator crews (e.g., laser designators for CLGP, etc.)
        - -tanks
        - -attacks helicopters
    - -dismounted infantry
    - -artillery crew
    - -other crew served ground weapons plus helicopters (omitting tactical aircraft)

*Functions suppressed -- those associated with an individual and weapon system crew in a combined arms engagement (firing, acquisition, maneuver, communications, etc.)

*Day and Night environments

[1]This excludes the threat fire suppression which causes changes in assigned tasks, i.e., change in suppressee's target, call for fire support on suppressor, etc.

Although nuclear aspects are excluded from this recommended scope, we believe the implications of suppression by tactical nuclear weapons are potentially so significant that a separate study of this issue should be conducted.

1.2 *Principal Observations*

This section of the report lists the group's principal observations regarding the state of knowledge, current research efforts, models, etc., of the fire suppression process which serve, in part, as a basis for some of our recommendations.

1. Although suppression by fire is a current and important topic in the military operations and planning community, we believe there does not exist a good understanding of the mechanisms which cause it nor an operationally useful description of the process.[1]

2. Based on briefings provided by CACDA, the TRADOC suppression program has as its objectives to: (a) develop models of suppression effects to compare alternative weapon systems in their suppressive capabilty; (b) define data requirements for these models; (c) identify data gaps and recommended experiments, tests, and studies to alleviate them; and (d) insure that all combat models that include suppression effects are consistent and will be improved as better information becomes available. Regarding this program, we observe that:

[1]Appendix G contains a bibliography of past efforts on fire suppression and related topics.

(a) Although the group found a high level of interest and concern about the subject of fire suppression, the TRADOC program, which is decentralized among the combat arms schools, CACDA, and CDEC, does not appear to have a master plan as a structure for effectively integrating the diverse efforts. There were no apparent direct, clear lines of responsibility for *technical* guidance and supervision of the overall effort.

(b) Except for the CDEC efforts, there does not appear to be a sufficient commitment of *technical* resources to the development of a unified and integrated fire suppression program. For example, while the Combined Arms Combat Developments Activity (CACDA) at Fort Leavenworth was recognized as the proponent for all of TRADOC's fire suppression study efforts, only one officer was assigned the responsibility for coordinating the fire suppression efforts of CACDA, CDEC, and the combat arms schools.

3. Although the Army's emphasis on "performance-oriented" training with increased "hands on" experience is an appropriate environment to do so, there does not exist a set of guidelines and realistic devices to train soldiers in appropriate behavior under suppressive fire for different combat situations.

4. There exist a number of different representations of fire suppression in TRADOC's and other combat assessment models (see

appendices D and E). These representations contain a number of questionable behavioral assumptions regarding the stimuli causing suppressive reactions, their duration, and their effects on performance. For example, the small unit action models generally use as input a constant duration of suppression of 10 - 60 seconds, while discussions with instructors of CGSC and staff of CACDA revealed that, in the recent mid-East war, a non-killing KE round hit on the turret of a tank at times caused the crew to stop activity for eight to ten minutes.[1] Although there have been a number of papers written reviewing the models (including appendices D and E), there is a need for a *critical* evaluation of the models, associated data bases, and methods of including suppression in field experiments

5. There appears to be an unsupported assumption underlying much of the thought and writings about suppressive fire that it is necessarily good for the suppressor and bad for the suppressee. In fact, it is liable to enhance some of the suppressee's capabilities and degrade those of the suppressor, and it is not difficult to specify a sequence of activities and results in which suppressive fire serves to reduce the combat effectiveness of the suppressor force.[2] The importance of suppressive effects on combat outcomes as compared to other effects areas has not been adequately quantified.

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[1]The suppression duration is an important component in the suppression submodels and, *a priori*, can have a significant effect on predicted combat results.

[2]This is due, in part, to the fact that combatants are not always rational in a game-theoretic sense.

6. Fire suppression is a complicated process involving many physical, environmental, physiological, behavioral, and operational variables, and, accordingly, will require major research program efforts[1] to develop credible knowledge that is useful for military planning. Such a program will, of necessity, require significant experimentation which will be difficult to perform directly because of social, ethical, and legal constraints on subjecting humans to risky situations.

1.3 *Summary of Principal Recommendations*

This section of the report presents a listing of the principal recommendations developed by the ad hoc group. Rationale underlying the recommendations is developed throughout the remainder of the report.

A. Definitions and Research Objectives

1. As a basis for a research program, define fire suppression as

   "...a process which causes temporary *changes* in performance capabilities of the suppressee[2] from those expected when functioning in an environment he knows to be passive. These changes are caused by signals from delivered fire or the threat of delivered fire, and they result from behaviors that are intended to lessen risk to the suppressee"

   and associate the degree of fire suppression effects with the joint probability distribution of the random variables which describe the amount of the changes in performance capabilities over time.[3]

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[1]In magnitude not unlike the lethality research efforts that have been performed by the Army and other services over the past three decades.

[2]Some of these changes may be viewed as having occurred to the suppressor's capabilities.

[3]Notationally, FIRE SUPPRESSION EFFECTS $\equiv g(\Delta p_1(t), \Delta p_2(t), \ldots, \Delta p_n(t))$, where Δp_i are the variables "changes in performance capabilities," t is a time variable, and g represents the joint probability distribution of the Δp_i.

2. The overall objective of a fire suppression research program should be to relate the changes in performance capabilities to physical and operational characteristics of suppressive weapon systems, combat operation descriptions, and environmental conditions either directly or through a hierarchical structure of the type described in this report.

3. For reasons identified in the report, it is not clear that initiation of a major fire suppression research program is warranted or justified. Rather, the scope should be limited and the program should be sequential in nature to develop more information before committing long term resources. The sequential nature should be implemented via a two-year short-term effort and then, if justified, a long-term research program.

4. Initial efforts in a study and research program should focus principally on "reactive" fire suppression processes in contrast to "threat" fire suppression, and on the fire suppression combinations recommended in section 1.1 of this report.

B. Short Term Study Program (2 years)

1. Evaluate, expand, enrich, and add precision to the definitions, structure, and ideas described in the ad hoc group's report. Define specific variables (i.e., weapon system characteristics, signals, population characteristics, behaviors, performance capabilities, etc.) for fire suppression combinations of interest.

2. Perform a *critical* evaluation of the behavioral fire suppression submodels contained in the spectrum of small unit and indirect fire combat assessment models.

3. Using the existing combat models,[1] perform a comprehensive parametric analysis on the behavioral assumptions underlying the suppression submodels (i.e., mechanisms causing suppression, capabilities affected, duration of suppression, levels of suppression, etc.), *in kind and degree* to determine the

   (a) combat value of fire suppression *vis-a-vis* other effects areas, and

   (b) critical behavioral assumptions.

   The analysis should be completed in the two year period. It should be used to determine if investment in an expensive, long-term research program is justified, and, if so, the appropriate areas of focus, bounds, priorities, etc. for experimentation, analysis, and modeling.

4. CDEC experimentation on fire suppression should be continued with the following objectives:

   (a) refine techniques and procedures for field simulation and experimentation of fire suppression processes and measurement of relevant variables;

   (b) develop fire suppression data for cost and operational effectiveness analyses and bounds for the parametric analysis noted in (3) above; and

[1]For example, a combined use of DYNTACS and AIDM.

(c) experimentally examine the operational feasibility and value of "quick fixes" to reduce the suppressibility of command guided weapon systems.

5. Design and conduct a set of "signals" experiments with gunners of command guided anti-tank weapon systems to determine what signals of fire directed at his position a gunner can detect and how well. The intent of these experiments is to examine our conjecture that such gunners may not detect suppressive stimuli (and react appropriately) as often as commonly assumed.

6. Perform preliminary investigations on promising experimental and analytic approaches for possible use in a long term research program. (Some possible approaches are discussed in section 4.2).

7. Analyze the technological feasibility, operational feasibility, costs, and operational value of the "quick fixes" cited below to reduce the suppressibility of command guided weapon systems.

8. Develop performance-oriented guidelines and devices to train combat soldiers to assess more accurately the risk associated with suppressive fire and in appropriate behaviors under suppressive fire.

9. Perform systematic interview and questionnaire studies to obtain, document, and analyze the fire suppression experience of Vietnam veterans. If possible, similar studies should be conducted with Israeli, Egyptian, or Syrian combat veterans.

10. The US Army Foreign Service and Technology Center (FSTC), Intelligence Threat Analysis Detachment (ITAD), or other appropriate intelligence agencies should be tasked to provide intelligence on the role of suppression in foreign military forces. This intelligence should include current doctrine, tactics, and training related to fire suppression and the existence of related applied research, technological developments, organizations, facilities, and programs.

C. <u>Long Term Research Program (if justified and feasible)</u>

1. Although no one "best" approach exists, and multiple methods should be employed, the main thrust of a research program should be experimental rather than analytical or historical. The experimental approach will be expensive and technically risky, but it is the only one that holds promise of providing credible and useful information. To reduce costs and insure timely and directly useful information, the experiments should be system and situation specific rather than parametric in nature.

2. The experiments and modeling efforts should be partitioned in a heirarchical manner into:

   (a) Signals research which relates input signals to the suppressee to weapon, operational, and environmental variables.

   (b) Human research which relates fire suppression behavioral reactions to signals input to the suppressee, given an operational and environmental setting, and

   (c) Performance effects research which relates changes in performance capabilities (e.g., aiming, acquiring, tracking, etc.) to behavioral reactions caused by suppressive fire, given an operational and environmental setting.

3. Human research should utilize both field and laboratory experiments. The latter should utilize ideas and procedures contained in the "studio simulation" approach described in Section 4.2 of the report. Although they contain a number of current weaknesses, the CDEC "game" and "credibility" field experiment approaches are potentially powerful. Analysis should be conducted to develop a conceptual basis for eliminating their weaknesses. Guidelines for such experiments are delineated in the report.

4. Experiments on "performance effects" can and should be conducted using restricted experimental situations which focus on performance of specific activities without detailed realism or feedback of combat results required in the human research area.

5. "Risk correlation" and "risk transfer" procedures should be considered as a means of further reflecting the impact of real risk on performance changes caused by suppressive fires. Assuming they do not violate legal, ethical, or social constraints, the combat stress situations (described in the report) to determine the validity of these procedures should be considered for inclusion in the long term research program.

6. Basic and exploratory research on processes underlying suppression should be initiated to support the recommended applied research program. Areas where such effort is needed are noted in the report.

D. Quick Fixes for Reducing Suppression of Command Guided Weapon Systems[1]

1. Modify direct fire (e.g., TOW) and precision guided (e.g., CLGP) weapon systems so that they can deliver fire at a target without exposure of the gunner or forward observer to suppressive fire through the use of optically-guided munitions technology.

2. Use rate-aided tracking technology to provide for continued guidance commands of command guided and laser designated munitions during the temporary loss of line of sight caused by suppressive fire.

3. Technologies such as charge coupled devices (CCD) for motion detection, IR sensors for flash detection, etc., being developed under the Army-ARPA-MIT HOWLS program should be examined as a means of rapidly pinpointing and direction of counterfires at the source of suppressive fire.

4. Consider the development of inexpensive, rapidly-deployable "decoy" systems that will simulate the firing signature of DRAGON and TOW for the purpose of diluting suppressive fire from actual systems.

5. Consideration should be given to training DRAGON and TOW gunners in better estimation of the closeness of rounds, bursts, etc., and assessment of associated danger so that they can assess the true risk of incoming suppressive fire and take appropriate action.

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[1] [illegible] [illegible]dition, a number of recent attempts to reduce these suppression [illegible] include the use of body armor, tactical deployment to fire from [illegible] foxhole," and mounting the system on armored vehicles.

E. Suppression Research Office

1. A Suppression Research Office (SRO) be formed under the overall direction of TRADOC to manage a fire suppression research program. The office should be responsible for:

   (a) Performing, or having performed, the ASAP short term study efforts recommended above.

   (b) Developing details of a long term research plan.

   (c) Performing, or have performed, the following elements of a long term research program:

   (1) Development of Outline Test Plans (OTP) for experiments.

   (2) Analysis of experimental results.

   (3) Development of appropriate fire suppression models.

   (d) Controlling, coordinating, and integrating the efforts and results of the research activities.

   A schedule of some of these activities is given in section 4.3 of this report.

2. The SRO initially should be provided a nucleus of a seven-person technical staff composed of one 0-6 combat arms officer as Director, two senior behavioral scientiests, two senior operations research analysts, one senior physicist, and one senior statistician, plus two persons for administrative support.

3. In addition to the currently planned resources for CDEC fire suppression efforts, approximately 12 - 15 person-years of effort should be provided by other organizations to assist in performing

some of the short term study activities. The SRO should be given a high priority for tasking this required support.

4. In view of the magnitude and uncertainties associated with it, it is recommended that an in-depth ASAP review of the short term study program results be made prior to a commitment to a long term fire suppression research program.

CHAPTER 2

STRUCTURE OF THE FIRE SUPPRESSION PROCESS

This chapter describes a conjectured structure of the process that produces fire suppression. This description is used as a basis for operationally defining fire suppression effects and an overall objective of a fire suppression research program. A more detailed discussion of each subprocess in this structure is given in Chapter 3.

2.1 *An Overview Description*

Figure 1 is a schematic description of the sequence of processes that are conjectured to occur in a single time slice when suppressive fire is delivered and affects combat results. The sequence is repeated, with appropriate feedbacks, in succeeding time periods. Although shown in the figure, the combat engagement process is not deemed part of the fire suppression process (in fact, the opposite is true). It is included in the schematic to indicate variables of the combat process effected by fire suppression and because combat results dynamically feedback and affect the fire suppression process.

The description was useful to the ad hoc group's deliberations and, we believe, will serve as a useful paradigm for the analysis community by

(1) providing a semantic base for communications within a suppression research program;

(2) providing a means of organizing existing information (e.g., studies, experiments, etc.) regarding fire suppression, and thus highlighting voids;

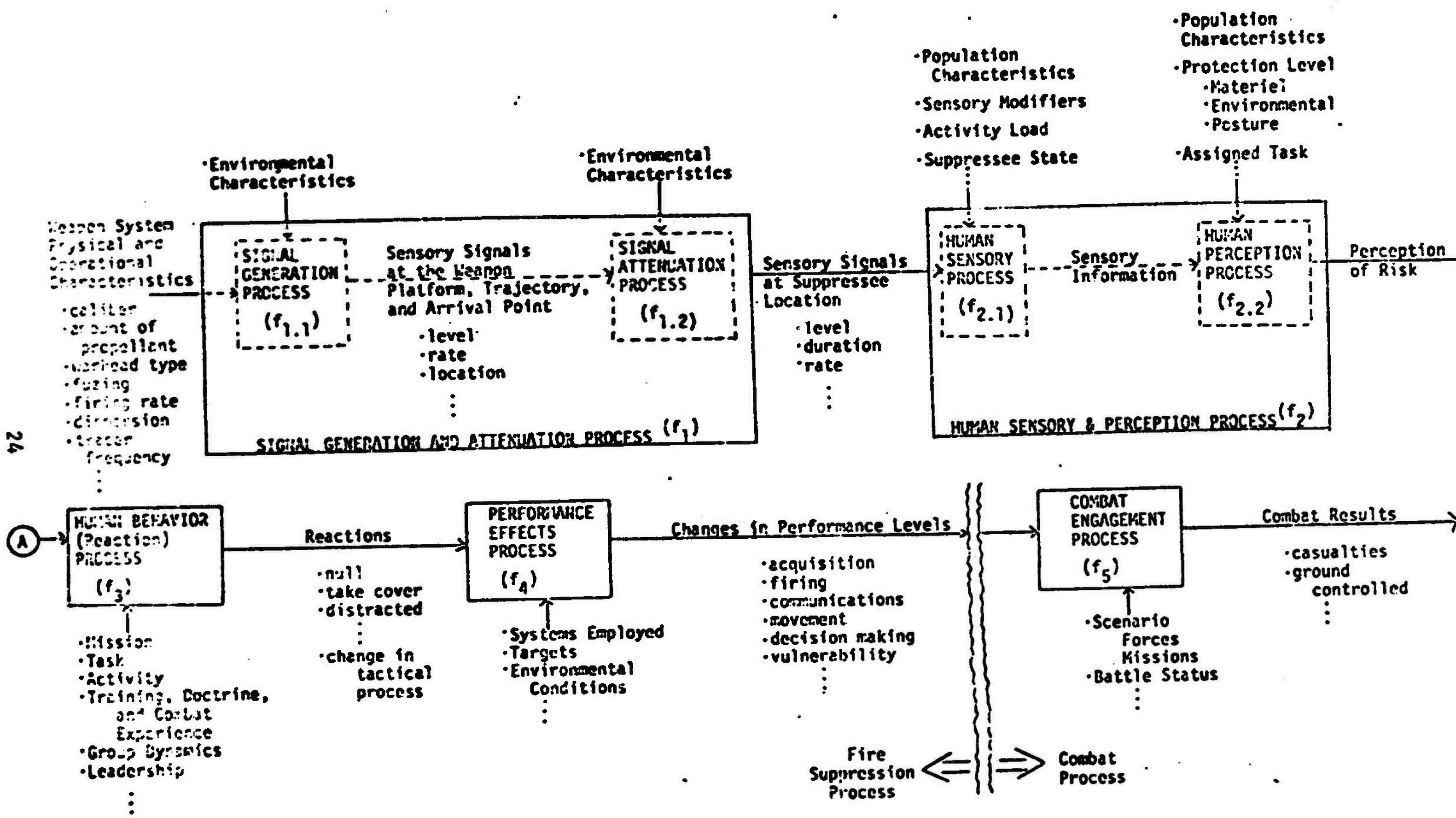

FIGURE 1: SCHEMATIC STRUCTURE OF THE FIRE SUPPRESSION PROCESS

(3) suggesting where in the overall process experiments might be feasible or need not be conducted;

(4) indicating where in the process the questions posed on page 2 (as the charge to a fire suppression research program) might be addressed; and

(5) suggesting an operationally useful definition of suppression effects.

The reader is cautioned that the schematic structure is not intended to suggest that separate experiments, analyses, and modeling will have to be conducted on each process in an eventual research program. In fact, it is reasonably clear even at this early structuring phase, that, as indicated in the figure, it is not feasible to examine the human sensory and the human perception processes separately, and it is more practical to consider the combined signal generation and attenuation process. Each process is included in the schematic for completeness of information content and exposition.

Each of the processes shown in Figure 1 requires a set of inputs and produces a set of outputs. With an anticipated modeling perspective, the process might be described by individual functions, and accordingly, are so labelled f_1 and f_5. Each of these is briefly discussed below, and, (except for the combat engagement process) in greater detail in Chapter 3.

Signal Generation Process ($f_{1.1}$)

Inputs to this process are the suppression weapon system's characteristics that generate sensory signals (which give rise to suppression effects) and the environmental characteristics which influence the level, duration, etc; of these signals. The weapon characteristics include its physical design parameters (e.g. caliber), amount of propellant, system dispersion, warhead type, tracer frequency, etc.) and its operating mode (e.g., firing rate employed, aiming pattern, firing range, etc.) characteristics which can be varied to increase or decrease the system's suppressive effects. Outputs are the sensory signals produced at the weapon system platform, along its trajectory, and at the arrival point of the round when the system is fired. The primary signals might be conjectured to be visual and auditory with olfactory and tactile of secondary importance. It should be (at least conceptually) relatively straightforward to estimate the level, duration, rate, etc. of these signals at their generated locations by existing methods of physics.

Signal Attenuation Process ($f_{1.2}$)

Inputs to this process are the stimuli (such as light, sound, etc.) generated by the weapon system (or some other mechanism) when it is fired (i.e., output of the signal generation process) and the characteristics of the environment which modify these stimuli as they are transmitted to the location of the suppressee. The weapon system input stimuli are those generated by the firing platform, the trajectory of the ordnance, and arrivel of the ordnance. Outputs of this process are the attenuated sensory signals that become input to the human sensory receptors. As with the signal generation process, at least conceptually, this process can be analyzed and modeled by existing methods of physics to predict input to the human sensory process. Combining analyses of the signal generation and attenuation processes, characteristics of sensory signals produced at the suppressees's location can be estimated as a function of the weapon system and environmental characteristics.

Human Sensory Process ($f_{2.1}$)

The human sensory process converts input physical stimuli into sensed information for the human. Conceptually, this occurs by evoking the human's sensory receptors (photo, audio, tactile, etc.) and the degree to which this occurs is influenced by gunner population characteristics (different sensor receptor systems), sensory modifiers (e.g., ear plugs, laser alarms, etc), sensor loading, the degree of activity loading (e.g. gunner involved in tracking and firing on a target may not sense a visual or auditory signal which would exceed a sensory threshold in the absence of such tasks or he may misestimate the miss distance of a projectile from auditory cues), and the state (e.g., posture of the suppressee).

Human Perception Process ($f_{2.2}$)

This cognitive process synthesizes or integrates sensory and other information to develop a perception of the risk involved in the situation that is cued by the sensed information.[1] The perceived risk depends on the individual's experience and training (population characteristics) *in assessing risk from sensory information* (perhaps by associating the sensory data with a particular weapon system and the latter's (inferred) casualty-producing capability with personal risk). Thus, for example, an experienced infantryman might, from auditory cues, sense that the pattern

1 For modeling purposes, this is viewed as a "thoughtful" process and shown to be part of a sequence of human activities from the receipt of sensory information to the perception of risk, and then an eventual behavioral reaction to this risk. In reality, instantaneous fear may drive the reaction process without a risk assessment, and the three human processes may occur simultaneously or in some different ordering.

of incoming rounds from a 50 caliber machine gun was such as to be risky, while an inexperienced one might not, or vice versa. The risk perception would also appear to depend heavily on the protection afforded the suppressee by man-made means, by cover provided by the environment, and by the individual's posture.

Human Behavior Process (f_3)

Given the input perception of risk, this process gives rise to physical and/or mental reactions (e.g., take cover, etc.) which depend on the current mission, task, and activity;[1] their status; the combat training (doctrine) and experience of the suppressee; group dynamics; and the quality of leadership provided. It is conjectured that two individuals who perceive the same degree of high risk, but who have different amounts of combat engagement experience, might be likely to react differently to the risks. Thus, the less combat experienced of two Dragon gunners might stop tracking the target (in order to guide the missile) and seek cover, while the more experienced might continue to track, recognizing that unless the oncoming tank is destroyed with this round it will overrun his position. Effective leadership could possibly instill similar behavior in the less experienced of the gunners.

Although they are motivated by similar perceived risks, and may in fact be part of the same spectrum of reactions to risk, it is useful to classify the reactions as "reactive" and "threat." The reactive behavior is triggered by the delivery of firepower (cued by the sensory signals) and results in the suppressee instinctively taking cover, being distracted, etc. Even after firing has stopped, the

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[1] See section 1.1.

suppressee may take cover periodically in anticipation of additional firings; however, the additional firings are *not caused* by his return to his original unsuppressed posture. In contrast, threat reactions are a result of a subjective belief on the part of the suppressee that performance of his assigned combat activities (e.g., search for targets, fire on targets, etc.) will *cause* fire to be delivered on his position. The reaction is to change the usual unsuppressed mode of tactical behavior (i.e., stay under cover) and is triggered by the threat of a retaliatory response.

Threat reaction may or may not result from receipt of firepower while reactive behavior requires it. For example, a Dragon gunner may take cover after observing and hearing a burst of 50 caliber rounds impact nearby and then oscillate between standing (so as to acquire targets) and covered postures in anticipation of succeeding patterns of fire. This is "reactive" behavior (and thus "reactive fire suppression"). If, after receiving a number of such bursts, he believes his position has been pinpointed, he may stay covered all the time since his standing posture will immediately draw fire. This is "threat" reaction (and thus, "threat fire suppression"). Threat reactions (and thus threat fire suppression) need not be activated by stimuli from incoming rounds, but rather learned behavior from previous combat experience. Thus, two Dragon gunners may not fire on a passing platoon of tanks if they believe it will lead to their positions being disclosed and a highly unfavorable (risky) engagement.

The step from perceived risks to behavior poses the difficult (and potentially dangerous) experimental problem. It should be noted that analytically combining the sensory, perception, and behavioral elements integrates the human processes that convert sensory signals input to the human to reactions that (for the most part) are readily measurable (e.g., posture sequence).

Performance Effects Processes (f_4)

Given the reactions as input (output of the human behavior process), it is conjectured that these directly affect performance of certain capabilities (activities) of the suppressee in a readily calculable or measurable way. Thus, if the suppressee takes cover, he may not acquire as well, may fire less often and less accurately, would present a smaller signature (and thus be less able to be hit by direct fire), and might be less vulnerable. The magnitude and duration of these *changes* in performance are dependent on the characteristics of the system employed by the suppressee and the "target" of his activity (e.g., movement status of the target he is attempting to acquire, size of the target at which he is firing, etc.). Thus, if the accuracy of fire against a target is low because of his poor aiming error when unsuppressed or the weapon's ballistic dispersion characteristics, the *loss* in accuracy capabilities may be small when he is suppressed by fire.

Combat Engagement Process (f_5)

Although it is reasonable to consider that, as depicted in Figure 1, suppression is a process that pertains to the suppressee in a single time slice, consideration of multiple periods and associated feedbacks makes it a two-sided process with regard to performance capability changes and their long run impact on combat effectiveness. As such, behavior due to suppressive fire can cause separate or simultaneous degradations and improvements in performance capabilities of the suppressee. Suppressive fire might enhance a suppressee's acquisition capability by making him more alert or it might degrade it if he seeks cover. While the acquisition or firing accuracy capabilities may be degraded when the suppressee takes cover, he will be less vulnerable in this posture.[1] Thus, it is possible that when measured in terms of the results of a combat engagement (e.g., overall casualty exchange ratio, ground controlled, etc.), use of suppressive fire in some situations may not necessarily be beneficial. In a like fashion, the design of a system to enhance its suppressive fire effects may, in a combat engagement outcome sense, result in negative benefits. Qualitatively, increasing dispersion characteristics of the suppressing system (generating mechanism) may increase suppression effects (which, as noted above, may reduce the suppressee's vulnerability in addition to producing desired effects), but it also may reduce the accuracy and lethality characteristics of the suppression system. Accordingly, it is argued that the net effect (i.e., value or utility) of suppression must and should be measured in context of a complete engagement process. These net effects then depend, not only on the changes in performance levels of the suppressee (and the suppressor), but also on the complete scenario of the engagement process (forces, missions, etc.) and the battle status when the suppressive fire is employed.

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[1] This might equally well be viewed as a change in the performance level of the suppressing system and not the suppressee.

2.2 An Operational Definition

A number of definitions of fire suppression have been advanced by the military and analytic community; however, most of these have not been detailed enough for operational and scientific measurement and use. Calling upon the notions discussed in section 2.1, a useful operational definition in terms of performance capability changes is given below:

> "Fire suppression is a process which causes temporary *changes* in performance capabilities of the suppressee[1] from those expected when functioning in an environment he knows to be passive. These changes are caused by signals form delivered fire or the threat of delivered fire, and they result from behaviors that are intended to lessen risk to the suppressee."

Based on this definition, it is clear that the *degree* or amount of suppression cannot be measured on a single quantitative scale because suppression effects are multidimensional and the amount of the effects varies among the dimensions. Because many characteristics of the overall fire suppression process as portrayed in Figure 1 are uncertain or affected by chance factors (e.g., suppressive fire impact points, suppressee characteristics, suppressee reactions to fire, etc.), it seems not unreasonable to associate the degree of fire suppression effects with the amount of the *changer* in performance capabilities over time.[2] That is,

$$\text{Fire Suppression Effects} = g\{\Delta p_1(t), \Delta p_2(t), \ldots, \Delta p_i(t), \ldots, p_m(t)\}$$

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1 As noted previously, some of these changes may be viewed as having occurred to the suppressor's capabilities.

2 In mathematical terms, the joint random processes.

where[1]

Δp_i = a random variable describing the amount of change in the i^{th} performance capability of the suppressee and possibly suppressor (e.g., changes in the suppressee's acquisition rate, aiming error, error rate in sending messages, etc.)

t = a time variable.

g = the joint probability distribution function.

Although defining the degreee of fire suppression effects in this manner is somewhat arbitrary, it does have some direct benefits:

(1) it is an operational definition in that the Δp_i are directly measurable or can be related to the suppressee reactions if these are found to be more directly measurable.

(2) the joint probability distribution function over time contains all the information about the effects of suppressive fire including the complete auto- and cross-correlations for the performance capability changes.

(3) information about the joint distribution of the Δp_i over time (or its parameters) can be used directly in many of the existing combined arms combat models[2] to assess the combat value of fire suppression, and indicates what capabilities should be

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1 Since Δp_i are random variables, moments or some other descriptors of the joint distribution would be used in a precise definition.

2 For example, DYNTACS, ASARS, BONDER-IUA, AIDM, BLDM, CARMONETTE, etc.

modified to simulate fire suppression in field exercises and tests; and finally

(4) it suggests that the overall objective of a fire suppression research program should be to relate the Δp_i to physical (e.g., caliber) and use (e.g., firing rate) characteristics of suppressive weapon systems, combat operations descriptors (e.g., mission, tasks, forces, etc.), and environmental conditions (e.g., terrain type) either directly or through a hierarchical analytic structure parallel to that given in Figure 1.[1] This would facilitate addressing the design questions suggested in the TOR.[2]

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1 Since the Δp_i are random variables, the weapon, operational, and environmental variables would be used to predict or estimate appropriate moments of the joint probability distribution of the Δp_i.

2 See question (3) page 2 of this report. Identification of methods to reduce the effects of fire suppression will require that some of the hierarchical structure of Figure 1 be developed.

CHAPTER 3

DISCUSSIONS OF INDIVIDUAL PROCESSES

The previous chapter presented a schematic overview of the sequence of processes and events that are conjectured to occur in a single time slice when suppressive fire is delivered and affects the combat results. In this chapter, the individual processes in the sequence are discussed in greater detail by discussing relevant input and output variables, measurement scales for the variables, existing models of the process, available data and data voids, etc. This material is included in the report with a number of intended purposes:

(1) to provide a better understanding of the content intended for each individual process;

(2) to communicate within the time and effort limits imposed on the ad hoc group, what we believe is known about each process;

(3) to suggest a rationale for approaches to developing process transfer functions for the individual processes, or combinations of them; and

(4) to document ideas, albeit sketchy, that should be considered in the formulation of a research program.

The discussions are organized into three sections: 3.1, Signal Processes (generation and attenuation); 3.2, Human Processes (sensory, perception, and behavior); and 3.3, Performance Process. Figure 1 is repeated here for information purposes.

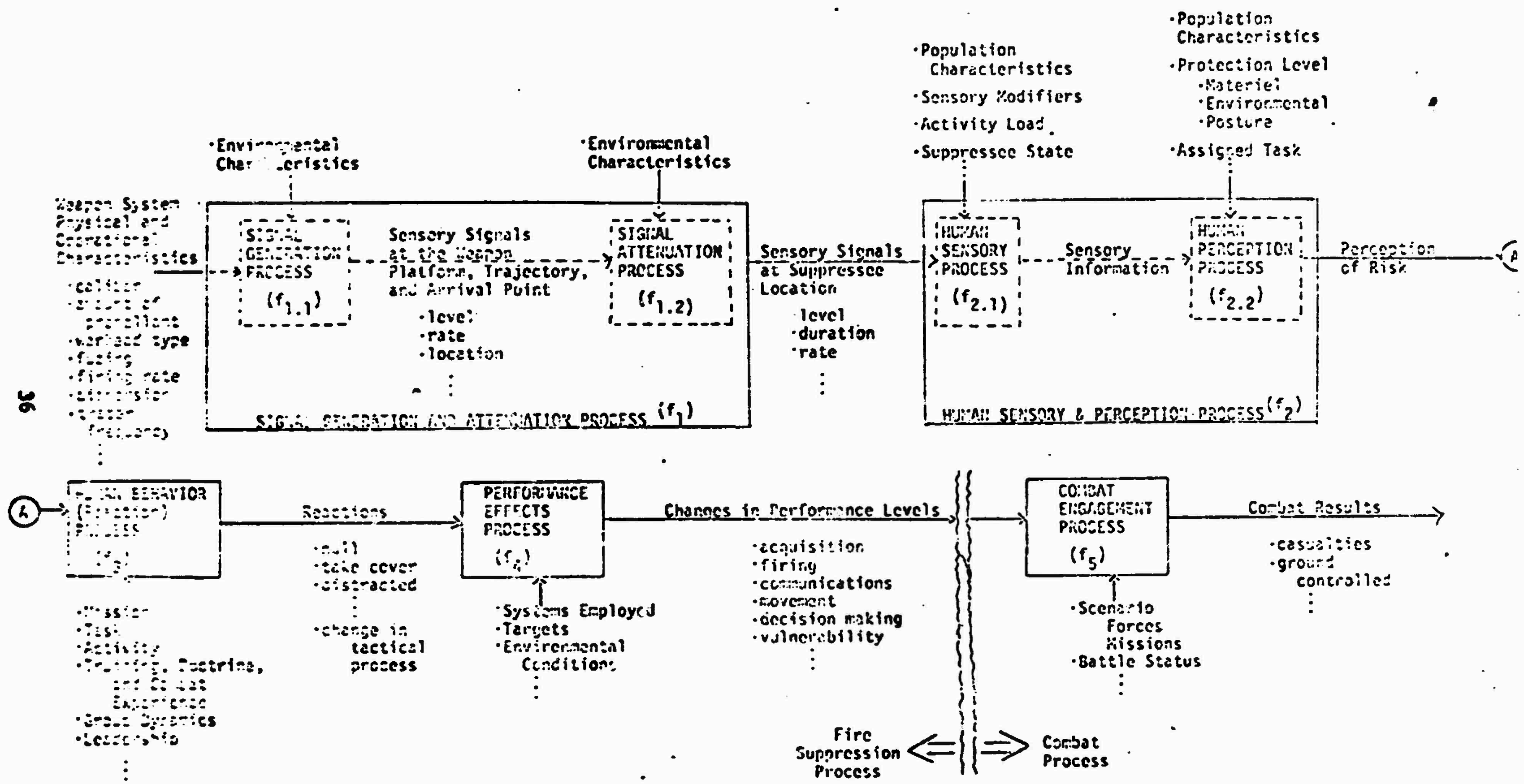

FIGURE 1: SCHEMATIC STRUCTURE OF THE FIRE SUPPRESSION PROCESS

3.1 *Signal Processes (f_1)*

The first process in the schematic structure of fire suppression is the generation of signals by the suppressing weapons. The second is attenuation of the signals during transmission to the suppressee. These processes bring to the suppressee signals that convey information that firepower is directed at or near him. The processes are strictly physical and external to the suppressee and, in theory, can be modeled with some degree of accuracy by direct application of established physical principles. In practice, however, most of the specific signal generation and attenuation processes of interest may be very complex and can only be approximated when working from first principles. Fortunately, the modeling can be directly supported by measurements that are relatively simple to obtain and from which sufficiently accurate empirical models can be developed.

In outline, the processes f_{11} and f_{12} occur in the following way. The suppressing weapons are fired. As determined by the input variables of the weapons, and influenced by the environment, signals are generated through process f_{11}. (At the same time through a parallel process f'_{11} lethality is generated which is also determined by the input variables of the weapons and affected by the environment.) The signals of the weapons are transmitted to the suppressee's sensors with attenuation or other changes through process f_{12}. The signals at the output of f_{12} can be received by the suppressee. We believe his perceptions are dependent on the signal output variables. Although processes f_{11} and f_{12} are independent of the suppressee, it is helpful to consider the sensations that the suppressee might get from the signal variables in order to show the importance of the output signal process variables listed for the signals.

Prior to a discussion of the specific signals associated with fire suppression, a more general list of possible signals occurring in combat is presented. From this we will see that there is a small set of signals generated by the suppressing weapon imposed in a background of many other signals. It is also important to note that only a small number of types of signals are of interest.

3.1.1 Overview of Weapons Signals in Combat

Some of the signals that might act as stimuli of suppressive behaviour by targets in combat are listed in Table 1. These signals are grouped in the table by the senses that receive them. The list gives a signal type, a mechanism by which the signal is generated and some weapon system types that may generate these signals. Not all of the signals of Table 1 result directly from suppression fire. Those that do not will not be discussed further. Nevertheless, in combat situations at least some of these signals will contribute to the environment in which weapon signals are produced and received. The restriction of our considerations to projectile and explosive types of weapons and the further exclusion of mines significantly reduce the number of things that must be reviewed for our present purposes. These exclusions are made to limit the scope of the working group's immediate considerations.[1] The remaining signal

1 For example, the group's focus on reactive vis-a-vis threat suppression. See page 10 for a list of suppression dimensions emphasized in our deliberations.

TABLE 1. Suppression Stimuli

Auditory Signals

Signal Type	Mechanism	Weapon System Generator
1. Pressure Pulse	Supersonic projectile	Passing bullet from gun at close range
	Gun shots	Gun shot nearby
	Explosion	Explosive round detonation Mine detonation FAE weapon burst Grenade burst
	Solid body impact	Projectile into ground or cover Projectile on armor Fragment onto ground or cover
2. Rapid Series of Pressure Pulses	Multiple SS projectiles	Passing shots from close automatic weapon
	Gun Shots	Automatic Weapon Firing Artillery Firing
	Multiple explosions	Artillery shells exploding Cluster bomblets exploding Bomb train or salvo
	Impacts	AW projectiles on ground or cover AW projectiles on armor Fragments on ground or cover
3. Sound	Subsonic projectile	Passing or approaching gun projectile Richocheting projectile
	Machinery	Armor moving Wheeled vehicles
	Airborne machinery	Airplane flying Helicopter flying
	Solid body impact	Projectile into ground or cover Projectile on armor Fragment onto ground or cover
	Fire	Burning Napalm Flame thrower

TABLE 1. (Cont'd)

Auditory Signals (Cont'd)

Signal Type	Mechanism	Weapon System Generator
	Whistles	Signal whistles Projectile whistles Armor sirens
	Resonating pipes	Signal horns
	Voices	Enemy shouting Friendly cries
	Animal sounds	Horse neighing Horse running
	Jet propulsion	Rocket motor burning

Visual Signals

Signal Type	Mechanism	Weapon System Generator
1. Flash or series of flashes	Explosions and rapid burning	Grenades exploding Shells exploding Gun flashes Photo flash flares
	Projectile Tracers	Machine Guns
	Incandescent or other lamp	Sweep spotlight Signal spotlight
	Laser (visible)	Pulsed illuminator Rangefinder
2. Persistent light	Burning material	Napalm Flame thrower Burning equipment
3. Obscuration	Smoke	Grenades exploding or burning Shells exploding Mines exploding Burning fuel White phosphorus Flare smoke
	Dust	Shell explosions Projectile impact Vehicle passage
4. Object moving	Weapon	Retarded bomb falling Retarded shell or flare falling Low velocity projectile Tracer from long range

TABLE 1. (Cont'd)

Visual Signals (Cont'd)		
Signal Type	**Mechanism**	**Weapon System Generator**
	Vehicle Moving	Tank Truck Robot mine Airplane Helo Missile or RPV
	Animate object	Men Horses Oxen, etc.
5. Eruptions	Explosions	Shell explosions Cluster bomblet explosion Bomb bursts Mine bursts
	Impacts	Projectile impacts (Debris impacts)

Tactile or Feeling Signals

Signal Type	Mechanism	Weapon System Generator
1. Body movement	Acceleration	Explosions Heavy nearby impacts Heavy vehicle passage SS shock
	Vibration	Distant explosions Distant firing Aircraft passing Distant vehicle
2. Body shock	Impact on body	Falling debris Spent fragments Own weapon firing

TABLE 1. (Cont'd)

Tactile or Feeling Signals

Signal Type	Mechanism	Weapon System Generator
3. Heat	Fire	Incendiary burning Napalm burning Flamethrower
	Laser	L.W.
4. Pain	Injury	Projectile impact Projectile penetration Fire Explosive blast Chemical

Olfactory (Smell and Taste) Signals

Signal Type	Mechanism	Weapon System Generator
Combustion products	Explosions	Shells Gun fire Bombs and Bomblets Mines
	Burning	Napalm White Phosphorus Engines Rockets (Equipment) (Rubber)
Dust	Eruptions	Explosions on ground
	Vehicles	Tanks Trucks
Decay	Dead material	Dead bodies Vegetable decay (muck, stagnant water)
Acrid substance	Chemicals	Lachrymators

sources are a major portion of the weapons used in fire suppression. Nevertheless, this limitation is not intended by the committee to identify the most suppressive weapons or to represent other judgements about the excluded signal sources. Any research program undertaken should be planned so that as progress is made, the base can be broadened by inclusion in the investigations of some or all of these omissions.

3.1.2 Types of Signals

From table 1 we see that we must consider two types of weapons auditory signals: pressure pulse and a sound train; perhaps three types of visual signals: light flash, movement and obscuration of vision; just one important type of tactile signal: body movement; and one weapon peculiar olfactory signal: the smell of combustion or explosion products. Each of these signals can be described by several measures. Only the auditory and visual signals will be discussed in detail. These are probably the most important signals for suppression although the other types should be considered at the outset of a research program to put that qualification on firm ground.

The auditory and visual signals are described below in terms of their operational variables and are summarized in Table 2. Some possible measures for these operational variables are indentified. Finally the sensation associated with each operational variable is suggested. The operational variable of the signals are the same in processes $f_{1.1}$ and $f_{1.2}$, with the addition of source direction as a variable in process $f_{1.2}$.

TABLE 2. Representative Input and Output Variables for Process f_1:

Signal Output Variables		Weapon Input Variables
I Auditory Signals		
A. Pressure pulse:		
1. Impulse (pressure-time integral)	A.1.a.	Gunfire: Muzzle velocity (velocity) Caliber (length) Projectile weight (mass)
	b.	Supersonic projectile: Projectile velocity (velocity) Projectile weight (mass) Projectile drag (C_{D_T})
	c.	Explosion: Charge weight (mass)
2. Pulse rise time (time)	2.a.	Gunfire: Muzzle velocity (velocity) Barrel length (length) Pressure P(t) (pressure)
	b.	Supersonic projectile: Projectile velocity (velocity)
3. Pulse peak pressure (pressure)	3.a.	Gunfire: (Complex interior ballistic and gas dynamic problem)
	b.	Supersonic projectile: Projectile velocity (velocity)
	c.	Explosion: Explosive charge weight (mass)
4. Pulse duration (time)	4.a.	Gunfire: (Interior ballistic and gas dynamic problem)
	b.	Supersonic projectile: Projectile velocity (velocity) Projectile weight (mass) Projectile drag (C_{D_T})
	c.	Explosion: Charge weight (mass)
5. Repetition rate ($time^{-1}$)	5.a.	Gunfire: Firing rate ($time^{-1}$)
	b.	Supersonic projectile: Firing rate ($time^{-1}$)

TABLE 2. (Cont'd)

Signal Output Variables	Weapon Input Variables
B. Sound	
1. Frequency ($time^{-1}$)	B.1.a. Subsonic projectile: Velocity (velocity) Spin rate ($time^{-1}$) Drag coefficients (C_D) (Complex acoustic process) b. Machinery: (Complex multisource process) c. Rocket motor burning: Mass flow rate (mass x $time^{-1}$) (Complex gas dynamic process)
2. Intensity (power x $length^{-2}$)	2.a. Subsonic projectile: Velocity (velocity) Weight (mass) Spin rate ($time^{-1}$) Spin inertia (mass x $length^2$) Drag coefficients (C_D) b. Machinery: (Complex multisource process) c. Rocket motor burning: Mass flow rate (mass x $time^{-1}$)
3. Frequency content, spectral power density (power x time)	3.a. For all source the process is complex and nearly unpredictable. Input variables uncertain.
4. Frequency modulation ($time^{-1}$)	4.a. Subsonic projectile: Spin rate ($time^{-1}$) Precession ($time^{-1}$) (Other generators have complex processes)
5. Amplitude modulation (power and frequency)	5.a. (Processes are complex and input variables uncertain)
II Visual Signals	
A. Flash:	
1. Visual power (luminous flux) (lumens)	A.1.a. Explosions: Explosive charge (mass) (Dependent on charge material) b. Gunflash: (A complex interior ballistic and gas dynamic process) c. Projectile tracer: (A complex highly directional process)

Signal Output Variables	Weapon Input Variables
2. Duration (time)	2.a. Explosions: Charge weight (mass) b. Gun Flash: (Complex process) c. Projectile tracer: Projectile velocity (velocitv)
3. Color (spectral power density)	3.a. (Complex processes depending largely on specific chemistry of burning material.)
4. Pulse repetition rate ($time^{-1}$)	4.a. Explosions: Firing rate ($time^{-1}$) b. Gun flash: Firing rate ($time^{-1}$) c. Projectile tracers: Firing rate ($time^{-1}$)
B. Movement:	
1. Solid angle or visual angles in two dimensions (steradians or degrees	B.1.a. Weapon: Weapon size ($length^2$) Weapon distance (length) b. Vehicle (tank) Size ($length^2$) Distance (length) c. Eruptions: Explosive charge (mass)
2. Solid angle rate (Steradians x $time^{-1}$)	2.a. Weapon: Velocity along line of sight (velocity) b. Vehicle: Velocity along line of sight (velocity) c. Eruptions: Probability not discernible
3. Angular rate (radius x $time^{-1}$)	3.a. Weapon: Crossing velocity (velocity) Distance (length) b. Vehicle: Crossing velocity (velocity) Distance (length) c. Eruptions: Probably not perceptible except as falling debris.
C. Obscuration or visibility along line of sight (length)	C. Processes by which weapons generate obscuration are complex.

Auditory Signal-Pressure Pulse

A pressure pulse signal is a single compressional wave of large amplitude. As shown in Table 1 it might be created by explosions or by shock waves from a supersonic body. The signal has the operational variables impulse, peak pressure, duration and rise time. The measures of these variables are obvious and are displayed in Table 2.

The operational variable impulse is probably related to the sensation of power or force. As impulse increases the sensation of force increases. Peak pressure, if sensed is also likely to be associated with force. Rise time giving a degree of sharpness to the impulse may be associated with nearness. It also affects quality by which recognition of the source may be made. Similarly, duration also affects quality and contributes to recognition.

A series of pulses have the above operational variables. In addition repetition rate, duration of series and changing impulse characterize the series. Repetition rate gives a quality to the signal by which recognition may be achieved. Duration of the series as measured by number of time gives a sensation of force or power. Changing impulse gives the sensation of approaching or receding action.

Auditory Signal-Sound Train

A sound train is a sound of a few cycles or more in duration. It is characterized by frequency, power, modulation of power, modulation of frequency, and frequency content and duration. The measures for each of these variables are shown in Table 2.

Frequency gives a sensation of pitch and is important to recognition. The sound power equates to loudness and gives the sensations of distance and of relative strength or force. The modulation of power gives quality to the sound that may create varied sensation. A steady decrease or increase in sound power gives the sensation of a receding or approaching source respectively. Frequency modulation can also result in varied sensations, the important one being the sensation of source motion. Both power and frequency modulation give quality to the sound that is important to recognition. The frequency content of the sound gives quality that is important to recognition. Duration of the sound conveys the sense of endurance of the source.

Visual Signals-Flash

A flash of light is illumination from a source that lasts for a short time compared to the normal visual processes. It has the operational variables of intensity, wavelength, spectral content, duration and when repetitive, repetition rate. Appropriate measures for these variables (suggested in Table 2) are strength or power, color, color quality, energy, and persistence and endurance respectively. The signal may provide for recognition through one or more of these variables.

Flashes are produced by the burning gases at the muzzle of a gun or by explosions of shells and bombs. Flashes of lower intensity may also be produced by tracers passing nearby. In all these cases the visual signal will be accompanied by an auditory signal.

Visual Signal-Movement

Moving objects associated with suppressing weapons may be weapons approaching or passing such as a retarded bomb, vehicles such as tank, or material impelled by the effects of weapons such as eruptions of earth. The sight of these objects is a type of visual signal. The operational variables of the signals are visual angle of the object, rate of change of the visual angle, and angular rate of the line of sight. This type signal for suppression will commonly be accompanied by a sound signal. It is less reliable than sound because vision is highly directional and can be "turned off" by the suppressee or by the environment.

This type of visual signal is important in detailed assessment of the threat by the suppressee. The variables provide sensations of distance, rate of change of distance along the radius vector (approach velocity) and rate of change along the transverse vector (crossing velocity) respectively.

Visual Signal-Obscuration of Vision

As a result of suppressive fire, smoke and dust are suspended in the air. They are seen directly by the suppressee and would be in the preceding class, or they obscure his vision of other things. It is postulated that the obscuration of his field of view constitutes a signal to the suppressee. This signal has operational variables that are less easy to define and measure than those preceding. Possible operational variables are scatter, diffusiveness and contrast reduction. The suppressee has sensations of reduced visibility and visibility in the materological useage may be a proper operational variable as well as measure.

3.1.3 Effect of Environment on Processes

The environment has an influence on both the signal generation process $f_{1.1}$ and the signal transmission process $f_{1.2}$. Auditory signals that result from the impact of projectiles depend heavily on the nature of the object or material impacted. A soft yielding material such as dusty ground or sand receiving the impact of a projectile will produce a different pulse and sound than will hard unyielding ground under the same impact. The environment affects the transmission of sound signals by attenuation greater than normal, as vegetation muffles sound. The sound signals can also be strongly attenuated by the shadowing effect of large obstacles. Or sound signals may be effectively increased by echo or reverberation.

In the generation process of visual signals the sight of moving objects is strongly modified by the conditions of ambient lighting. Night lighting greatly reduces the signals of moving objects that can be received.

Visual signals are affected by environment mainly in the transmission process. As already mentioned, obscuration of the visual field can occur. Other signals are attenuated thereby. The obscuration of the visual field can occur naturally as well as from weapons fire. Haze, fog, rain and snow act similarly to smoke and dust. The visual field is also reduced and interrupted by terrain and other obstacles.

3.1.4 Weapons Variables

The inputs to process $f_{1.1}$ (and $f'_{1.1}$) are weapon parameters. Some of the useful parameters are derived variables, others are basic weapon design parameters. The parameters that are considered to be important to suppression signals are discussed below. They are also identified in Table 2 in association with the signal types that they affect. These same input variables are inputs to the lethal effects generation process of the weapons.

<u>Muzzle Velocity</u>

This parameter is derived. It is used to determine the effectiveness of guns in range and effects of kinetic energy on targets. With caliber and projectile weight the sound of firing should be amenable to empirical modeling. Projectile sounds depend on projectile weight, velocity, drag and spin. Generally we associate increases in signal variables and in lethality with increase in muzzle velocity.

Caliber

The measure of the gun tube diameter might be used in an empirical model to determine the signals generated by gun firing. As caliber increases, the firing signals and projectile signals increase along with lethality.

Projectile Weight

The projectile weight is a parameter to determine velocity as a function of time. From velocity the sound or supersonic pulse generated by the projectile may be determinable. Penetration depends on weight and velocity at impact and affects the explosive pulse by muffling and increases shock coupling to ground, and size of crater eruption. Projectile weight increase is associated generally with increase of signals and lethality.

Projectile Spin

Projectile spin affects the sound produced by a projectile at subsonic speeds. Although spin affects signals, it has no direct or easy correlation with lethality.

Projectile Drag

Total drag of the projectile is important to determining the velocity history. Sound of the projectile in flight, sound of impact, and time between projectile sound and gun sound are all dependent on velocity as a function of time. There is not a simple relationship between drag and the output variables of the signals or the lethal effects of the weapon.

Warhead Charge Weight

The explosive charge weight of a bursting warhead is a parameter for determining the energy in the pressure pulse caused by detonation and in the intensity and duration of the visible flash. The charge weight is also a major determiner of the destructive energy of the warhead.

Propulsive Impulse

The velocity of rockets guided and unguided is a function of the propulsive impulse, a derived parameter. It is alternative to a higher level derived parameter, velocity as a function of time, which may be given for missiles. For determining signals for suppression, the basic parameters pressure, mass flow rate and time are more directly related to sound of rocket burning and the visible light from the rocket exhaust. The lethality of a rocket is generally directly related to the propulsive impulse so that signal variables and lethality tend to be positively correlated.

Fuze Timing

The fuze timing relative to the weapon impact time is a parameter that influences the generated auditory and visual signals. Large delays for bursting result in muffling the explosive sound, in obscuring the visible flash, but in exchange creating crater eruptions. VT or proximity fuzing, on the other hand, gives an air burst having different quality. Fuze timing has an effect on the destructiveness of the weapon, but the effect is sensitive to targets. For infantry without overhead cover, it is possible for signal variables (and sensations from them) to be negatively correlated with lethality as fuze timing is varied.

Fragment Weight and Velocity Distribution

This weapon parameter determines with charge weight and fragment (projectile) drag the range to which fragments are thrown and their impact velocities. Fragment impact sounds are thereby affected. These sounds are not likely to be of great importance in suppression because they are masked by the explosive sound. On the other hand the fragment distributions are of primary importance in determining warhead lethality.

Dispersion

Dispersion, as input variables of weapons, measures the scatter of impacts or hits about the central tendency. Dispersion like aiming error, does not affect the generation of signals directly but gives quality to the signals. The suppressee may have difficulty distinguishing between the effects of aiming and of dispersion as he receives signals. For observed and adjusted fire, high dispersion has effects like poorly aimed or area fire. It makes the fire ineffective and to the suppressee, if he is the target, the fire may seem like random or unaimed fire. Low small dispersion enhances the suppressiveness of adjusted fire. However, if the fire is area fire, not adjusted or individual targets, then high dispersion will in some respects resemble fire that is precise and moved about.

Weapons Use Variables

Besides variables that are inherent to the design of weapons, there are variables that are associated with the way in which the weapon is used. These variables are important to the signals that the weapons generate. The variables also affect lethality and are especially important in suppression because they are the means by which firepower of a suppressee is altered. There are four weapon use variables:

a. Aiming mode (aimed or area)

b. Firing mode (periodic or nonperiodic)

c. Rate of fire

d. Duration of fire.

The first of these weapons use variables affects the quality of the signals of the weapons fire in connection with accuracy and dispersion. In general, aimed fire that is directed at the suppressee will seem more threatening and dangerous than area fire. If the fire is inaccurate because of poor aiming, its danger is reduced, and it may not be perceived as aimed at the suppressee. If it has large dispersion it may also appear to be unaimed.

The fire mode of the weapon also affects the quality of the signals generated by the weapons fire. If the fire is periodic and regular, the suppressee may find it not seemingly directed at him unless it is accurately aimed. It may still have a greatly threatening character. The fire may, on the other hand, be aperiodic. If the suppressee perceives the fire as being reactive to his own behavior then the personal danger factor will be reinforced.[1] Fire that is not periodic but also not reactive to his behavior may be like periodic fire in its personal threat except more difficult to overcome.

The rate of fire of the weapons perceived by the suppressee is a factor in the apparent danger of the fire. The threat of the fire will tend to seem greater as the rate of fire increases. The variation of rate of fire for some weapons is limited but by use of tactics even inflexible weapons can be given apparent differences in rate of fire. In general, it is likely that a high rate of fire means to the suppressee that his enemy is willing to expend a lot of effort to kill him.

Duration of fire also lends quality to the signals of the weapons. Like rate of fire, it may convey the sense of the amount of effort the enemy is willing to expend on the suppressee. The duration of fire is measured in the lengths of bursts from automatic weapons and also in the duration of a barrage by either direct or indirect weapons fire. It is generally believed that psychological stress of the suppressee increases as the duration of fire increases and that the suppressee is more easily suppressed as his stress increases.

3.1.5 Modeling Processes $f_{1.1}$ and $f_{1.2}$

The input variables of weapons are associated with output variables of signals in Table 2. An attempt has been made to illustrate the complexity

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[1]This was earlier categorized as a particular type of threat suppression.

of the process that stems from the large assortment of signals variables and the variety of input variables that are involved with only a very few signals. The table contains just five basic signals and a limited number of generators of all those listed in Table 1. In general, the signals listed have not been studied in the detail that the lethal effects of the weapon have. As a consequence, although the signal generation processes are physical and chemical and thus conceptually could be modeled from first principles, such a process could be extremely difficult. It is likely that a more satisfactory approach would be to develop empirical models based on field measurements.

Process $f_{1.1}$ occurs at the signal generator. There remains the further process of transmission to the suppressee. This process $f_{1.2}$ is more amenable to modeling and indeed for some of the signal variables can be modeled easily. If the generation of signals is to be modeled empirically from experimental data, then it would be most efficient to make those empirical models cover processes $f_{1.1}$ and $f_{1.2}$ in one step if possible. It would do little good to have models for $f_{1.2}$ if appropriate inputs are not available, and they may not be. Measurement of some of the signal variables at the generator could prove to be very difficult, and the model $f_{1.2}$ would have to be used to project measurements back to the signal sources. For these reasons, it is recommended that models for $f_{1.1}$ and $f_{1.2}$ be developed empirically at least as a first step. Some data of the sort necessary for such model development may be available already from CDEC experiments.

3.2 *Human Processes* (f_2 and f_3)

The signal processes (generation and attenuation) discussed in the preceding section provide the primary input to the human processes of sensation, perception and reaction (f_2 and f_3). The output of the human processes, reactions, provide the input to the performance effects process (f_4). While the sensory, perceptual and reaction processes can be discussed separately in meaningful terms, it is useful to characterize them together in broad outline prior to a detailed discussion of each process. Toward a presentation of this broad outline of the three components of the human process, we will introduce a variant on the schema provide in Figure 1 - a variant which emphasizes the complexity of the human processes.

The suppression process is basically one of human behavior and can be represented, in its simplest conceptual form, in the familiar paradigm of Stimulus-Organism-Response (S-O-R) of Figure 2. The important point to emphasize is that the behavior involved is in response to stimuli that originate both externally (combat environment) and internally (personal background, training and experience) to the soldier suppressee. The intensity and extent of suppression cannot be predicted from a knowledge of the combat environment alone, but requires an analysis of the underlying motivational and cultural factors and of the context of the combat environment.

The first task is to characterize the nature of the matrix of stimuli, both external and internal, that determine what the soldier will do on the battlefield. He is there, perhaps not of his own choice, as a member of a combat unit under authorized leadership with the overall mission to

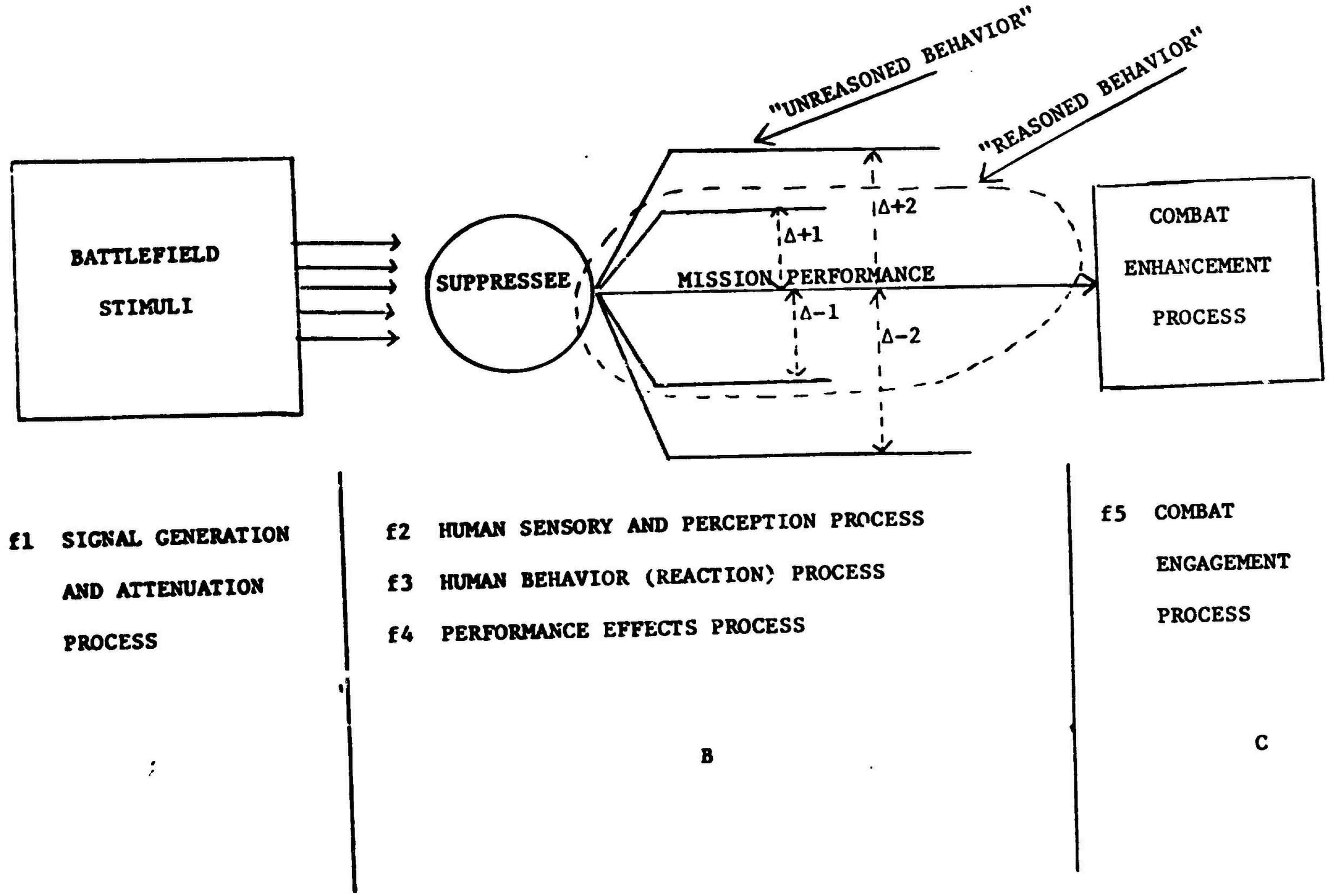

Figure 2: Schematic Structure of the Human Processes in the Fire Suppression Process

engage and to destroy the enemy. He is to accomplish this mission in coordinated activity with members of his unit through the performance of a variety of mission-oriented responses that collectively aggregate into the major combat activities of observing, moving, shooting and communicating.

The individual soldier's performance upon the battlefield is based upon his training and prior experience in the Army. During individual traning he has learned to perform a variety of individual tasks required in combat. In later stages of training he has learned to integrate these performances with those of other soldiers to produce coordinated combat performance.

Traning is a process during which the individual learns to make certain responses to certain stimuli. In Army training some of the stimuli of the battlefield are present througout all stages of training--such things as weapons, terrain (with its properties of extent, contour, coverage, etc.) and targets (including those which simulate enemy personnel). In addition, there are social stimuli of other soldiers, NCOs and officers, as well as the instituational aspects of Army life. Also, of course, is the variety of stimuli which arises from the soldier himself which fluctuates from day-to-day and changes over time as he gains experience during his tour in the Army. The objective of combat training is to provide the soldier with an ability to ultimately assess and to react in an effective, aggressive manner to the complex stimuli presented by the enemy on the field of engagement.

At any one instant during the battle itself aggressive behavior directed at the enemy may not occur, either because it is inappropriate at that moment, or even when it is appropriate, the soldier does not exhibit it. Part of the combat training of the soldier includes (or should include) instruction and practice in the assessment of the risk associated with enemy actions and fire. Thus, the soldier learns how to be suppressed at appropriate times, in order that he may not become a casualty and can continue aggressive action at a later time.

It is apparent that the enemy on the battlefield presents a great variety of stimuli. This stimulus complex can be characterized as "ambiguous," because it appears to be one which could be both attacked and avoided at ay particular instant in time. These two kinds of behaviors, attack and avoidance, cannot take place at the same time. The experienced soldier alternates between them as is appropriate at the moment. This fact is the key to the schematic structure of the fire suppression process which is shown in Figure 2 and is the basis of an approach to modeling the human processes elaborated in Section 3.2.2.

In Figure 2 those elements of the fire suppression process include in Figure 1 are grouped into three phases - A, B, and C. Phase A represents the total stimulus complex of the battlefield: the signal generation and attenuation processes discussed earlier. Phase B represents the human processes which are discussed in this section and the performance effects process which is discussed in Section 3.3. Phase C represents the combat engagement process.

A very large number of stimuli impinge on the soldier (suppressee) in Phase B, which involves the sensory, perceptual, response processes.

The essential aspect of Phase B is that the suppressee can make a variety of responses of differing duration and accuracy. The critical response is that of mission performance which is made up of a variety of mission-related activities. However, he also can make other responses which are incompatible with mission activity performance. Insofar as these occur, mission performance will either be enhanced or degraded as illustrated by the delta increments or decrements (Δ+ and Δ-) to mission performance. Phase A of the process can be described in physical terms. Phase C is a matter of modeling and analysis. Phase B involves processes which may be best studied in behavioral science terms.

The separation of the sensory, perceptual and reaction processes although convenient, is somewhat arbitrary. These processes represent a continuum of cognitive activity and experimentation purely on any one process in isolation is not possible. This is because in the last analyses, one can only present stimuli and observe reactions; independent exact measures of the three processes are not possible. Thus, any experimentation or analysis must of necessity consider all three processes even when the focus is on one specific process.

An important point about the possible reactions of the suppressee (Figure 2) is that those associated with mission performance include some which are not, at the moment, in furtherance of mission activity performance (i.e., observing, moving, shooting, or communicating). They include the temporary taking of cover, etc., which is taught as part of normal combat training. Performing these kinds of behaviors may be considered as included in "reasoned behavior" involving sensible assessment of risk and the exercise of judgment about the demands of the immediate situation and the necessity to observe, move, shoot, or communicate at that instant. A dotted line has been placed around some of the responses exhibited by the suppressee and labelled "reasoned behavior."

Behavior also must be taken in account which seriously interrupts mission performance over a longer period of time. The soldier may become incapacitated as a result of fatigue, cold, hunger and other conditions which are typical results of prolonged combat. Also, he may suffer from a state of "psychological stress" which may become progressively more intense as combat continues. As Kern[1] pointed out, soldiers under prolonged exposure to combat may pass through three stages which differ in terms of the relative amount of attention that he pays to immediate stimuli which arise from the battlefield and those which come from inside himself:

> Stage 1. The soldier is reacting in an intelligent or rational manner, assessing risks and firing, moving, observing, communicating, or taking cover as is appropriate. There is reason to believe that the soldier will improve in this behavior-selection process in the early stages of his exposure to combat if he is not an immediate casualty.

> Stage 2. The soldier begins to pay more and more attention to the harmful aspects of battlefield stimuli and he spends more time in cover and concealment, paying less attention to opportunities for aggressive action.

> Stage 3. The soldier ceases to behave and crouches in his foxhole, etc., appearing to be insensitive to almost all stimuli of the battlefield, including commands and communications.

The extent to which the soldier maintains his behavior at Stage 1 is a function of all sorts of variables within the soldier, which result from his early background, his ability to cope with the stresses of life throughout his lifetime and his specific military training. It is because these

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[1]Kern, Richard P. A Conceptual Model of Behavior Under Stress, With Implications for Combat Training. HumRRO Tech. Rept. 66-12, June 1966. AD-637 312

these experiences are incorporated within the soldier and give rise to stimuli coming from within himself that it is necessary to consider the soldier himself (the organism) in Figure 2.

The research program needs to distinguish between the kinds of behaviors in Stage 1 above and the other two. Stage 1 behavior probably can be studied in field and laboratory experiments. This experimentation will be difficult to perform because of social, ethical and legal constraints on subjecting humans to risky situations. It is unlikely that Stage 2 or Stage 3 behavior which occurs under prolonged exposure to risky situations can be studied experimentally. However, the factors which may move the soldier into Stage 2 and Stage 3 must be considered. Suppression should be thought of in terms of the organism (the soldier, the suppressee) as a whole who is reacting to all sorts of stimuli, both external and internal. Training should be designed to strenghthen the "mission activity" type of reaction until it is so well practiced and so strong that maladaptive (Stage 2 and Stage 3) behaviors cannot compete with it. (This point is further elaborated in Section 5.1.)

A description of the individual soldier's performance on the battlefield would be incomplete without mentioning the variability of this performance. First, different soldiers will respond to the same battlefield environment in different ways. Some will make responses incompatible with mission activity performance and performance will be degraded. Some will show increased alertness and respond in a manner which will enhance activity performance. Some will be apparently "immune" and will exhibit no change in activity performance. Second, the same soldier may react one way to one set of battlefield stimuli at one time and may react differently to presumably identical battlefield stimuli at a different time.

Because many of the determinants of the soldier's performance on the battlefield are unknown, uncertain, or influenced by chance factors, the individual soldier's reactions can be thought of as a random variable. This is not to imply that the soldier's reactions are in fact random. Rather, this represents the limitations of our capability to predict human behavior. It seems reasonable to describe the reactions of the soldier in terms of a probability distribution which describes the probability of occurence of specific reactions.

3.2.1 Human Sensory and Perception Processes ($f_{2.1}$ and $f_{2.2}$)

The first stage of the human processes - sensory and perception - convert the matrix of stimuli, both internal and external, into a perception of the risk involved in the situation. The discussion of the sensory process focuses on the operating characteristics of the senses such as vision and audition. The discussion of the perceptual process focuses on the perception of risk. Prior to examining these processes in more detail, the input variables (the stimuli) of these processes are identified and briefly discussed.

Section 3.1, Signal Process, provides an exhaustive compendium of the weapons system signals which might serve as stimuli for the suppressee (Table 1). Previous research suggests that the following six characteristics of the weapons systems signals are primary determinants of suppression:[1]

1. Proximity of incoming rounds to the individual.

2. Loudness of the projectile signature.

3. Volume of incoming rounds to the individual.

4. Type of weapons systems employed against the individual.

5. Unique projectile or weapons system signature.

6. Visual and auditory signature associated with impact of the projectile.

These characteristics represent a useful summary interrelating the individual stimuli listed in Table 1. The precise relationships between the weapons system stimuli (Table 1) and these characteristics have not been explicity determined, although some suggestions for doing this are presented later in this section.

Weapons systems signals are the primary determinants of suppression. However, the perception of risk is primarily a cognitive activity and the perception, as well as the subsequent reaction, to weapons systems signals are strongly influenced by other moderating factors. Table 3 lists a sample (not exhaustive) of factors which moderate the perception of risk and the level of risk an individual will accept. The moderating variables are grouped into the following categories:

1. External

   a. military
   b. environmental

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[1] Kushnick, S.A. and Duffy, J.O. The Identification of Objective Relationships Between Small Arms Fire Characteristics and Effectiveness of Suppressive Fire (U). Final Report TF-72/002, Sunnyvale, Calif. Defense Sciences Laboratories, April 1972 (AD 519874).

TABLE 3.

MODERATING VARIABLES OF RISK PERCEPTION AND RISK ACCEPTANCE:

CONJECTURED EFFECTS AND MODELING FEASIBILITY

Type of Variable			Effect on Perceived Risk*	Effect on Level of Risk Accepted*	Modeling Feasibility*
1. External					
a.	Military	Mission	±	±	Yes
		Task	±	±	Yes
		Activity	±	±	Yes
		Engagement			
		high, long intensity	+	±	Yes
		long, duration	±	±	Yes
b.	Environmental	Climate	NE	NE	No
		Weather, bad	-	-	Yes
		Night opns	±	-	Yes
		Posture of Suppressee	±	NE	Yes
		Terrain	±	±	Yes
		Protection level			
		high protection	-	+	Yes
		Sensory modifiers	±	±	Yes
		Close proximity to			
		other members	+	+	?
		commander	±	±	?
		auto weapons	±	±	?
		enemy	+	-	Yes

Key: + increases
- decreases
± can move either way
NE no effect
? questionable

TABLE 3.
(cont.)

Type of Variable		Effect on Perceived Risk*	Effect on Level of Risk Accepted*	Modeling Feasibility*
Internal				
a. Individual	Training	±	±	Yes
	Doctrine	±	±	Yes
	Combat experience	±	±	Yes
	Activity level high	±	±	Yes
	Task load high	±	±	Yes
	Stress/Fatigue high levels	±	-	Yes
	Sensory overload			
	acute	-	±	Yes
	chronic	±	±	Yes
	Information overload	±	±	Yes
	Emotional value of stimulus	+	±	Yes
	Religious values	±	±	Yes
	Personality	±	±	?
b. Group	Leadership	±	±	Yes
	Morale	±	±	Yes
	Group Dynamics	±	±	Yes
	Casualties, high	+	-	Yes

Key: + increases
- decreases
± can move either way
NE no effect
? questionable

2. Internal

   a. individual
   b. group

This categorization identifies what appear to be the major classes of moderating variables. The two sorts of external variables serve to specify the situation.

Military factors such as the solder's mission, activity, etc., identify the context of the combat engagement; and similarly, environmental factors such as climate, weather, etc., identify the context of the engagement. The factors listed within these two categories set the stage. The next two categories identify factors which define the soldier population in terms of both individual and group factors. It is apparent that the factors listed are not independent. For example, personal stress/fatigue may be highly correlated with the intensity and duration of the engagement. Nevertheless, they provide a useful framework for considering the effect of man weapons systems variables upon the human sensory and perception processes.

The number of factors and basic stimuli that are relevant to perceived risk present both a conceptual and an experimental problem. There are so many distinct stimuli to be considered simultaneously for any suppression problem that any general parameteric research or analysis seem impractical. It is not that we can not model the individual steps in the perception of risk, but rather that there is a large variety of stimuli that may be applicable to a perceived risk. These stimuli are so diverse that it is hard to conceive of a research program that will eventually allow us to precisely model the perceived risk of a given soldier using the various inputs resulting from a single source of fire.

Consider, for example, an attack helicopter firing an automatic weapon at an individual. All of the following basic stimuli may contribute to that individual's perception of the risk: (1) the sound of the helicopter; (2) the sight of the helicopter; (3) the flashes of the gun; (4) the smoke from the gun; (5) the glow of the tracers; (6) the sound of the gun; (7) the "crack" of a passing bullet; (8) the sound of bullets impacting nearby; (9) the sight of the dirt kicked up by bullets impacting; (10) the tactile impression from being hit by dirt kicked up by the impact of the bullets; (11) the individual's mission; (12) the length and intensity of the engagement; (13) the individual's training and experience; etc. Some or all of these stimuli and moderating factors, taken together and considering not only instantaneous values but recent trends, as seen by the individual solder, will determine the perceived risk. The problem in conducting research on the human processes is not the modeling of the generation or transmission of each of these stimuli, or the effects of the moderating factors, or even in assessing the human's ability to detect each of these stimuli, but rather in trying to bring together all of these variables in formulating the human's perception of risk to be associated with the combination of these stimuli.

Instead of a parametric approach to the weapons system signals, it is recommended that experiments be system and situation specific (i.e., use existing weapons systems or simulate signals of proposed systems that are the direct concern of the decision problem). Implicit in this recommendation and the approach taken in subsequent parts of this section is the idea that analysis or experiments on the human processes (sensory, perception and reaction) should:

a. focus on understanding the mechanisms of the process; and/or

b. be system and situation specific.

Experiments should be designed, in so far as possible, to allow comparability among the results of separate weapon system signals experiments. A data base could then be developed to support more general analyses and findings concerning the effects of weapons systems signals.

Instead of separate experiments concerning the effects of various moderating factors such as training, morale, leadership or personality, it is recommended that other experiments incorporate these factors as covariates. Not all of the moderating factors are easily amenable to measurement or experimental study and significant effort may be required to incorporate certain of the moderating factors into experiments. It is recommended that a priority listing be developed of the moderating factors in terms of their presumed impact or risk perception and risk acceptance. For a sample of moderating factors Table 3 summarizes our nominal estimates of their influence on risk perception and on risk acceptance and on whether they are amenable to computer modeling and experimental study. This priority can be used to identify those specific factors which should be considered as covariates and for which measurement scales are required.

3.2.1.1 Sensory Processes $(f_{2.1})$

The complex of battlefield stimuli which effect the individual are detected and converted into sensory data by sensory processes such as vision and audition. This section characterizes aspects of the sensory process by which stimuli are attended to; it discusses effects of the complex of battlefield stimuli on the individual; and it indicates the relevance of existing data and data voids. Extensive supplementary data for this section is available concerning the functioning and basic operating characteristics of the sensory process.[4]

Basic Parameters

Parameter	Definition
Sensitivity (lower threshold)	Minimal intensity and frequency of signals that can be sensed.
Sensitivity (upper limit)	Limit on intensity and frequency beyond which sensitivity is lost and/or damage may occur to sense organ.
Sensitivity range (upper limit minus lower threshold)	Maximum "bandwidth" of a physical energy that can be sensed.
Differential sensitivity (difference threshold)	Intensity for frequency by which: a signal must be increased or decreased for the change to be detected; two signals must differ to be detected.
Information transmission capacity	Maximum number and type of codes possible within a stimulus dimension.

Most of the data related to the sensory processes has been collected in quiet environments under optimum conditions, both in the laboratory and in the field. Battlefield stimuli considered singly are generally within the sensitivity range of man's senses. However, this by no means

[4]For example:

Geldard, F. A. The Human Senses (2nd edition). New York: John Wiley & Sons, Inc., 1972.

Graham, C. H. (ed.) Vision and Visual Perception. New York: John Wiley & Sons, Inc., 1966.

Gulick, L.W. Hearing - Physiology and Physchophysics. New York: Oxford University Press, 1971.

Wolman, B. B. (ed.) Handbook of General Psychology. Prentice Hall: Englewood Cliff, N. J., 1972.

establishes his capabilities to detect and discriminate among stimuli in the complex battlefield environment.

The Effective Stimulus

The signature of a weapons system at the suppressee's location can be determined from the physics of the situation. However, the battlefield is not quiescent and there are many different stimuli impinging on the senses. Consider the TOW gunner--firing of the TOW is accompanied by:

1. Noise,
2. Blast/Shock,
3. Smoke/Dust and
4. Flash.

These stimuli serve both to mask the signature of a suppressor's weapon system and to increase the sensory threshold of the gunner. Additionally, he actively engages in the tracking task with a restricted field of vision. Thus, a TOW gunner may not detect that he is being fired on. In other instances, the effect of the ambient "noise" may be to reduce the discrimination of the stimuli generated by the specific weapons system which is firing on an individual. The rifleman located in proximity to a TOW to protect the gunner; (a) may not perceive that he is being fired on; or (b) may not be able to discriminate the weapons system which is firing on him. An individual in a squad defending against an infantry attack may detect that he is being fired on, but not the specific source or type of fire.

Two features of these examples are of note:

1. The effective stimulus at the suppresse's location is not merely the signature of the suppessor's weapons system, but the stimulus resulting from the interaction of all the battlefield stimuli arising from both friendly and enemy activity.

2. The suppressee may not be capable of discriminating specific suppressor weapons systems from the ambient noises.

These features of the sensory processes suggest that the weapon systems stimuli relevant to suppression are the loudness, the visual impact, and distinctive or unusual visual/auditory stimuli which are detectable in a noisy environment.

The level of "noise" on the battlefield serves as more than the background against which the weapon system signature is perceived. The sounds of aircraft, moving vehicles, near weapons fire or explosions, etc., also provide information concerning the imminence of threat/danger. This background influences both the perceived risk associated with a specific weapon system and the surprise level of firepower. The rifleman who perceives he is being fired on by another rifleman may assess the risk level as far higher against a background of the sound of mechanized vehicles and a high volume of rifle fire than a background only of near scattered rifle fire.

There are a number of moderating factors that influence the operating characteristic of the sensory processes and that determines which stimuli are effective. Three of these factors - Sensory Modifiers, Activity Load, and Posture - are of evident importance in suppression and are briefly discussed.

Sensory Modifiers. The use of such things as ear-plugs, goggles, and night vision devices serve to change the users sensitivity range, and, hence, the kind of stimuli that are sensed by him. Although such devices may not be widely distributed among individuals on the battlefield, they are likely to be present among critical personnel, such as TOW/DRAGON or SAGGER gunners. A major effect of these devices is to change the salience or conspicuousness of stimuli. Thus, for the TOW gunner wearing ear plugs, the visual impact stimuli are a more salient indication of being fired on than is the auditory signature of a weapons system.

Activity Load. High concentration on an activity (e.g., a TOW gunner tracking a target after launch) or a high level of effort on an activity (e.g., a gunner reloading DRAGON with an approaching target) may increase the absolute threshold or the differential threshold or both. Thus, for these individuals the intensity of the stimulus is a significant determinant of its salience.

Posture. The posture of the individual (standing, crouching, etc.), and the sequence of postures (e.g., observing, ducking, observing, etc.) influence the sensory capabilities of the individual. Estimates of sensory capabilities as a function of posture are easily derivable from existing data. However, the effect of a sequence of postures allowing only intermittent observation cannot be so derived and little data currently exists. For example, it is clear that observing for 10 seconds continuously is not equivalent to observing for 5 seconds, ducking for 10 seconds and observing for 5 seconds. This type of data could easily be obtained experimentally for a given sequence of postures.

Stress[1]

Stress can have a significant sensory operating characteristics, e.g., the detection threshold and/or sensitivity may decrease as a result of stress.[2] The complex of battlefield stimuli contribute to the stress/shock placed on an individual in at least two ways: sensory overload and the emotional value of stimuli. Although there is little data relevant to either area, both appear to play a role in suppression.

Sensory Overload. High intensity stimuli in any modality tend to produce stress. This may occur through distraction, increasing the level of arousal, or disorienting the individual. One mechanism through which suppression occurs may be the impulse noise associated with gunfire and exploading warheads.

Emotional Value. Stimuli gain an emotional value through training and experience and may have some inherent emotional value. For example, the auditory signature of small arms fire overhead appears to arouse combat veterans more than civilian observers. Similarly, it appears reasonable that certain sounds, e.g., a loud thunder clap or a high pitched siren, inherently produce more fear than others. The question is whether there are stimuli which are inherently suppressive?

Existing Data and Data Voids.

Existing data concerning sensory processes could be used to estimate

1 Fatigue is also a significant factor. The results of fatigue studies, however, are notoriously difficult to interpret and to apply in any practical context. Some reasons are the lack of an adequate definition of fatigue and the absence of any metric for fatigue effects. The effects may be so great, however, that an attempt should be made to develop an adequate technological base.

2 For example, Weltman, G., Christianson, R.A. and Egstrom, G.H. Visual fields in the scuba diver. Human Factors, 1965, 7 423-430.

operating characteristics analytically for such quantities as miss distance in a battlefield environment. Such analytic estimates can be used to provide initial data for modelling or as base-line data for experimentation on sensory operating characteristics in high ambient noise conditions representative of the battlefield environment.

The effects of stress on the sensory process are not well understood and there is little data available on the effects of non-traumatic stress on performance. Although there are severe ethical, legal and social constraints on the type of research which can be conducted, the need for information is so great that reasonable attempts to generate and obtain data should be made.

3.2.1.2 Perception Processes ($f_{2.2}$)

This cognitive process synthesizes and integrates sensory and other information into a perception of the risk involved in the situation. Perceived risk represents the output of the combined sensory and perception processes, $f_{2.1}$ and $f_{2.2}$ in Figure 1; and is a function of the perceived stimuli (Table 1) and the moderating variables (Table 3). The determinants of perceived risk remain largely unexplored. Although a wide variety of stimuli and moderating factors have been identified as relevant to perceived risk, there is little data of any sort concerning either perceived risk or the structure of the risk perception process in specific real world situations.[1] Descriptive accounts or analyses of

1 Psychological research on risk has focused on simple gambles in the laboratory or real-world situations such as horse-racing which fit a gambling paradigm. (e.g., Payne, J.W. Alternative approaches to decision making under risk: Moments vs. risk dimentions. Psychological Bulletin, 1973, 80, 439-453.)

combat performance (e.g., S.L.A. Marshall's books), as well as the opinions of combat veterans, provide perspective and a basis for conjecture. However, they do not provide either the data or the concepts required to develop useful models of fire suppression.

A critical analysis of risk perception and risk-taking behavior which attempts to interrelate various approaches was not possible within the time and resources available to this group. In this section, the concept of risk and weapon system lethality are briefly discussed. Some possible mechanisms of risk perception are discussed as well as existing data and data voids.

The Concept of Risk

The term risk is commonplace both as a descriptive and as an explanatory construct of behavior.[1] Although there have been various attempts to define risk, there is no generally accepted definition. Concepts of risk are to some degree idiosyncratic. Like beauty, it is in the eye of the beholder. Rather than provide another definition of risk, the following discussion identifies the main elements of risk.

Objectively, risk refers to the uncertainty of damage, injury or loss. Risk is a characteristic of decision situations in which the consequences of choosing an action are uncertain. For example, the TOW gunner who is taken under enemy fire after launch has a choice of actions - continue tracking, duck, etc. For each action the gunner may choose, the

1 See for example: Lee, W. Decision theory and human behavior. New York: Wiley, 1971; or Kogan, N. and Wallach, M.A. Risk taking as a function of the situation, the person, and the group, in New Directions in Psychology III. New York: Holt, 1967, pp. 111-278.

consequences or outcomes are uncertain - survival, injury, killing the tank, missing the tank, etc. If there is no uncertainty, there is no risk.

Uncertainty is not the only component of perceived risk. A second component of perceived risk is the potential gains and losses associated with an action. That is, the subjective value or importance the individual associates with each outcome (technically called utility) clearly influences perceived risk. The potential losses in combat are clear - death or injury. However, it is equally clear that the utility associated with death or injury is not a simple term. For example, there are differences between "suppressive systems" such as napalm vs. machine gun fire which cannot be explained simply in terms of uncertainty.[1] The potential gains are less clear - status, motivation, etc. However, it is clear that these influence the perceived risk.

Perceived risk is a function of uncertainty and utility. Discussions of fire suppression, and this report, have focused on the uncertainty associated with losses - e.g., the perceived probability of death, injury or other loss. The uncertainty associated with gains and an analysis of individual utility functions has been ignored. One reason for this failure is that uncertainty and the utility of losses and gains do not necessarily make equal contributions to perceived risk. The perceived probability of death, injury or other loss is clearly a significant determinant of perceived risk. However, it should be noted that none

1 A conjectured model which includes utility is presented in section 3.2.2.

of the previous experiments related to suppression have found a relationship between perceived risk and the actual probability of death, or injury.[1]

It is recommended that suppression experiments should consider both uncertainty and utility. As a corollary of this recommendation, the contribution of uncertainty and utility to perceived risk should be considered separately; however, recommended experiments will initially confound their effects.

Weapon System Lethality[2]

The expected kill probability (P_k) of weapon systems acting against a soldier is usually considered by combat analysts to be the true risk[3] (R_t) to an individual soldier in that time period. Expected P_k is a function of several target/weapon systems variables such as the individual's level of protection, and the accuracy and lethality of specific weapons systems. As a measure of R_t, expected P_k is important for the following reasons:

1. It is frequently used as an analogue of perceived risk (R_p) in combat models (see Appendices D and E for examples).

2. It provides a baseline for an analysis of R_p.

3. Combat veterans indicate perceived lethality is a major determinant of R_p. Although R_p is related to R_t, the nature of this relationship is

1 Gividen op. cit.

2 The potential significance of the relationship between weapon system lethality and perceived risk is indicated in Appendix F.

3 True risk associated to be objective uncertainty of future outcomes.

not obvious. None of the experiments related to suppression have found a relationship between P_k and R_p.

The expected P_k of the weapons systems acting in a given time period can be decomposed into two factors: expected hit probability (P_h), and the terminal effects of the rounds. Confusion between these two components of risk could explain the failure of previous research to find a relationship between P_k and R_p.

1. There are battlefield stimuli which provide a sensory basis for individual assessments of P_h. However, it should be noted that there are no classes of battlefield stimuli which have a direct relationship with P_k.

2. P_h is closely related to characteristics of weapons systems signals which have been suggested as principle determinants of suppression. Terminal effects of rounds appear to be unrelated to suppression unless the weapon system acting against the individual can be identified.

The preceding discussion has focused on the relationship between weapon system lethality and R_p. Although both P_k and P_h are important determinants of R_p, clearly neither is equivalent to R_p. In evaluating the effect of both various weapons system stimuli and moderating factors, both P_k and P_h should be used to provide a baseline for comparison. Two factors are suggested as primary determinants of perceived risk. The first is perceived P_h. The second is weapons systems identification.

Mechanisms of Perceived Risk

Based on discussions with officer combat veterans the following factors appeared to be important determinants of perceived risk:

Class of Weapon: Indirect Fire vs. Direct Fire; Automatic Rifle[1] vs. Rifle

Type of Fire: Aimed vs. Zone (Unaimed)

Mode of Fire: Point vs. Area

These were not the only factors brought up in discussion, nor are they likely to be the only factors which are important. However, they are sufficient to indicate some alternative conjectures of the risk perception process. Two alternative mechanisms are conjectured. The first, Model A, focuses on the process involved in learning to identify specific weapons systems. Model B focuses on the sequential *structure* of the weapon identification and risk perception process.

Model A. Learning, either through training or through combat experience is an important aspect of risk perception. The relationship between various weapons system signals and risk is not immediately obvious, but must be learned. The perceptual learning process can be conceptualized as evolving through a series of stages which form a cognitive hierarchy (Figure 3). The learning process is one of increasing differentiation of weapons system stimuli through experience. A four stage learning process is illustrated, although the number of stages may actually be greater.

1 Includes machine guns.

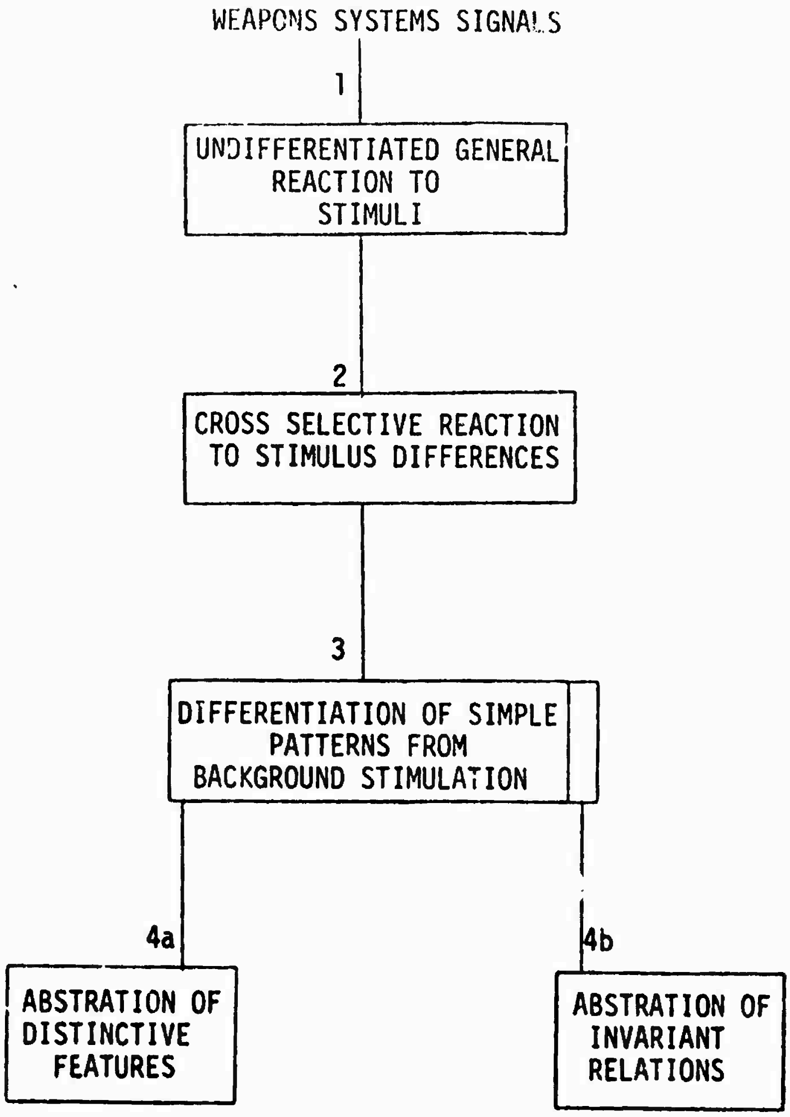

Figure 3: Schematic of the Perception and Learning Process

The first two stages of the process are representative of the soldier on his first exposure to combat. In the first stage, "undifferentiated general reaction to stimuli," each loud or unusual noise--artillery explosion, rifle fire, etc.--elicits a general suppressive reaction. The first stage soon evolves into the second stage, "gross selective reaction to stimulus differences." In the second stage, the soldier has learned to selectively react to differences in weapon system stimuli, e.g., he may pause or crouch rather than "pop down" when hearing artillery shells impact in the near, but not immediate vicinity.

In the third stage after more experience he learns to selectively react to simple patterns of weapons system signals; e.g., to react differentially to aimed vs. unaimed fire in his vicinity. The fourth stage of the learning process contains two subprocesses. One subprocess, "abstraction of distinctive features," represents the process of learning to identify specific weapons systems. The other subprocess, "abstraction of invariant relations" represents the process of learning the summary characteristics of weapons system stimuli such as loudness. The relationship between weapons systems signals and risk learned in this stage do not appear to be acquired in current combat training, but rather are acquired through combat experience.

The hypothesis illustrated in Figure 3 suggests the critical role of training and experience in the risk perception process.

Model B. The factors indicated above as determinants of perceived risk are not considered collectively, but rather represent a sequence of judgments which appear to occur in the order shown in Figure 4. Thus, the soldier discriminates among indirect and direct fire, automatic weapons fire, and rifle fire before discriminating between aimed and

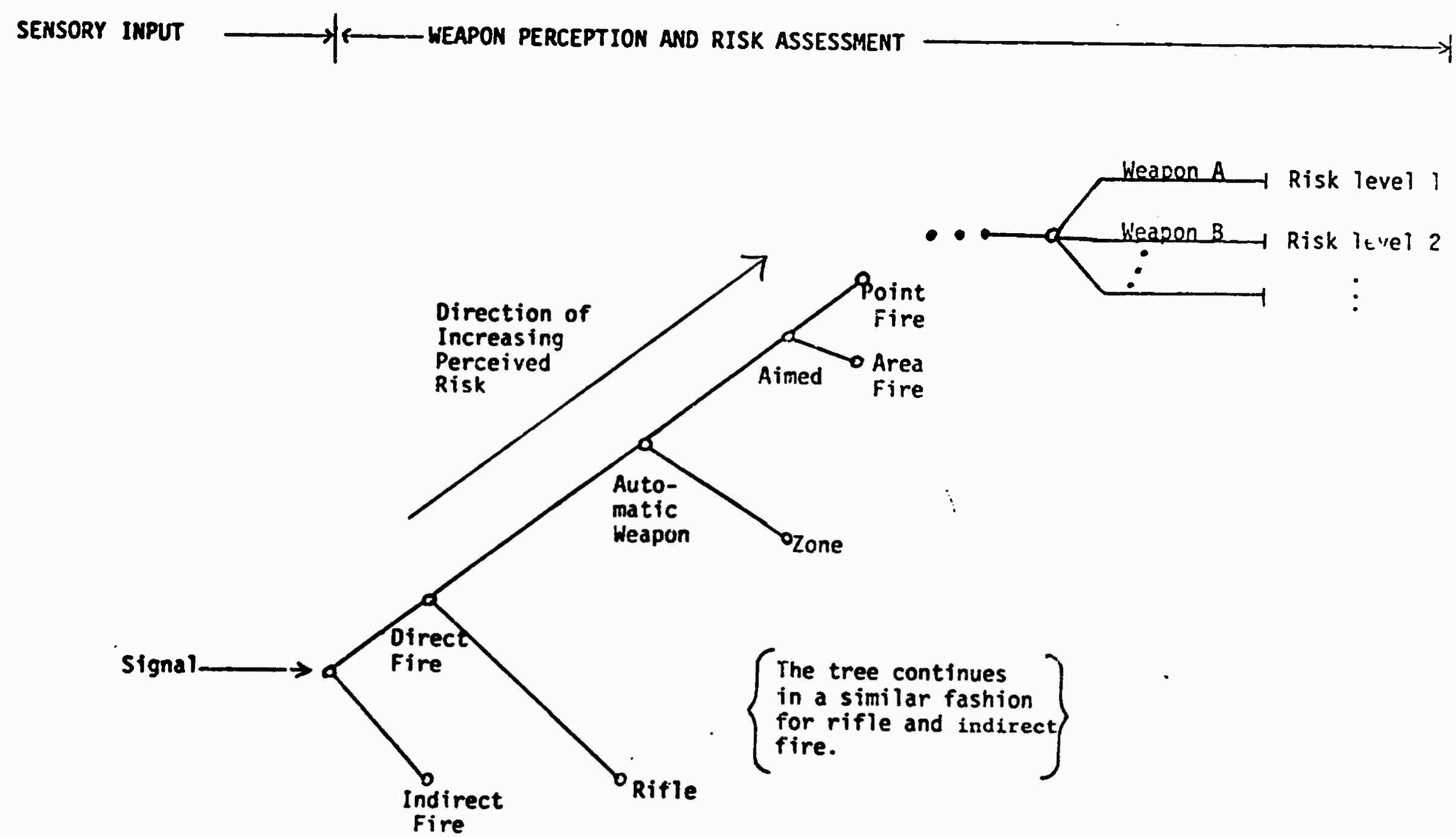

FIGURE 4: SCHEMATIC REPRESENTATION OF WEAPON AND RISK PERCEPTION

unaimed fire. The last stage of the process is the discrimination of weapons system type, and an associated risk assessment.

The tree structure shown in Figure 4 implies a process of sequential risk assessment. Each node is a decision or perception point in the identification activity. As a corollary hypothesis of this structure, it appears that the reaction to stimuli occurs at successively later points in the structure as a function of the soldier's experience and training. That is, as the soldier gains skill in assessing the risk associated with weapons systems, he makes increasingly more precise discriminations before reacting.

Existing Data and Data Voids. There is very little existing data which could be used to estimate perceived risk as a function of weapon systems, combat operations and environmental conditions. Several types of experiments are suggested by the mechanisms of risk perception which were conjectured and these are outlined in Section 4.2.5. Risk perception is clearly a complex, highly cognitive process which cannot be understood or predicted solely on the basis of weapons systems signals. The moderating variables (Table 3) as well as man's ability, to perceive/estimate uncertainty must be considered.

In terms of the six summary characteristics of weapons systems signals which previous research identifies as primary determinants of suppression (See Section 3.2.1), it would be valuable to verify these results under experimental conditions, much as CDEC is doing at this point. Such studies would produce confirmatory data that would also be useful in determining the accuracy of miss distance estimates, identification of weapon type, and accuracy of estimates of volume of fire under high ambient noise conditions representative of the battlefield.

3.2.2 Reaction Process (f_3)

There are two major aspects of the reaction process which need to be studied. The first is the set of specific reactions which may occur, their duration, and their sequence. The second is the process by which specific reactions occur in response to perceived risk. The present section characterizes these two components and provides a perspective for further research. There is very little data available concerning the reaction process and the concepts presented represent working hypotheses. The focus is on "reasoned reaction" involving a sensible assessment of risk and the exercise of judgment about the demands of the immediate situation and the necessity to observe, shoot, move or communicate at that instant.

An Initial Framework: The reactions of the soldier can be classified along several dimensions:

activity-oriented[1] vs. threat-oriented

"reasoned" vs. "unreasoned" (voluntary vs. involuntary).

effective vs. ineffective

As an initial framework consider reactions to be a change in the response of the soldier caused by signals from delivered fire or the threat of delivered fire. For example, a TOW gunner may flinch or duck after observing machine gun fire impacting near his position. Within this framework the reactions of interest are those which are threat-oriented rather than activity-oriented. That is, the reactions of the soldier to the perceived risk. Although the reaction is threat-oriented, the effect may either increase or decrease activity performance (cf the section on Performance Effects).

---

1 Activities were defined in section 1.1. Examples include firing, maneuvering, searching and observing, etc.

The "reasoned" reaction of the soldier is to decrease the perceived risk, by increasing the protection level, e.g.,

Pop Down-Prone

Pop Down-Crouch

Move to Cover

Button-up (Tank Crews)

or by attempting to reduce the perceived risk through reactions oriented toward more effective aggressive action against the enemy. Thus, the TOW gunner after observing machine gun fire impacting near his position may move faster in reloading TOW. Another possible "reasoned" reaction is the "null reaction" or no change in task performance.

"Unreasoned" or involuntary reactions of the soldier are responses such as:[1]

Reduction/increase in the level of Motor Control

Startle/Flinch (momentary loss of control)

Momentary Pause in Task Activity

Run

.

.

.

For example, the tracking error of a TOW gunner after observing machine gun fire impacting near his position may either increase or decrease.

---

1 Shock effects produced by intense and/or long lasting artillery bombardment have not been considered because of time and resource constraints. These effects appear to differ from suppression both in duration and in the mechanisms through which the effects are produced. However, the potential importance of these effects is such that they should be considered in any more detailed analysis of suppression processes. An initial analysis of these effects is available in Army Materiel Systems Analysis Agency Technical Memorandum No. 142 (Confidential), Proposed Criterion for Assessing the Effects of Neutralization Bombardment (U), August 1972, by R.D. Blakeslee.

The soldier's reactions lead to a change in performance through the performance effects process. The weapon system employed by the soldier clearly influences the reactions which occur. Thus, a rifleman observing machine gun fire impacting near his position may be more likely to duck than a TOW gunner observing machine gun fire impacting near his position. The effect of ducking may be greater on the TOW gunner's performance than on the rifleman's performance.

The soldier's reactions are also influenced by his current state. A TOW gunner who has recently ducked may be more likely to duck than one who has not, given the same delivered fire. A good predictor of the soldier's reaction may be his prior reaction or sequence of reactions. For example, in the following possible sequence of reactions by a rifleman to small arms fire, each reaction is of different duration and complexity: "startle-pop down prone-move to cover". Each of the reactions has an identifiable beginning and end. However, it is not clear that each reaction is of equal importance or that the level of detail used is required. Each reaction in the sequence has an allocated time distribution.

Data Deficiencies and Voids.

An adequate and useful description of reactions to firepower is required. The literature currently available (SLA Marshall's books, for example) serve to provide perspective rather than to provide data which could be used for modelling. A description of reactions should be based upon a common unit of analysis such as

A small sequence of behavior with an easily identifiable beginning and end (e.g., move to cover). This includes both instinctive and highly learned reactions.

Time line data of reactions should be obtained in sufficient detail to allow an assessment of the duration of suppression. There is no data available, either qualitative or quantitative, on the duration of suppression. Although different reactions occur over different time spans, a common time interval can be defined (e.g., 3 to 10 sec) and reactions analysed in terms of this interval.

A Conceptual Model of the "Rational" Suppressee

A variety of concepts, hypotheses, and conjectures related to human processes in fire suppression have been discussed in the proceding sections. To illustrate how these notions are interrelated, provide a basis for useful models, and identify data requirements, a conjectured conceptual model of the reaction process for a "rational man" will be briefly described.

"Rational Man" bases his choice of action not on habit or reflex, but on deliberate and knowledgeable reasoning about the possible results of his actions; his choice is that course of action that brings him maximum gain.[1] The concept of rational man implies a number of assumptions concerning man's capabilities some of which have been shown to be unwarranted (e.g., that man knows the consequences of each possible action he may choose), or which clearly do not apply to the soldier on the battlefield (e.g., that man does not base his choice of action on habit or reflex). However, the concept of rational man does provide a perspective for the development of a concept of "reasoning man": a concept of the reaction process which makes realistic assumptions about man's cognitive capabilities.

1 von Neumann, J. and Morgenstern, O., "Theory of Games and Economic Behavior," Princeton, New Jersey, Princeton University Press, 1944.

The reactions which occur at any one point in time may be viewed as the result of a decision problem -- the choice between attempting to continue assigned combat activities or to avoid them. These two actions are mutually-exclusive alternatives and cannot take place at the same time. Thus, at any one point in time, the suppressee may either attempt to continue mission oriented activity (A) or not attempt to continue mission oriented activity ($\bar{A}$). The reaction of a TOW gunner who ducks would be classed as "No Attempt;" whereas the reaction of the TOW gunner who continues to track, but whose tracking error increases would be classed as "Attempt."

This simple dichotomy leads to a binary decision model of the reaction process. The choice between "Attempt" and "No Attempt" depends on the value structure of the individual (as the member of a larger unit from a particular culture) and his perceived uncertainty. The individual attaches some value or utility to various outcomes or events that can occur, given he "attempts to perform his combat activities" (action A) and given he does not attempt them (action $\bar{A}$). In an aggregate sense, it is conjectured that the individual projects the results of his action into a three-dimensional outcome that will occur at some future point in the battle. Elements of this joint outcome space are:[1]

- .Mission Accomplishment (M) or Failure ($\bar{M}$)
- .Task Accomplishment (T) or Failure ($\bar{T}$)
- .Survival (S) or Casualty ($\bar{S}$)

The suppressee's action (behavior) to the suppressive fire conceptually is a result of integrating this information regarding future outcomes. A paradigm for doing this is to assume he determines the probability of each of these outcomes and the value or utility to him if the outcome occurs.

1 The reader is referred to section 1.1 of the report for the specific meaning of mission, task, and activity.

Notationally, he determines

$$
\begin{array}{ll}
P[T.S.M/A] & U[T.S.M/A] \\
P[\bar{T}.S.M/A] & U[\bar{T}.S.M/A] \\
P[T.\bar{S}.M/A] & U[T.\bar{S}.M/A] \\
\cdot & \cdot \\
\cdot & \cdot \\
\cdot & \cdot \\
P[\bar{T}.\bar{S}.\bar{M}/A] & U[\bar{T}.\bar{S}.\bar{M}/A] \\
P[T.S.M/\bar{A}] & U[T.S.M/\bar{A}] \\
P[\bar{T}.S.M/\bar{A}] & U[\bar{T}.S.M/\bar{A}] \\
\cdot & \cdot \\
\cdot & \cdot \\
\cdot & \cdot \\
P[\bar{T}.\bar{S}.\bar{M}/\bar{A}] & U[\bar{T}.\bar{S}.\bar{M}/\bar{A}]
\end{array}
$$

where

P[.../.] = the suppressee's estimate of the joint probability of outcomes, given action (.) is taken,

U[.../.] = the suppressee's utility or value he assigns to the joint outcome, given action (.) is taken

and the T, S, M, and A symbols were previously defined.

A model of the rational suppressee requires that these utilities and outcome probabilities (risks) be obtained from prospective suppressees via experimentation, subjective probability estimation techniques, and utility assessment procedures.[1] To be useful for predictive purposes, the estimates (for all relevant mission, task, activity combinations) would have to be functionally related to the many exogenous variables discussed

1 See "Decision Theory and Human Behavior" by Lee for a discussion of subjective probability estimation and utility assessment procedures.

earlier (e.g., see table 3) including the suppressing weapon system, the suppressee's protection level, his capability at performing the activity, his past experience in assessing risk (i.e., training and combat experience), his belief in controlability of the outcomes, morale, etc. Conceptually, this is possible, especially if the joint probabilities are appropriately decomposed to isolate some of the marginal outcomes.[1]

Given these utilities and probabilities, the conceptual model of the rational suppressee assumes that the course of action (i.e., his reaction) taken by the suppressee for the particular situation (i.e., mission, task, activity and suppressing weapon) under consideration is chosen by selecting the max$\{U(A), U(\bar{A})\}$ where

$$U(A) = \sum U[.../A].P[.../A]$$

$$U(\bar{A}) = \sum U[.../\bar{A}].P[.../\bar{A}]$$

where the sums are taken over the elements of the joint outcome space. That is, the suppressee will select that reaction which maximizes his "expected utility." Figure 5 is a schematic representation of the "rational suppressee" model for a particular situation shown by the bold path through the decision tree.

If such a model were to be used as a basis for experimentation and eventual prediction of reactions to suppressive fire, the reaction (action) space would have to be extensively expanded from the binary case of A

---

[1]For example P[T.S.M/A] = P[M/S.T.A].P[T/S.A]P[S/A]. Terms on the right hand side should be easier to assess than the joint probability.

and $\bar{A}$[1]. Determining the level of detail required to describe a useful reduction space is clearly an experimental problem which, although tractable, would require significant effort. This problem, however, would need to be resolved for any model of the reaction process. The major problem with the model is that years of experimentation have indicated that:[2]

(1) it is extremely difficult to assess and separate out the probabilities and utilities needed for the model

(2) maximization of expected utilities is not a good predictor of human behavior.

The first problem, obtaining good input data, is experimental and although tractable, would require significant effort. The second problem, developing a good predictor, is experimental and analytic and requires the development of more realistic assumptions that maximization of expected utilities for predicting the choice of action taken by the suppressee. Thus, although a rational man model is a valuable construct to assist in thinking about the problem, experience suggests that it should not be used as the only model for formulating an experimental and modeling research program to predict reactions to suppressive fires. Other conceptual models should be developed to the stage where they can be evaluated as predictive

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1 For example A_1 = attempt to perform all activities, A_i = attempt to perform i of the activities, $\bar{A}$ = attempt to perform none of the activities (i.e., take cover).

2 See Decision Theory and Human Behavior by Lee.

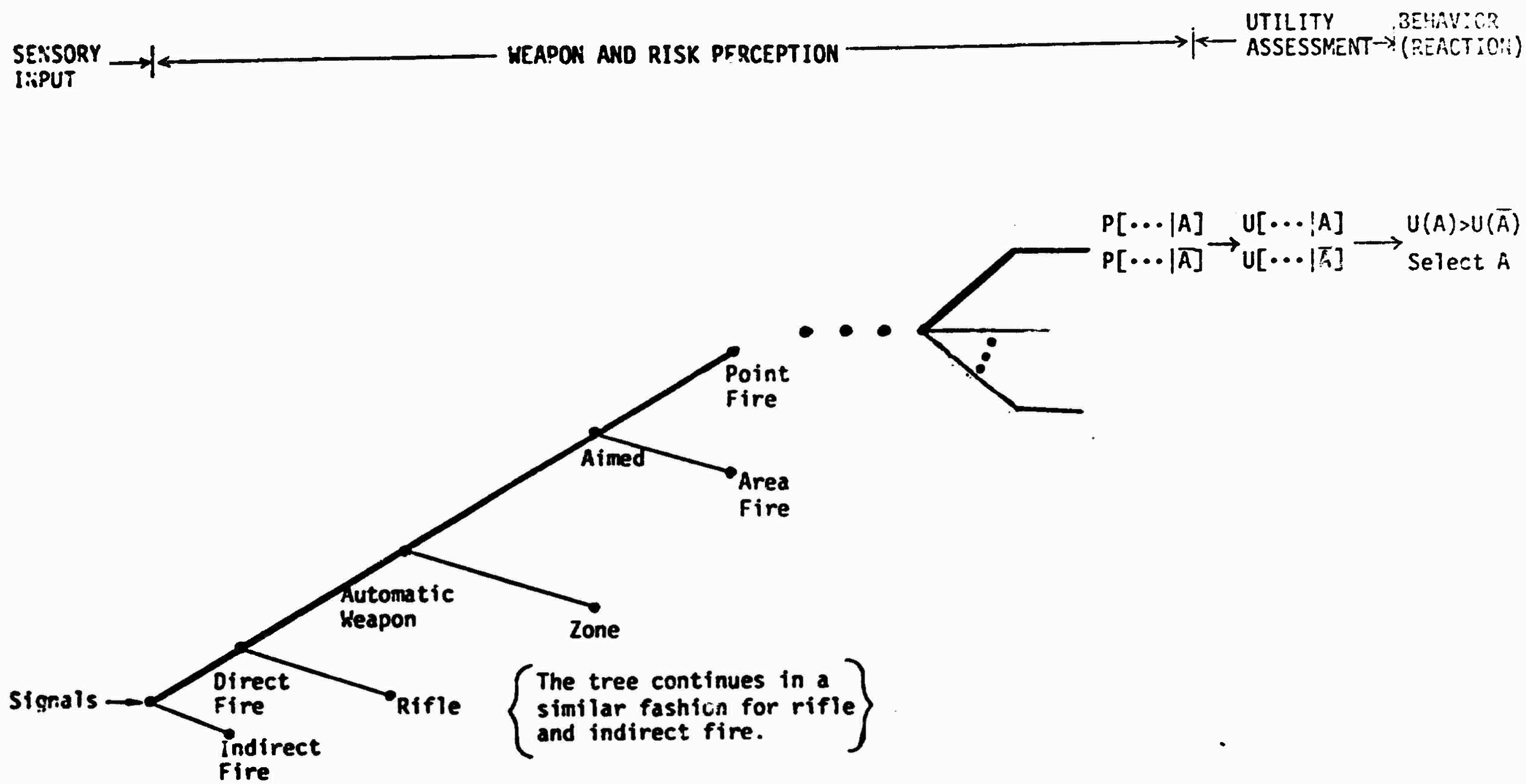

FIGURE 5. SCHEMATIC REPRESENTATION OF THE "RATIONAL MAN" HUMAN PROCESSES (f_2 and f_3) FOR A SPECIFIC SITUATION (MISSION, TASK, SUPPRESSION)

vehicles. The development of credible models is within the state-of-the-art and their development should be pursued in parallel with any experimental program.

3.3 *Performance Effects Process* (f_4)

Previous sections of this chapter discussed the signal (f_1) and human (f_2 and f_3) processes. In a modeling sense they are hierarchically related in that output of the signal process, are input to the human processes, which (via the sensory, perceptual, and behavioral processes) generate suppressive reactions by the suppressee. Continuing the hierarchical modeling viewpoint, the reactions are input to the performance effects process (f_4) which determines as output the nature and duration of changes in performance capabilities (i.e., the Δp_i).

The Δp_i outputs provide a natural method of quanitatively reflecting the effects of fire suppression on combat results, since the performance capability variables (the Δp_i) or related variables are

(a) as shown in figure 1, used as input in most combat models to represent the level at which combat elements perform activities;

(b) variables the combat models usually assume are affected by suppressive fire;[1]

(c) variables describing the suppressor's capabilities that are assumed to be the mechanisms causing suppression and influencing the suppression level and duration.[1]

Although the suppression behavioral assumptions used in these models are questionable, they are probably a good, intuitive, first attempt to include some major considerations of suppression, they are, however, not based on either a detailed examination of the structure of the fire suppression process, nor any significant suppression research data.

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1 This is shown for small unit combat models in table 4.

The purpose of this section of the report is to indicate the kinds of performance capability variables that, at least initially, should be considered in research on the performance effects process. This information is given in table 5, which is organized by performance area and principally the perspective of a suppressee's capabilities. For each category, the table contains relevant performance variables names (those variables usually considered as input in combat assessment models), associated measurement scales, related variables (those variables directly affected by behavioral reactions and which, in a sense, are the variables that "cause" the change in performance variable value), comments on models used to predict values of performance variables, and comments on tests that have been conducted to obtain data for the performance variables. Examination of the table will indicate that it is neither complete nor exhaustive -- its principal intent is to indicate the kinds of information that must be developed for relevant fire suppression combinations (see section 1.1) to determine the content of experiments on performance effects processes.

The remainder of this section presents brief, general comments on some of the performance areas regarding interactions between suppressive effects and lethality effects, available data, environmental interactions, and interactions among the performance areas. Discussions are keyed to the numbered subjects in table 5.

CHARACTERISTICS \ MODELS	DYNTACS	ASARS	CARMONETTE	BONDER/IUA	BLDM	AIDM
MECHANISMS CAUSING SUPPRESSION	FRONT NEAR MISSES NON-DAMAGE HITS MOBILITY-KILL HITS K-KILLS	NEAR MISSES DIRECT HITS -KILLING -NON KILLING	NEAR MISSES	FIRE RECEIVED	FIRE RECEIVED (SPECIAL TREATMENT FOR NON-LETHAL HITS)	CASUALTIES
PROCESSES AFFECTED (SUPPRESSEE)	NON-FIRING DETECTIONS FIRING COMMUNICATIONS (FDC)	MOVEMENT FIRE OBSERVATION COMMUNICATIONS	FIRE MOVEMENT OBSERVATION	FIRE OBSERVATION BEING ACQUIRED	FIRE OBSERVATION BEING ACQUIRED	FIRING
LEVELS OR STATES OF SUPPRESSION	LONG-TERM SHORT-TERM	SEVERAL STATES	"PINNED-DOWN" PARTIALLY NEUTRALIZED -EVASIVE ACTION -PROCEEDING WITH CAUTION (BUTTONED-UP)	SUPPRESSED UNSUPPRESSED	SUPPRESSED UNSUPPRESSED	SUPPRESSED UNSUPPRESSED
DURATION OF SUPPRESSION	INPUT CONSTANT	INPUT CONSTANT	INPUT CONSTANT	INPUT CONSTANT	WEAPON DEPENDENT INPUT CONSTANT	EXPONENTIAL
FACTORS INFLUENCING LEVELS	MISS DISTANCE	NEAR-KILL, EXISTING STATE OF SUPPRESSION OLD; NUMBER OF ROUNDS, ROUND TYPE, AVERAGE MISS DISTANCE	SUPPRESSEE TYPE NUMBER OF ROUNDS IN AI ROUND TYPE	NONE	NONE	NONE
FACTORS INFLUENCING DURATION	MISS DISTANCE STATE OF SUPPRESSION SEVERITY OF HIT	MAXIMUM CURRENT LEVEL OF SUPPRESSION	MOVEMENT OUT OF AREA OF IMPACTS	SUPPRESSEE TYPE	SUPPRESSEE TYPE	NONE
ELEMENTS [illegible]	ALL BUT AH'S	ALL	ALL	ALL BUT ARTY	ALL BUT ARTY	ALL BUT ARTY

Table 4: Summary of Suppression Characteristics as Represented in Various Small Unit Combat Models

Table 5: PERFORMANCE EFFECTS VARIABLES[1] (output of f_4)

PERFORMANCE AREA	PERFORMANCE VARIABLE[2]	MEASUREMENT SCALE	RELATED VARIABLE[2]	MODEL COMMENTS	DATA COMMENTS
I. Firepower					
A. Suppressee's firepower					
1. Accuracy of fire	·Total impact error in x, y, and z coordinates ·Hit probability	·Distance - mils ·Probability ·Probability	·Means and standard deviations of laying error in x and y coordinates ·Means and standard deviations of aiming error in each coordinate	(a) Direct fire systems ·Bivariate normal pdf ·component error models assume independent error sources (b) Indirect fire systems ·Trivariate normal pdf ·Independent error sources (c) Consider stationary and moving targets and firers	·An abundance of data exists on error sources, total errors, and operational hit probabilities (e.g., AMSAA, LDSR, NWC, etc.)
2. Timing of fire	·Time between rounds ·Firing rate	·Time (seconds) ·Rounds/time (bursts, volleys, etc.)	·Amount of down time ·Time to load ·Time to aim	(a) Tank fire ·Log normal or Erlang (k=2) pdf (b) Riflemen - (UK)[3] (c) Artillery - (UK) (d) AH - (UK) ⋮	·Tank fire - project STALK ·DRAGON - OT-2 ·Probably contained in operational tests of most new systems since 1970 ·SANS experiments

[1]This table lists the variables affected by the performance effects process, it being understood that there is a time duration associated with each

[2]The heading "performance variable" is intended to reflect the performance effects that are usually used as input variables in a combat assessment model. The heading "related variables" is intended to indicate those variables that are directly affected by behavioral reactions and which are, in a sense, the variables that "cause" the change in performance variable value. At times the "related variables" are used directly as input to combat assessment models and the "performance variable" is predicted via a separate equation or model.

[3]Unknown.

Table 5: PERFORMANCE EFFECTS VARIABLES (output of f_4)
(continued)

PERFORMANCE AREA	PERFORMANCE VARIABLE	MEASUREMENT SCALE	RELATED VARIABLE	MODEL COMMENTS	DATA COMMENTS
3. Mode or technique of fire	·Aimed/unaimed ·Mode ·Single shot ·Burst ·Volley	·None	(Same as performance variable)	Doctrine	·Can be observed readily during conduct of OT
E. Attrition of Suppressee					
1. Vulnerability	(a) Point target P(kill|hit) P(kill|miss) (b) Area targets ·kill probability ·lethal radius (c) Aircraft ·kill probability	 ·Probability ·Probability ·Probability ·Distance ·Probability	·Vulnerable area ·Presented area variations with time (which causes suppressor accuracy variations)	(a) Point target ·Armor vehicles ·Grid vulnerability model ·Depends on accuracy and lethality of fire ·Rifleman - (UK) (b) Area target ·Damage function model ·Integrated with accuracy in coverage models (c) Aircraft-shoebox model	(a) Point targets ·Armor vehicles-models based on mix of hardware component damage data and subjective data estimating loss in vehicle function ·Infantryman-AMSAA casualty data (b) Area targets ·Test firings at Fort Sill (c) Aircraft (UK)
2. Availability as a target	(makes suppressee available for acquisition and receipt of firepower)		·Time sequence of presented area		

Table 5: PERFORMANCE EFFECTS VARIABLES (output of f_4) (continued)

PERFORMANCE AREA	PERFORMANCE VARIABLE	MEASUREMENT SCALE	RELATED VARIABLE	MODEL COMMENTS	DATA COMMENTS
II. Target Acquisition					
A. Acquisition by suppressee[1]					
1. Ability to acquire, or otherwise observe the enemy or an area	(a) Visual			(a) Visual	(a) Ground-to-Ground
	·Time to detect	·Time	·Search time	·Poisson process (continuous)	·OSU experiments ·Psychophysical experiments ·TETAM ⋮
	·Detection rate	·Reciprocal of mean time to detect	·Decay in detection probability as a function of length of LOS interruption	·Geometric process (discrete) ·Detection rates based on psychophysical models of Lamar, Blackwell, etc. or detection time data regressed on target and environmental variables	Air-Ground ·CDEC 43-6 ·SEEKVAL ·Joint helicopter tests Ground-Air ·Joint helicopter tests ·CDEC 12-6
	(b) Pinpoint			(b) Pinpoint	(b) Project PINPOINT
	·Number of rounds to detect	·Number of rounds	·Search time	·Geometric pdf	
	·Single round detection probability	·Probability	·Pinpoint detection probability (as a function of number of rounds fired)	·None	
	·Location error (affects ability to aim)	·Distance - mils		·Univariate normal pdf	
	·Change in location error	·Distance			

[1]Audio and electronic detection means not included.

Table 5: PERFORMANCE EFFECTS VARIABLES (output of f_4) (continued)

PERFORMANCE AREA	PERFORMANCE VARIABLE	MEASUREMENT SCALE	RELATED VARIABLE	MODEL COMMENTS	DATA COMMENTS
(II.A.1. continued)					
	(c) Audio detection				
	(d) Detection by CB radar				
	(e) FLIR				
B. Acquisition of Suppressee					
1. Ability to acquire due to loss of LOS by suppressee posture sequence	(a) LOS duration ·mean visible time ·mean invisible time	·Time ·Time ·Time	(Same as performance variables)	·Deterministic LOS windows ·Renewal process models with terrain dependent transition rates	·Data collected in many European tests (e.g., NATO Range Study) and in US tests such as [illegible]
	(b) Pr[LOS exists]	·Probability	·Mean visible time ·Mean invisible time	·Bernoulli process with terrain-dependent parameter	
2. Ability to fire due to loss of LOS by suppressee posture sequence	·Pr[LOS exists] ·Artillery systems ·Rate of fire ·Location error ·Up ·Down	·Probability	·Amount of time suppressee visible ·Time to aim, -aim ·Tracking error when tracking through [illegible] LOS increment	·Bernoulli process with terrain-dependent parameter	·Data collected in many European tests (e.g., NATO Range Study) and in US tests such as [illegible]
III. Suppression					
A. Suppression by suppressee	·Δ performance effects variables ·Marginal Δ performance effects variables				

Table 5: PERFORMANCE EFFECTS VARIABLES (output of f_4)
(continued)

PERFORMANCE AREA	PERFORMANCE VARIABLE	MEASUREMENT SCALE	RELATED VARIABLE	MODEL COMMENTS	DATA COMMENTS
IV. Maneuver/mobility					
A. Suppressee					
1. Speed of movement ·Attack ·Defend	·Speed	·Distance/time	·Acceleration (in an attempt to attain cover position)	·Physics models degraded by human performance and behavior effects	
2. Direction of movement	[*The velocity of movement is functionally dependent on the means of movement (mounted/dismounted, crawl, etc.) and the mode of movement (e.g., buttoned up).]				
B. Suppressor					
1. Speed of movement ·Attack ·Defend	·Speed	·Distance/time	·Acceleration (in an attempt to get better target coverage)	·Physics models degraded by human performance and behavior effects	
2. Direction of movement	[*The velocity of movement is functionally dependent on the means of movement (mounted/dismounted, crawl, etc.) and the mode of movement (e.g., buttoned up).]				
V. C^3					
1. Communication	·Rate at which send and receive messages ·Error rate		(Same as performance variables) ·Commission errors ·Omission errors		
2. Command/control	·Rate of issuing orders ·Rate of order execution ·Error rate in coordination with participating elements ·Risk estimation ·Rate (duration) of risk acceptance (leadership)				

Table 5: PERFORMANCE EFFECTS VARIABLES (output of f_4)
(continued)

PERFORMANCE AREA	PERFORMANCE VARIABLE	MEASUREMENT SCALE	RELATED VARIABLE	MODEL COMMENTS	DATA COMMENTS
VI. Individual Decision Processes					
1. Selection of weapon/rounds (suppressee)					
2. Target choice (suppressee)					
3. Threat estimation (suppressee)					
4. Route selection (both)					
5. Choice of firing position (both)					
6. Risk estimation (suppressee)					
VII. Crew Coordination					
1. Delivery of ammunition to weapons	·Time to bring ammo to weapon site	·Time			
2. Weapon loading	·Load time	·Time/round			
VIII. Electronic Warfare	(Usually not a capability delivered by an individual in the company area)				

I. Firepower

A. Suppressee's Firepower

1. Accuracy of Fire

From the point of view of the soldier being suppressed, the suppressive mechanisms which most directly influence his overall performance are those which affect his ability to properly locate himself and aim his weapon. In the case of an artillery crew, these are described in part by the laying and aiming errors, and in the case of the rifleman, his aiming error. Once a round is fired, those combine with the aeroballistic performance to determine the total error in mils which, in turn, is combined with the fuze and warhead characteristics to determine the hit probability and lethality. In the artillery case the lethality has been quite well characterized through the JMEM manuals, but the relationship of these variables to the suppression effects that this fire has on its target (and perhaps the suppressor) is yet to be determined.

2. Timing of Fire

There is also a strong relationship between lethality, suppression, and timing of fire. The related variables of amount of down time, time to load, and time to aim would maximize the amount of effective ordnance delivered in the unsuppressed state. However, each weapon system, i.e., rifle, tank, artillery, DRAGON, and TOW has an optimized rate of fire and impact pattern which is peculiar to the weapon. The optimized rate of fire and impact patterns which consider suppression effects have not been clearly determined, and the performance variables of time between rounds and fire rate would be expected to be significantly altered when the effects of suppression are included. This is particularly true in considering command guided weapons in a suppression environment. The line of sight and target tracking are maintained only at a potentially significant risk to the gunner. At the same time, the hit probability is directly effected by the performance of the gunner in continuously tracking the target and maintaining a clear line of sight.

3. Mode or Technique of Fire

The technique of fire can, and probably will, differ significantly in a suppressed versus an unsuppressed environment. One of the most important considerations is whether the fire is aimed or unaimed, and this is generally related to whether the target has been acquired. Aimed fire by a suppressor is most effective in a lethality sense when the suppressee has not been able to determine that it is aimed. However, apparently suppressive effects are maximized when the suppressee perceives that fire he is receiving is aimed.

B. Attrition of Suppressee

1. Vulnerability[1]
2. Availability as a Target (Discussed together)

The optimum balance between the ability of the suppressee to deliver firepower and the requirement that he minimize his vulnerability is not

1 We note that, although vulnerability is in a sense discussed as a capability of the suppressee, it can alternately be viewed as the lethality capability of a suppressor.

well understood. If the suppressee is in an exposed state while delivering firepower, and thereby is wounded or killed, then his net contribution to the favorable outcome of the combat may be negative. The main variable that the suppressee controls is his own vulnerable area, and he controls this as a function of time. The ability of the suppressor to kill the suppressee is significantly degraded when the suppressee assumes a physical position which minimizes his vulnerable area. At the same time, the suppressee usually has virtually no capability to deliver firepower on the suppressor in this posture. It is well known how to calculate the suppressee's vulnerability if his presented and vulnerable areas can be specified. The research problem is to relate the human reaction to the suppressive firepower in terms of the suppressee's position and vulnerable area. In essence, the suppressee controls his availability as a target by trading off the necessity for delivering firepower as a function of time with the risk he perceives in increasing his own vulnerable area.

II. Target Acquisition (By and of Suppressee)

The problem of target acquisition by a gunner who must maintain a line of sight to the target is terrain and environment dependent. In considering the terrain, the data are often expressed as (a) probability that a line of sight will exist between an observer and a target, and (b) the probability that once established, a clear line of sight will exist for at least t seconds. The terrain having been defined, the related variables of search time and probability of detection can be experimentally determined. Tests using both battlefield and simulated environments have been conducted to bound the performance of test subjects. Once a target has been detected and identified, then the accuracy of firepower delivered is controlled by the ability of the gunner or forward observer to locate or track the target. This will be quite dependent upon his state of suppression and his state of perceived risk. When the suppressee has been forced to minimize his vulnerable area due to suppressive fire, he then has the problem of re-acquiring the target and reestablishing the tracking or locating process. When reacquiring, his performance in terms of time to acquire or re-acquire should improve significantly. This should also be true of his ability to deliver firepower because he has learned something about the target characteristics and its ability to return lethal firepower. Indeed the suppressee may have moved far enough along in this learning process to reverse the roles wherein he now becomes the suppressor.

III. Suppression (no discussion)

IV. Maneuver/Mobility

Maneuver and mobility are capabilities that are heavily directionally restricted by suppressive fires, but are enhanced in magnitude. They are oftentimes used to reduce the effect of suppressive fire. The suppressee often chooses to increase his vulnerability temporarily in order to gain a more covered position, an activity that is quite terrain dependent. This applies to the foot soldier, the tank, and particularly so for the crews of command guided weapons. When the DRAGON or TOW gunners experience suppressive aimed fire, their ability to move quickly is an important parameter in determining overall weapon effectiveness. If they have no inherent capability to deliver counterfire rapidly; i.e., suppress the suppressor, then the suppressor has a distinct advantage if he can simultaneously move and fire at the suppressee. Many of these effects discussed above have not been considered in the suppression models nor in performance evaluations of command guided weapons, and may actually be the determining factor in the effectiveness of these weapons.

V. Command Control Communication
VI. Individual Decision Processes (Discussed together)

Although the stress imposed by suppressive fire logically affects the amount of change in performance capabilities discussed above, a major part of the change in many of them can reasonably be associated with the physical reactions, per se. Thus, for example, although the stress may affect visual acuity, and therefore a suppressee's ability to acquire targets, the continual reactive ducking for cover, with intermittent attempts to look for the targets, would appear to heavily influence the change in acquisition performance capability. In contrast, some changes in performance capabilities associated with C^3 and decision making due to suppressive fire would appear to be more related to the stress phenomenon than the physical reactions. The C^3 function plays an important role in effective firepower delivery for command guided weapons, laser homing weapons, and artillery fire. Stress of suppressive fire can cause the forward observer to transmit inaccurate or misleading information which, at a minimum, can result in the useless expenditure of ordnance and, more importantly, lead to errors in the command function and dramatic consequences. As shown in many studies, tactics variables[1] (i.e., decision behavior) such as those shown in table 5, can have significantly more effect on predictions of combat results than the weapons performance variables.[2] However, these effects of suppressive fire are generally not considered in combat assessment models, probably because of the lack of any (even intuitive) understanding of the amount of the effects (i.e., pi) or the mechanisms causing them.

VII. Crew Coordination. (No discussion.)

VIII. Electronics Warfare. (No discussion.)

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1 Usually considered as rules of engagement in small unit action models.

2 See for example, *Investigations of the Variation of Combat Model Predictions with Terrain Line of Sight,* Farrell, Robert L. and Freedman, Richard J., AMSAA-1, FR74-1, Vector Research, Incorporated, August 1974.

CHAPTER 4

RESEARCH PROGRAM

Chapter 2 described a conceptual structure of the process that generates fire suppression effects in terms of a number of hierarchically related subprocesses. (The subprocesses were discussed in greater detail in Chapter 3.) To address the design issues suggested in the TOR,[1] we indicated that the overall objective of a fire suppression research program should be to relate *changes* in performance capabilities (the Δp_i) caused by fire suppression to (1) physical (e.g., caliber) and use (e.g., firing rate) characteristics of suppressive weapon systems, (2) combat operations descriptors (e.g., mission, tasks, forces, etc.), and (3) environmental conditions (e.g., terrain type).[2] The purpose of this chapter is to present our views on the adminstrative approach, ideas that should be considered, organization, etc., of such a research program.

Notationally, the overall objective of the research may be viewed as

$$M(\Delta p_i) = f(W, O, E, t)$$

where

$M(\Delta p_i)$ = moments of the joint probability distribution of the Δp_i,

W = vector of weapon system physical and use variables,

O = vector of combat operations variables,

E = vector of environmental variables, and

t = a time variable.

and f is a functional relationship between the moments and the noted variables.

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1 For example, see question (3) on page 2 of this report.

2 Since the Δp_i are random variables, the weapon, operational, and environmental variables would be used to predict or estimate appropriate moments of the joint probability distribution of the Δp_i.

Conceptually, the function f can be developed directly or (as recommended in section 4.2) hierarchically through the type of structure described in Chapters 2 and 3. That is, the function f is developed by determining and hierarchically relating the outputs and inputs of the individual functions f_1 through f_4. Regardless of which technical approach is used, there exist a number of considerations and observations about the fire suppression process that suggest an administrative approach to the research program:

(1) Although suppression by fire is a current and important topic in the military and planning community, we believe there does not exist a good understanding of the mechanisms which cause it.

(2) There exist a number of different representations of fire suppression in TRADOC's and other combat assessment models. (See, for example, appendices D and E.) Although there have been a number of papers reviewing the models, there has not been a *critical* evaluation of their underlying behavioral assumptions (e.g., stimuli causing suppressive reactions, their duration, effects on performance capabilities, etc.) to determine critical information requirements. The models tend to consider a limited number of stimuli, effects, etc., and appear to contain some, *a priori*, questionable behavioral assumptions.

(3) Although there exists the general belief that fire suppression is important, the importance of suppression effects on combat outcomes as compared to the effects of other areas such as firepower, mobility, intelligence, command/control, etc., has not been quantified adequately. There appears to be an unsupported assumption underlying much of the thought and writings about suppressive fire

that it is necessarily good for the suppressor and bad for the suppressee. However, we believe there exist situations in which it will enhance some of the suppressee's capabilities and degrade those of the suppressor, and it is not difficult to specify a sequence of activities and results in which suppressive fire serves to reduce the effectiveness of the suppressor force.[1]

(4) Fire suppression is a complicated process involving many physical, environmental, physiological, behavioral, and operational variables of the kinds enumerated in Chapters 2 and 3. Accordingly, major research program efforts will be required to develop credible knowledge that is useful for military planning. These research efforts will be similar in magnitude to the firepower research efforts that have been performed by the Army and other services over the past three decades to develop methodology for predicting and effectively designing accuracy, lethality, etc., characteristics of weapon systems.

(5) A fire suppression research program will, of necessity, require significant experimentation on behavioral attitudes and reactions to risk. It is now well accepted that it is difficult to induce in field experiments actual behaviors of soldiers. the HumRRO FIGHTER studies in the 1950's showed that soldiers felt true psychological stress only in contried situations in which they *believed* (cognitively) that they, or one of their buddies was in real danger. Such situations are not only difficult to contrive and control but are also constrained by current social, ethical, and legal regulations, governing experimentation with

1 This is due, in part, to the fact that combatants are not always rational in a game theoretic sense.

human subjects in hazardous or potentially hazardous situations.

This type of experimentation will be difficult to perform directly. Because (a) critical information requirements have not been identified, (b) the importance of fire suppression has not been quantified adequately, (c) difficulties exist in direct experimentation, and (d) the large expense required, it is not clear at this time that initiation of a major fire suppression research program is warranted or justified. Rather, we believe that the scope of the research program should be limited and the program should be sequential in nature to develop more information before committing long term resources. The scope initially should be restricted to the types of suppression, combinations of systems, and situations shown below:

- Reactive and that threat fire suppression which may follow the reactive one[1]
- Fire suppression that occurs within tactical company level combined arms engagements
- Suppressing systems
  - All ground and air launched weapon systems types
  - Munition types
    - all delivery types
    - impact and fragmentation warheads only
- Suppressee systems
  - Force size
    - the individual
    - weapon systems crew

1 This excludes the threat fire suppression which causes changes in assigned tasks, i.e., change in suppressee's target, call for fire support on suppressor, etc.

. Type -- in order of priority

. those that fire command guided munitions

. antitank systems

. designator crews (e.g., laser designators for CLGP, etc.)

. tanks

. attack helicopters

. dismounted infantry

. artillery crew

. other crew served ground weapons plus helicopters (omitting tactical aircraft)

° Functions suppressed -- those associated with an individual and weapon system crew in a combined arms engagement (firing, acquisition, maneuver, communications, etc.)

• Day and night environments

The sequential nature of the research effort should be implemented via a two-year short-term effort and then, if justified, a long term research program. The objective and activities of the short term program are described in the next section of this Chapter. Approaches and methodological ideas for consideration in a long term research program are given in section 4.2. The functions and composition of a suppression research office are presented in section 4.3.

4.1 *Short Term Program*

The two-year short term research program has a four-part objective:

(1) to determine the feasibility (e.g., experimental concepts and

methodology, measurement techniques, etc.), information requirements, costs, and value of a long term research program to ascertain if one is justified;

(2) to structure a long term research program is one is justified;

(3) to continue to enrich and improve the current models of fire suppression used in combat assessment procedures; and

(4) to examine the feasibility and value of implementating the "quick fixes" for reducing the effects of fire suppression on command guided antitank systems such as TOW and DRAGON.

It is recommended that the activities described in this section be performed to accomplish this objective.

(1) <u>ASAP Ad Hoc Group Suppression Study</u>

Although we believe that the structure and ideas generated by this study will be useful, it should be recognized that the output is a result of minimal effort,[1] and, accordingly, lacks technical precision and review. Efforts should be devoted to evaluating, expanding, enriching, and adding precision to the definitions, structure, and ideas described in the ad hoc group's report. Specific variables should be defined to describe weapon system characteristics, signals, population characteristics, behaviors, performance capabilities, etc., for the recommended fire suppression systems and situations.

1 Approximately 80-90 man-days of technical effort, about one-third of which was used to obtain background information from CDEC, CACDA, CGSC, etc.

(2) Evaluation of Fire Suppression Submodels

As noted in appendices D and E, there exist a number of representations of the fire suppression process used in small unit and indirect fire combat assessment models. A *critical* analysis and evaluation of the underlying fire suppression behavioral assumptions (e.g., stimuli causing suppressive reactions, their duration, effects on performance capabilities, etc.) is needed to determine weak areas, information requirements, etc., and to provide some preliminary insight into identifying critical assumptions. Additionally, this evaluation should be used to determine which, if any, of the existing models should be used as a basis for an interim model of suppression until better knowledge of the process is developed via experimentation and measurement. The selection should consider criteria such as potential for modification and incorporation of new ideas, availability of input data, and agreement with intuitive judgements about the process.

(3) Parametric Analysis

Using existing combat assessment models (e.g., combined use of DYNTACS and AIDM) performs comprehensive parametric analysis of the behavioral assumptions underlying the suppression submodels. This should include analysis of the mechanism causing suppression, duration of suppression, performance capabilities affected, etc. The assumptions should be varied in *kind* and *degree* (e.g., which performance capabilities are affected and the amount of the change in capability). The study should examine the effect that the variations have on combat results in order to assess the value of fire suppression as compared to the effect of other areas such as firepower, mobility, intelligence, command/control, etc. The intent of the analysis is to determine if investment in an expensive, long term research program is justified, and, if so, the appropriate area of focus (i.e., critical behavioral assumptions), bounds, priorities, etc., for experimentation, analysis, and modeling.

(4) CDEC Efforts

CDEC is currently involved in a number of fire suppression experimental activities. These activities should be continued with the following objectives:

(a) refine techniques and procedures for field simulation and experimentation of fire suppression processes and measurement of relevant variables;

(b) develop fire suppression data for cost and operational effectiveness analyses and bounds for the parametric analysis noted in (3) above; and

(c) experimentally examine the operational feasibility and value of "quick fixes" to reduce the suppressibility of command guided antitank weapon systems. The quick fixes are described in section 5.1 of this report.

(5) Signals Experiment

It is not unreasonable to assume that part of the motivation to form this ASAP ad hoc group was the possible suppression of antitank missile gunners while guiding their missiles. Both TOW and DRAGON missiles are command guided and require the gunner to track his target for about ten seconds while the missile is in flight toward long range targets. Interruption of the tracking process can cause missile guidance failure. An underlying assumption is that fire on the gunner's position would quickly suppress him and effectively spoil his shot. Further consideration, however, has put the issue in doubt and its resolution may depend on field observations of the techniques of employment and conduct of experiments on the gunner's perceptions.

Gunners of command guided AT weapons are exposed to a very high sound level at launching. To protect their ears, they wear ear muffs or plugs which they would ordinarily be unable to remove during missile flight. The launchers and tracking sights are arranged so that the gunner must be partly exposed while launching and guiding a missile. Throughout the process, his version is concentrated on the target through a sight with a limited field of view. Thus, the gunner's primary senses are fully occupied during the firing and tracking process. In addition, the gunner's attention will be riveted to the target, and his normal suscepti-bility to external distractions may be greatly decreased. If the conceptual model of the fire suppression process suggested in Chapter 2 of this report is valid for the antitank gunner, the gunner must detect signals that present a threat to him before he can be suppressed by that fire.

A set of signals experiments should be designed and conducted with gunners of command guided antitank systems to determine what signals of fire directed at or near him a gunner can detect and how well. In these experiments, the gunner should be given tasks equivalent to actual tracking if live firings of DRAGON or TOW cannot be conducted. The sound and blast of the weapon should be accurately simulated, and the obstructions to vision and hearing of the battlefield should be simulated as well.

The intent of these experiments is to examine our conjecture that such gunners may not detect suppressive stimuli (and react appropriately) as often as commonly assumed. If this conjecture is verified, gunners may continue to attempt to track targets longer than commonly believed but possibly at the expense of their survivability.

(6) Investigation of Research Approaches

If justified and pursued, a long term research program on fire suppression will have to address the difficult problem of obtaining behavioral attitudes and reactions to risk without violating social, ethical, and legal constraints on subjecting humans to risky situations. A number of cursory ideas to this problem such as the "Studio Simulation" and the "Risk Correlation" approaches are sketched in section 4.2. Preliminary study of these approaches should be undertaken to assess their feasibility, costs, potential utility of the information, etc.

(7) Analysis of "Quick Fixes"

A number of suggestions for "quick fixes" to reduce the suppressibility of command guided antitank systems are presented in section 5.1 of this report. A study should be conducted to analyze their technological feasibility, operational feasibility, costs, and operational value before consideration is given to implementation.

(8) Develop performance-oriented guidelines and devices to train combat soldiers to more accurately assess the risk associated

with suppressive fire and in appropriate behavior under suppressive fire.

(9) Interview and Questionnaire Studies

Based on the premise that valuable information on the fire suppression process is stored in the minds of combat veterans, systematic interview and questionnaire studies should be designed and conducted to tap this experience. Principal emphasis should be on veterans of the Vitenam conflict; however, similar studies with Israeli, Egyptain or Syrian veterans of the 1973 Yom Kippur War would be useful since newer weapons were employed and the combat was shorter and more intense. The studies would attempt to obtain answers to the following types of questions which would provide valuable input to the critical evaluation of current fire suppression models (see (3) above) and other short term activities.[1]

(a) What kinds of enemy weapons caused you to take cover most often?

(b) Was it the sight or sound of the weapon firing, the round in the air or its impact effect that caused you the greatest concern?

(c) What kinds of things did you do to take cover and protect yourself?

(d) What differences, if any, did you observe between the reactions of American and South Vietnamese soldiers to various kinds of hostile fire?

1 An extensive study of this type was performed by Litton Industries (Contract Number DAAD05-71-C-0066) for the USA Small Arms Systems Analysis Agency. The sponsor did not wish to retain the original data and the incompletely analyzed data were discarded by Litton after several years storage.

(e) Think of one or more particular situations in which you were pinned down by enemy fire. Can you give any estimates of the time the incoming fire lasted? Can you estimate how long you stayed down? Could you observe or communicate when pinned down?

(f) What did you observe as to the reactions of your buddies when one or more of your unit became a casualty?

(g) Can you comment on something that your squad leader, platoon leader, or one of your buddies did which set a good (or bad) example of proper behavior under fire? What effect did it have on members of the unit?

(h) What aspects of training, both in CONUS and after you arrived in Vietnam, do you think helped you most in how to behave under enemy fire?

Some thoughts on study methodology include:

(a) try a preliminary interview form with a sample of veterans;

(b) consider whether a useful supplement can be made to personal interviews with a mailed questionnaire;

(c) we believe sampling for interview or questionnaire purposes can be drawn from the extensive tape files maintained by the Manpower Research and Development Group (MARDC) operating under Navy auspices, funded by DoD ASA (M&RA), located at 300 North Washington Street, Alexandria, Virginia (The HumRRO Building);

(d) the sample should include

- men still in the Army
- discharges
- men in V.A. hospitals
- those who served as EM, NCO's and Officers
- those who served both with US units and as advisors to ARVN units.

(10) Suppression Efforts by Foreign Military Forces

The US Army Foreign Service and Technology Center (FSTC). Intelligence Threat Analysis Detachment (ITAD), or other appropriate intelligence agencies, should be tasked to provide intelligence on the role of suppression in foreign military forces. This intelligence should include current doctrine, tactics, and training related to fire suppression and the existence of related applied research, technological developments, organizations, facilities, and programs.

4.2 *Long Term Program*

Given that a long term research program is justified and funded, we previously noted that notationally its objective should be the development of the function shown on page 110. Responding more directly to the TOR, the such a research program must lead to ... useful models of suppression that can be employed:

(1) in combat assessment procedures to indicate the effects of suppression on combat results (i.e., to determine the value of fire suppression as compared to other effects areas);

(2) to simulate suppression effects in field exercises and tests;

(3) to determine what characteristics should be designed into a suppressive fire system; and

(4) to determine ways in which effects of suppressive fire on the suppressee can be reduced.

The first use, concerning combat assessment, requires numbers that can be employed in computer simulations. These numbers represents two kinds of variables: weapon system physical, use, and capability variables, and human suppression performance, given operational and environmental conditions. Currently, the main source of the suppression performance numbers appear to be from combat reports and the pooled judgements of combat experienced personnel. How good they are is open to question -- they are presumably the best available. Better numbers for these analyses is a major objective of the research program.

The second use, simulation of suppression effects in field exercises and tests has two purposes:

(1) to provide for better field evaluation of weapon systems when employed by operating troops (i.e., in MASSTER and CDEC tests), and

(2) to provide for better training and the development of better doctrine.

These two purposes may not be compatible, and may, therefore, require different types of detailed information. Training would be designed to develop the component skills and capability of the soldier to react effectively against suppressive fire. This would involve partitioning these skills into easily learned segments. However, the incorporation of suppressive effects into field evaluations of weapons systems emphasizes the entire suppression process and its effects on performance.

For the third use, characteristics which should be designed into a suppressive fire system, information will have to be developed experimentally which will indicate what characteristics of weapons systems would have more "suppressive stimuli" than another. This information will have to be correlated with information concerning the effects of suppression upon performance in order to design weapons systems with appropriate effects on the combat engagement process.

Concerning the fourth use, ways to reduce the effects of suppressive fire, clearly more precise training can be designed and new different tactics developed. Additionally, we believe that insights into other ways of reducing the effects of suppressive fire will be obtained if a detailed understanding of the separate processes is developed, i.e., what signals cause the human to be suppressed, how individuals perceive risk, how reactions are related to risk perceptions, etc.

Thus, we see that the research program has a number of diverse information objectives, and since suppression is a complex behavioral phenomenon, there is no one "best approach" for a research program to accomplish these objectives. Accordingly, the research program should use multiple methods and types of measurement to develop a broad base of data from multiple sources.

Although multiple methods should be employed, the next section recommends a specific approach to structuring a research program to accomplish the above noted information objectives. Some ideas and thoughts on implementing the approach are presented in sections 4.2.2 - 4.2.4. Principal discussion is on means of obtaining behavioral attitudes and reactions to risky situations (section 4.2.3).

4.2.1 *Program Approach*

Although in practice many different and supporting means will be used in generating information and knowledge about the fire suppression process, three main approaches might be employed -- analytic, historical, and experimental. The analytic or pure rationalistic approach would involve trying to mathematically model or simulate the fire suppression process (and perhaps each of its component subprocesses) from first principles. We believe this approach to be infeasible for two reasons: (1) the processes involved are too complex, and our knowledge about them insufficient to rationalize their intricate dynamics on a purely intuitive basis, and (2) theoretically modeling behavioral attitudes and reactions to risk will likely require use of the "rational man" construct[1] which experimental evidence indicates is not valid.

The historical approach would involve use of data from previous combat situations directly or interview type studies with combat veterans to provide information as a basis for predicting changes in performance capabilities. We believe that this approach, as the main thrust of a research program, would be unwise since (1) our experience suggests that sufficient combat data is not available, and (2) the approach truly has an historical perspective and not a planning one in which predictions are needed about the impact of future weapon systems. Although they will provide valuable insights, responses of combat veterans will be heavily associated with characteristics of the weapon systems used in previous combats, not future ones.

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1 See section 3.2.2 and associated game-theoretic descriptions of behavior in "Games and Decisions" by Luce and Raffa and other related texts on decision and game theory.

The experimental approach would involve the use of laboratory and field, controlled and uncontrolled, experiments with appropriate populations to provide information and data as a basis for modeling and/or directly predicting changes in performance capabilities due to fire suppression. Although probably the most expensive and technically risky, we believe this approach is the only one that, as the main thrust, holds promise of providing credible and useful information to address the issues noted on pages 1 and 2 of this report. The experimental approach (1) can provide a current and future weapon systems perspective, (2) will avoid restriction to the "rational man" construct, (3) will allow consideration of "reasoned and unreasoned" behavior, and (4) will provide an appropriate data base for analytically modeling or simulating the fire suppression. To reduce the costs and to insure that timely and directly useful information (in addressing suppression design, tactics, etc., questions) be provided, it is recommended that the experiments conducted in the research program be system and situation specific rather than parametric in nature (i.e., use existing weapon systems or simulate signals of proposed systems that are the direct concern of the decision problem).

In discussing the objective of the research program, we noted that the function which related changes in performance capabilities due to fire suppression to weapon, operational, and environmental variables could be developed directly or hierarchically by determining the transfer functions of each subprocess of the fire suppression process. We believe that the approach of partitioning the process is technically sounder (especially in view of the experimental approach recommendation) since (1) it makes the experiments more feasible, (2) it will be easier to exercise control over the smaller experiments (when desired), (3) it will reduce the sample size problems, and (4) it will provide more insight into the dynamics of the process which usually leads to more innovations for improvements.

Clearly, there exist many ways of partitioning the overall information requirements of the research program to conduct experiments, even if one accepts the conjectured fire suppression process structure described in Chapter 2. Principally for reasons of feasibility, we recommend that the overall process be partitioned in a hierarchical manner into signals (Type I), human (Type II), and performance effects (Type III) experiments. In relation to the fire suppression structure of Chapter 2, the signals experiments would provide information about the function f_1 relating input signals to the suppressee to weapon, operational, and environmental variables. Notationally,

$$S = f_1\{W, O, E, t\}$$

where S is the vector of variables describing the magnitude, duration, etc. of signals at the suppressee's location. Type I experiments can be conducted (to support physics modeling) without the need for experimental subjects.

Type II experiments provide combined information about the sensory ($f_{2.1}$), perception ($f_{2.2}$), and behavioral (f_3) processes of figure 1. The objective of the experiments is to provide information to relate fire suppression behavioral reactions to signals input to the suppressee, given an operational and environmental setting. Notationally,

$$R = f_{23}\{S, t | O, E\}$$

where R is the vector of behavioral reactions and the other terms have been previously defined.[1] Clearly, this set of experiments will have to address the difficult problems of how to reflect real risks in the information without exceeding social, ethical, and legal constraints.

Type III experiments provide information about the changes in performance capabilities as a function of behavioral reactions to suppressive fire, given an operational and environmental setting. Notationally,

$$\Delta p_i = f_4 \{R, t/O, E\}$$

Hierarchically, the sequence of functions f_1, f_{23}, and f_4 conceptually constitute the information objectives of the research program.

In summary of this section on program approach, we have recommended that a heavily experimental approach be used, that the experiment be specific rather than parametric in nature, that the experiments be partitioned, and that the partitioning be into three categories -- signals, human, and performance effects. Sections 4.2.2, 4.2.3, and 4.2.4 present some ideas and thoughts on ways to generate the sensory, human, and performance effects information, respectively. Section 4.2.5 briefly notes some additional experiments that might be conducted to support the mainstream of experiments and modeling in the research program. A summary discussion of the general relationships among the related activities is given in Section 4.2.6.

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1 Although, based on the behavioral model of section 3.2.2, we considered further partitioning to experiment with the functions f_2 and f_3 separately, past behavioral experiments suggest that it is difficult to separate the perceived probabilities of future events from an individual's utilities associated with them.

4.2.2 *Signals Process (Type I Information)*

This section presents some thoughts on the kinds of experiments that should be conducted on the signals process. The objective of the experiments is to validate existing signal generation and attenuation models and to provide data to support empirical modeling. Measurement of signals variables is a minor part of the total recommended experimental program for the scope of the fire suppression problem defined by the ad hoc group. Nevertheless, for a complete consideration of the conceptual suppression process modeling of the signal processes must be carried out. The conceptual process of suppression, figure 1, shows separate processes $f_{1.1}$ and $f_{1.2}$ for signal generation and signal transmission. As noted in Section 4.2.1, significant simplification in the modeling of these processes can be obtained by combining the two processes into one. There is no loss of relevant information in doing this since the intermediate variables cannot directly affect the suppressee. The experimental program should be treated as though the modeling will be performed in this way. In actual fact, for some of the signals (for example, impulse from an explosion) the data that can be obtained most practically in a measurement program is that for the combined processes. The data for process $f_{1.1}$ would have to be developed by extrapolation or computing back by a model for process $f_{1.2}$.

There are five signal types that must be modeled. Experiments are required for three of these: sound pulses, sounds, and light flashes. Models for visual signals of object movement and for obscuration can, in general, be developed relatively simply. The last of these is partly important in its effect in attenuating the other two visual signals.

The primary emphasis must be put on measurements to support modeling the combined process f_1 for sound pulses, sounds, and light flashes.

In each of the signals, there are several output variables that may be measured. Although tentative sensations of the suppressee have been identified for these variables, the relative priorities for the measurement of the variables should be established carefully before a program of measurement is finalized. The cost of an experimental program will also depend on the accuracy and precision of the measurements. These specifications should be considered carefully from the needs of process f_2 and f_3 modeling before the program is finally undertaken. Clearly, since the ultimate receiver of the signals is a human, the specifications for the measurements should not greatly exceed the capability of the human receiver.

Sound Pulse Experiments

Data exists for some of the variables of this type of signal generated by some weapons. In particular, impulse and pressure are typical measurements made in explosive warhead tests. Similar measurements have been made of gun firings. These experiments are commonly made in environmental conditions typical of good weather, in a physically uncluttered and clear area. Prior to the measurements program outlined below, the existing data should be examined for guidance -- the conduct of the experiments.

The basic data to be acquired through experimentation is pressure versus time for several locations at several ranges from the generator. The maximum range of the measurement should be well beyond the lethal radius of the weapon. Generators to be considered are explosive warheads, scaled bare explosive charges, supersonic projectiles and gun shots from guns of different calibers.

The attenuation and modification of the signals in the transmission process may require experimental measurements to be conducted in some varied environmental conditions. Important among these are heavy rain and heavy vegetation.

Sound Experiments

This signal type is extremely complex and is likely to be very difficult to model with accuracy. There are a number of signal variables that are of interest. The basic data to be gathered is broad band sound recordings. The sound recordings are to be made at several locations in a two dimensional field. This field should allow evaluation of the signal variables for both distance and direction from the source.

A major compounding factor is the great variety in the signal generation process. The weapons that must be considered as input variables are subsonic gun projectiles, air dropped weapons, and rockets. Dense vegetation and heavy rainfall and snow are conditions of the environment that should be among the experimental variables.

Light Flash Experiments

Light flash is a third type of signal that may need experimental data before accurate modeling can be achieved. Flashes are produced mainly by explosions and by gun flashes. Less commonly, flashes may be produced by rockets burning and by tracers. Flashes are more directional than sound; thus measurements must be made in a very carefully designed measurement field. The weapons variables are explosive charge, gun calibre, rocket impulse and burning time. Basic measurements are visual flux versus time and direction at each location of measurement. It may be desirable from a human factors position to measure flux in discrete wavelength bands. Environmental conditions variables should include those of the two sound experiments.

4.2.3 *Human Processes (Type II Information)*

Long term research efforts in this area are intended to develop information to relate sensory signals input to the human to his reactions, given an operational and environmental setting. Although there exist social, ethical, and legal constraints which preclude direct experimentation involving real combat risk, the above information should be obtained experimentally in ways that simulate true risk situations. These experiments should be conducted in the field or in a laboratory setting as deemed appropriate. Based on discussions with military personnel who have been in combat, it is clear that combat experienced soldiers will exhibit different fire suppression behavior than those without experience.[1] Accordingly, the experiments should be performed with combat veterans or the methods employed should be such that many trials of the experiment can be conducted to develop quasi combat experience with suppressive fire.

Regardless of the specific approaches used, there exist a number of guidelines that should be considered and incorporated into the experimental research:

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1 Discussions suggest that this change in behavior appears to occur after 2-3 days of combat and that the learned attitude and behavior pattern is retained.

- The experimental setting/scenario should be a simulated, two-sided, combat engagement appropriate to the weapon systems employed and best available estimates of the weapons effects (e.g., kill probability) used in the simulated engagement.
- The stimulus complex should be a high fidelity simulation of critical aspects of the total battlefield stimulus complex experienced by soldiers during combat engagements.
- The activities performed, and the responses available to the player, must be directly translatable into the activities and responses available to an individual in combat. Some examples are aiming and firing a rifle, changing posture, or controlling a TOW or DRAGON missile.
- The responses available/allowable must be related to the threat in such a way as to enable the player to alter the perceived risk. An example is a change in vulnerability by a change in posture.
- The relationship between perceived outcomes (results of the experiment) and player performance must have an effect on the combat engagement outcomes.
- The experiments should be controlled and monitored, and feedback on combat results provided to players on a near real-time basis. This requirement for near real time feedback, and many trials noted earlier, suggests that combat results be obtained via some of the existing combat assessment models (e.g., AIDM, DYNTACS, etc.). The experimenter should have continuing knowledge of the true risk

levels (i.e., the probabilities defined in section 3.2.2) associated with the suppressive fire.

- Player payoffs and rewards must be explicit, desirable, and directly related to player performance.

A number of simulated experimental approaches to measure fire suppression effects are being examined at CDEC. Some comments on these approaches are presented below and an alternative approach to measurement of suppression reactions is discussed.

(1) CDEC "Game" Approach

Field experimentation concepts being developed and evaluated at CDEC for DUCS (suppression experiment Degradation Under Controlled Stimuli) represent one approach to Type II Experiments. The DUCS methodology is essentially a two sided competitive game with scoring rules being used to evaluate player performance. For example, a scenario might consist of a player in the role of an antitank guided missile gunner -- using a gun-camera mounted on a tripod--engaging two APC's advancing in a bounding overwatch pattern on his position. The sound of weapons fire from the APC's is given to the player over headphones; and ground poppers are used to simulate the impact of rounds. Player performance is scored using the film from the camera.[1] There are a number of general weaknesses in the DUCS approach. However,

1 This example is based on a demonstration presented to the Ad Hoc Group at CDEC.

these weaknesses result, in part, from the exploratory nature of "DUCS" and the approach is potentially very powerful.

One problem is that a two-sided competitive game paradigm is the sine qua non of rational man. Although clearly not appropriate as a model of human processes, the paradigm may provide a useful baseline (see Section 3.2). To interpret player performance, however, with or without a formal baseline for comparison, requires that "reasoned performance" in DUCS be defined.[1] That is, what are the criteria for reasoned behavior in the DUCS approach? What constitutes good data? Prior to any formal experimentation, these questions must be answered and appropriate techniques developed for identifying and measuring player performance.

A second problem inherent in the use of any game paradigm is the players actual knowledge of the relevant probability and utility functions. In order to respond appropriately, the player of any game needs to know the probabilities which the experimenter builds into the game and the rules which the experimenter will use to score his performance. Since DUCS uses a simulated combat, combat veterans may have this knowledge if the scenario and weapon system cues[2] are realistic. However, it is completely unwarranted to assume that the player knows

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1 Assuming criteria for reasoned behavior can be developed, it is not clear what should be done with unreasoned behavior.

2 Although not addressed, the quality of the recording and play back of the sound weapons fire currently used in DUCS could and should be improved.

the relevant probabilities and utilities the experimenter has built into the game. The player's knowledge of the probabilities and utilities should be assessed and used either as a basis for player training or in interpreting the results.

Related to the problem of player knowledge of the rules of the game is the current lack of real-time feedback to players. Performance is scored after play is completed using the camera film. A player may be "killed" several times in the course of a trial and never receives any feedback during a trial on the effectiveness of his actions. The player is required to perform a sequence of actions based on simulated weapon systems stimuli with no opportunity to change his actions to match the sequence of events as they unfold in the scenario. The lack of feedback also reduces player motivation. One function of real-time feedback is to provide a source of player motivation. CDEC has suggested some scoring approaches which may enhance player motivation. For example, "group scoring", where a squad is scored as a unit rather than as individuals. Group scoring will increase the peer pressure for good performance if the player rewards are explicit and desirable. Feedback could be provided for players through the use of real-time simulation of laser technology.

Fourth, there is no real risk involved. Ethical, legal and social constraints preclude the introduction of actual physical risk. Players must be taught the "rules of the game" and risk defined in that context. The extent to which this will be successful depends upon player motivation and willingness to play a role; the role being that of an individual participating in a combat engagement. One approach, discussed later in this section, to evaluate the effectiveness of role-playing would be to use post-play debriefing to separate ascribed role players from non-role-players. The performance of these two groups could then be compared to determine if any differences in performance exist.

The two-sided competitive game paradigm is a potentially powerful concept for field experimentation. Further analysis and exploratory efforts are required before its value for suppression research can be determined. Such efforts are being undertaken by CDEC.

(2) CDEC "Credibility" Approach

The CDEC approach discussed above is in essence a "game" in which players attempt to achieve a high score. Subjects are not exposed to any semblance of risk. It has been conjectured that they will not develop an appropriate attitude to play the role of a soldier in combat and may produce results that are far from representative of actual combat situations. The "credibility" approach currently being examined by CDEC is an attempt to induce more realistic behavior into the experiments.

The credibility approach involves the identical experimental game situation. Just prior to running the experimental trials, sessions will be held to "psych-up" each of the subjects into a combat mental attitude. Post-experiment interviews will be conducted with the subjects to identify those who believed the responses they exhibited in the experiment were similar to those they would have exhibited in a real combat situation. Only the data for these subjects would be analyzed and used in modeling efforts.

Although we believe this approach is an improvement, it still retains a number of the problems associated with the game approach. No real risk is involved, feedback on combat results is not provided, etc.

(3) Studio Simulation Approach

It is difficult to experimentally simulate the complexity, confusion, and tempo of combat, and even more difficult to reliably create the sense of danger that goes with suppression by fire in a combat situation. In certain scientific disciplines, it is customary to get around this type of limitation, i.e., the inability to deal with the real thing in a laboratory or field experiment, by studying what happens in the real world. Economists, ecologists, astronomers, etc., all make use of this approach. An adaptation of this approach, drawing on what has happened in past combat situations, can provide some data needed to model the response of an individual soldier to suppressive fire. In what follows, we shall suggest a technique for obtaining the relationship between what the individual soldier senses and thinks is going on in combat to the kind of response he might make to suppressive fire. This technique, which relies on detailed computer simulation of a simulated individual's response to a combat scenario and evaluation by combat veterans of that simulated individual's response, provides a unique, indirect interview technique. Similar techniques for evaluating the credibility of simulations have been extensively used.[1]

We contemplate a rather elaborate computer-controlled audio-visual display which will present to the interviewee (the combat veteran) a representation of some combat engagement in terms of one simulated suppressee taking part in that engagement. The presentation would not have to represent the total battle-field in detail, but rather would be designed to easily communicate to the interviewee at a real time rate what the suppressee

1 See, for example Bellman, R. & Smith, C.P." Simulation in Human Systems," New York: Wiley, 1973. Newell, A & Simon, H.A., "Human Problem Solving." Englewood Cliffs, N.J.: Prentice-Hall, 1972.

being simulated by the computer model sees, hears,[1] and thinks is going on, and what that soldier is doing, i.e., moving, communicating, taking cover, scanning his field-of-view, or shooting. The emphasis would be on easy assimilation of this information by the interviewee and on creating a realistic scenario.

The computer-driven presentation would follow on a quasi-realistic combat scenario, including all features of combat normally simulated in the best of the present generation sophisticated computer combat models. The simulation would incorporate some nominal suppression model. After a twenty-minute to one-hour presentation representing an offensive or defensive action in the combat simulation, the interviewee would be asked to evaluate and comment on the behavior of the simulated individual he had been watching.[2] His judgement of the performance of that individual would constitute the basis for modifying the suppression model. The kind of response the interviewee might make would range over such comments as:

(1) He is acting like a coward!

(2) His actions were foolhardy. He is going to get killed.

(3) He isn't afraid enough of nearby artillery fire.

(4) When he is being shot at, he takes cover and stays down too long, whereas, what he should have done is try to get to a new position.

etc.

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1 Concussive and olfactory stimuli could be added if Type I research efforts determined they were necessary.

2 This technique could be modified so that the iantervlewee is presented with some portion of the simulated engagement and asked to specifiy the behavior for the simulated individual.

Based on comments like this from a wide variety of combat veterans, the suppression model could be upgraded to the point where response to suppressive fire is judged to be reasonable. Analysis of the parameters in this suppression model after it has been adjusted to conform with an extensive set of this sort of criticism will provide data concerning suppressive reactions which are judged by combat veterans to be credible.

The key to this type of quasi interview lies in the presentation made by the computer-driven audio-visual system. Initially, a detailed, realistic combat engagement could be generated by the running of one of the better combat models. The key feature is that an individual, actually a whole set of individuals, are followed through a combat engagement moment by moment, keeping track of each round of fire, where each individual is looking, what targets he detects, and what localities he becomes suspicious of, what information he receives from others, what fire comes near him, as well as what fire he delivers, and where he is on the battlefield at each instant. From this computer run of the complete combat engagement, a data file can be built up which will drive the audio-visual display. This event data file, in turn, would be used to generate the audio-visual display sequence. The event data file could be repeatedly used to run the display for a series of combat veteran interviewees so that we could get an evaluation from many combat veterans of the credibility of the same simulated individual's response.

A reasonable audio-visual presentation, would include a CRT line drawing suggesting the prominent features of the field-of-view seen by the simulated soldier, and audio presentation of information pertaining to both what the simulated individual hears and *sotto voce* comments on what the individual thinks is going on. To hurdle such things as target detection, the CRT display would call attention to the detected target by making the symbol for that blink on the screen while the audio would, *sotto voce*, comment on what the individual thought the target was. Similarly, when the individual being simulated fired his weapon at the target, a blinking circle on the CRT display would indicate where he aimed while audio comments would state that he was firing at that target. If the individual thought he was being fired at, not only would the sound of bullets passing near him be reproduced on the audio system, but a comment such as "I think they have spotted me," would be announced, *sotto voce*. If the individual took cover, this would be announced on the audio system and the CRT display would essentially go blank. As the individual moved, the display on the CRT would change, perhaps not continuously but at least smoothly to indicate such motion. The sound of firing in the distance would be presented on the audio system, as would sounds associated with artillery fire and of other weapons.

This type of computer-driven audio-visual display can present to a combat veteran easily understood representation of what some simulated individual sensed was going on during a combat engagement. The combat veteran would be able to follow at a real time rate the situation and the individual's behavior. Based on that, he would be able to formulate a realistic assessment of how that individual behaved and whether his response to suppressive fire was reasonable or unreasonable or in what ways it was unreasonable. From a series of such "interviews" with various combat veterans, defects in our present formulas for modeling suppression could be determined and could improve them to the point where the behavior of a computer simulated soldier under fire would be judged by a wide variety of combat veterans to conform to the behavior they recall as existing in combat.

A studio stimulation of this type would provide a unique test bed for suppression research. It would allow rapid experimentation with a wide variety of stimulus conditions and rapid evaluation of stimulation concepts and models, new doctrine and tactics. It also would provide a method for the independent evaluation of field experiments. Initial development of this type of simulation would be expensive. The technology to develop this type of man-in-the-loop simulation exists, although it is not clear that there exists an adequate data base to guide development of an initial facility. However, the development itself is a research effort.[1]

[1] There is a potential side benefit to this approach in that data voids and deficiencies would be identified and the validity of widely used engagement models could be evaluated by the combat veterans.

4.2.4 Performance Effects Process (Type III Information)

Experiments (and associated modeling activities) discussed in previous sections address the problem of relating suppression weapon system characteristics to reactions of a suppressee when exposed to suppressive fire, given an operational and environmental setting. In this section we shall briefly discuss the type of experimental approach to relate these reactions (or reaction sequences) to changes in performance capabilities (e.g., aiming, observing, etc.) expected of a suppressee. Additionally, we shall discuss a method of modifying the resultant performance changes (Wpi) to reflect risk effects more realistically and an experimental procedure which, if feasible, may provide a means of quasi-verification of the performance modification procedure.

4.2.4.1 Performance Experiments

Over the past 10-15 years a number of field and laboratory experiments have been conducted to determine the ability of combat personnal to perform a spectrum of combat activities. Many test have been run to determine the ability of observers to acquire targets visually,[1] to detect and locate targets by pinpointing firing flashes,[2] to track targets,[3] to fire,[4] etc. Although some of these were run in the field in operational situations, the measured capabilities do not reflect the effect of fire suppression.

1 For example, the tests conducted at Fort Knox to acquire tank targets reported in "The Tank Weapon System" edited by Bishop and Stollmack, 1968.

2 For example, Project PINPOINT.

3 For example, the Check/Operational tests for DRAGON.

4 For example, the OT-III tests of DRAGON.

Information to determine the change in performance capabilities due to simulated suppressive fire can be obtained by essentially repeating these test conditions and imposing the appropriate suppression reaction sequences on the subjects as applicable. Thus, for example, AT gunners might be required to perform a visual acquisition task but be constrained in their observation periods.

Although conceptually correct, the approach to getting performance capability changes due to suppressive fire by repeating conditions of past experiments would be costly and may be technically difficult since past experiments are not well documented. Additionally, it would not facilitate examining performance changes on activities associated with new weapon systems (e.g., target designation for CLGP). Since experiments to develop the reaction sequences are performed under quasi-combat conditions[1], albeit without real risk, we believe the performance effects experiments can be conducted using experimental situations which focus on performance of specific activities (e.g. aiming, tracking, etc.) without detailed realism or feedback of combat results. Just the activity setting need be realistic. Because of the relative simplicity of the experiments, they could be run

(a) with and without the reaction sequences imposed on the subjects to develop information for estimating the Δp_i,

(b) with parametric reaction sequences to provide some insights into means of reducing the effects of suppressive-fire reactions on

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1 See section 4.2.3.

changes in performance, and

(c) in conjunction with training in the activity itself (e.g., training of DRAGON or TOW gunners to track targets).

After some experience with this type of experiment, consideration should be given to running similar experiments using an indoor studio-type environment with movie and sound projection.

4.2.4.2. Risk Correlation and Transfer Experiments

The experiments noted above (and associated analyses and modeling) should provide a means of estimating changes in performance (Δp_i) of specific activities as a function of reaction sequences. Although the latter will be obtained from experiments which attempt to simulate risk situations or reflect risk experience of combat veterans, it should be recognized that a full degree of real combat risk will not be reflected in the reaction sequences and thus not in the estimated Δp_i. Even if the reaction sequences were a result of realistic risk, the change in performance obtained using these reactions would still lack the effect of stress on performance (e.g., possible degradation in visual acuity with stress).

Two procedures are suggested below as a means of reflecting the impact of real combat risk on performance changes, without violating legal, ethical or social constraints.

(1) Risk Correlation

One means of reflecting the impact of real combat risk in the pi is to correlate it with other risky non-combat situations that exist in society (e.g. police work, fire fighting). As an overview, performance change associated with activities in the non-combat situation would be used to modify the Δp_i obtained from the performance effects experiments.[1] This is illustrated in the following matrix.

	Combat Situations	Non-Combat Situation
NO RISK	p_o	q
RISK	P	Q

where:

p_o = performance on a combat activity without real or simulated suppressive fire present,

P = predicted performance on a combat activity with real suppressive fire present,

q = performance on a non-combat, but related, activity without risk present,

Q = performance on a non-combat, but related, activity with risk present,

The risk correlation methodology is based on the hypothesis to be tested that there exist identifiable, risk dependent, correlations between

1 Or performance measured during the CDEC scoring or credibility experimental approaches.

changes in performance for comparable activities and risk situations. Assuming that (1) appropriate taxonomies and scaling of risk and activities can be developed, and (2) combat risks and activities can be associated with comparable entries in these taxonomies and scales, the performance capability which reflects real risk can be related to the performance capabilities estimated from Type III experiments, (or the CDEC scoring or credibility experiments) by

$$P = \frac{Q}{q} p_o,$$

$$= \frac{Q}{q} (\Delta p + p_1),$$

where

p_1 = performance on a combat activity obtained by simulating suppressive fire (in Type III, scoring, or credibility experiments), and

$\Delta p = p_o - p_1.$

The scaling Q/q is used only as an example. The appropriate scale transformations would have to be determined for each of the activities when research on this methodology is conducted.

(2) Risk Transfer

Another possible means of reflecting the impact of combat risk in Δp_i is to conduct a parallel set of Type III experiments with subjects who are in a stressed physiological state due to a real risk situation.

The physiological symptoms caused by stress situations do not completely decay for about 1 - 1/2 hours. It is conjectured that if the physiological symptoms are similar across different situations, then the change in performance is similar. Accordingly, fire fighters, policemen, etc. (i.e. risk takers) who have just performed in a risk situation could possibly be used to perform combat activities under the appropriate reaction sequences. The results of these tests could be used to modify results of Type III tests performed with soldiers in a manner similar to the risk correlation approach with $q = p_o'$ and $Q = P'$

where

p_o' = performance of risk takers on a combat activity without real or simulated suppressive fire when they have not been subjected to a risk situation,

P' = performance of risk takers on a combat activity involving a reaction sequence immediately after performing in a risk situation.

Thus, using the same scale transformation example

$$P = \frac{P'}{p_o}(\Delta p + p_i)$$

4.2.4.3 Verification of Δp_i Modification

Section 4.2.4.1 discussed experimental concepts to estimate changes in performance (Δp_i) using reaction sequences as input. Recognizing that the resultant estimates of Δp_i would not be obtained under real combat stress conditions, the risk correlation and transfer concepts were advanced as a means of modifying or scaling the Δp_i to reflect the effect of more stressful conditions in the performance changes due to suppressive fire. Although the various ethical, legal and social constraints must be carefully examined, we believe that a number of real stress situations can be used to determine the validity of the Δp_i modifications procedures. Two possible approaches are outlined below:

(1) Nap of the Earth Flights:

Subjects could be used to perform a tracking task in the nose of a Cobra helicopter during straight and level flight and his performance (p_o) measured. After a number of such trials, the subject would be required to perform the same task[1] while the Cobra flies apparently risky nap-of-the-earth maneuvers and his performance (P) is measured. It is conjectured that such manuevers will appear to be sufficiently dangerous to the subject that they will produce stress similar to that caused by fire suppression.

(2) Unexpected Firings:

Although clearly approaching some of the experimental constraint conditions, it might be possible to study the performance effect (and thus the Δp_i) of "unexpected firings" to simulate actual suppressive fire. Unexpected firings might be employed during the training of AT gunners with live firings. The subjects would be told that simulated suppressive fire will be used to make their training more realistic. When the simulated fire is initiated, more realistic effects

1 With reaction sequence constraints.

than indicated are used. The instructor states that the suppressive fire is real and not simulated and that the gunners should return fire on the tank spraying the suppressive fire.[1] Measurements would include tracking error under normal training conditions (p_o) and reactions and tracking error under the simulated but realistic suppressive fire (P).

4.2.5 Supporting Experiments and Analyses

This section briefly discusses some additional experiments and analyses to support the experimental program discussed in preceding sections.

S.1. The Relation Between Uncertainty and Reaction.

The Type II experiments described above will provide information on the relationship between weapons system stimuli and the suppressee's reactions. In Type II experiments the experimenters should have knowledge of both the probability of kill (P_k) and the probability of hit (P_h). Although not the focus of Type II experiments, the data obtained in these experiments can be used to determine the relationship between P_k or P_h and the suppressee's reactions. This data could be used to simplify models of the suppression process, for the design of combat training, and for the development of doctrine. Thus, these experiments involve the re-analysis of data obtained in Type II experiments from a new viewpoint.

S.2. Identification of Suppression Weapon System.

A key element in perceived risk is the extent to which the suppressee can identify the suppressor weapon system. Identification

1 Dummy rounds are actually in the AT weapons.

of the weapon system conveys information concerning the terminal effects of the weapon system and is a primary determinant of perceived lethality. There is little information, other than preliminary data from CDEC, on the ability of soldiers to identify weapon systems or the stimulus cues which are used for identification.[1] Experiments should be conducted in this area on a broader base than currently, and include factors such as ambient noise and the effects of number and location of weapons systems.

S.3. Characteristics of Weapons System Stimuli (or derived parameters) That Influence Suppression.

A wide variety of stimuli and several derived parameters have been identified as relevant to suppression. The relationship between these stimuli or parameters and suppression or perceived risk is largely unknown. The type of questions which need to be answered are, "Does the loudness of the projectile signature increase the perceived level of risk? And if so, by how much?" Experiments should be designed which can develop data of this sort; both identifying the most significant stimuli and parameters and scaling their relationship with perceived risk.

S.4. The Partitioning of Probability and Utility.

Experimentally independent, separate measurement of the perceived probabilities of events and the utilities associated with the potential

[1]Emerging results from CDEC experiments suggest that the question of which stimulus cues are used to identify weapons systems is complex and that the cues differ between weapon systems. For example, CDEC studies suggest that the auditory cues of the .30 and .50 cal. machine guns are signficantly different for rounds passing nearby, permitting either the "crack" or the "thump" of the passing round to be used in discrimination between the two weapons.

consequences is difficult and not always feasible. This partitioning is not necessary for Type II experiments. However, data of this type would allow a more flexible design of combat training[1] and the development of more precise computer models of suppression.[2] Experiments of this sort have been conducted in laboratory settings, but we know of none conducted in the context of real-world performance.[3]

S.5. Impact of Training, Morale, Leadership, and Personality on Suppression.

The moderating factors identified earlier (Section 3.2.1) are major sources of variation in suppressee performance. These factors are clearly important and they should be incorporated into other experiments as appropriate. Following their inclusion as covariates in other experiments, additional experiments should be conducted to clarify the relationships of the more important factors with suppression. Data from these experiments should enable more precise predictions of suppression, and the identification of methods for reducing the impact of suppression.

4.2.6 Relationship Among Research Activities

Sections 4.2.2 - 4.2.5 discussed Type I, II, and III and supporting experimental and analysis efforts. In this section, we briefly note the relationship among these activities in terms of their general timing, information requirements, etc. with the intent of clarifying their role in the overall long term research program.

1 An understanding of the determinants of suppressive reactions will allow training to be focused more precisely on making perceived risk congruent with true risk, independent of the utility of various consequences.

2 The separation of probabilities and utility will allow the effects of motivational and cultural variables to be more easily determined.

3 Lee, W., and Kogan, N. and Wallach, M. A., op. cit.

Because of the need to know the magnitudes, frequency, and kinds of signals as input to Type II experiments, the signals experiments and modeling and the supporting experiment S.3 should be initiated early in the research program. When sufficient (although not necessarily all) signal information is available, the Type II experiments to assess suppressive reactions should be started. These experiments are to be supported by combat assessment procedures to provide the experimental subjects with feedback on combat results on essentially a real time basis. The combat models will include the best suppression submodels available at that time[1] to reflect the effect, albeit erroneously, that fire suppression has on performance capabilities and thus on combat results. The fire suppression models may be erroneous in using incorrect signal stimuli or incorrect affects on performance capabilities. Thus, the combat results feedback in the Type II experiments may be in error and consideration should be given to running Type II experiments iteratively with continual improvement in the suppression submodels based on results of the Type I, II, III, and supportive experiments and analyses. Thus, the signal stimuli assumptions in the models will be modified by results of the Type I, S.1, S.2, and S.3 efforts, some of which are derived from the Type II experiments themselves. Information to modify assumptions regarding the type and amount of performance capabilities affected (i.e., the Δp_i) are to be obtained from results of the Type III experiments. Since the latter require reaction sequences as input, they should be initiated after the first iteration of the Type II experiments and then run concurrently with them.

[1]As determined in the short term program effort to critically evaluate existing suppression submodels.

In summary, the long term research program is an iterative and integrated modeling and experimental effort in which the fire suppression and combat models are used to provide required feedback from the experiments and the experiments are used as a basis for improving the modeling assumptions. At any point in time the most valid models and supporting data will be available to address the spectrum of fire suppression issues noted in Chapter 1 of this report.

4.3 Suppression Research Office

Based on briefings provided by CACDA, it is our understanding that the objectives of the TRADOC suppression program are:

(a) to develop models of suppression effects to compare alternative weapon systems in their suppressive capability;

(b) to define data requirements for these models;

(c) to identify data gaps and recommend experiments, tests, and studies to alleviate them; and

(d) to insure that all combat models that include suppression effects are consistent and will be improved as better information becomes available.

Although the group found a high level of interest and concern about the subject of fire suppression, the TRADOC program, which is decentralized among the combat arms schools, CACDA and CDEC, does not appear to have a master plan as a structure for effectively integrating the diverse efforts. There were no apparent direct, clear lines of responsibility for *technical* guidance and supervision of the overall effort. Additionally, except for the CDEC efforts, there does not appear to be a sufficient commitment of *technical* resources to the development of a unified and integrated fire suppression program. For example, while the Combined Arms Combat Developments Activity (CACDA) at Fort Leavenworth was recognized as the proponent for all of TRADOC's fire suppression study efforts, only one officer was assigned the responsibility for coordinating the fire suppression efforts of CACDA, CDEC, and the combat arms schools.

If the fire suppression research activities research activities (short- and long-term) delineated in previous sections of this chapter are to be pursued, we believe a Suppression Research Office (SRO) should be formed under the overall direction of TRADOC to technically manage and coordinate efforts of the research program. The office should be responsible for:

(1) Performing, or having performed, the short-term study efforts recommended in section 4.1;

(2) Developing detailed plans for the conduct of a long-term research program, including SRO personnel requirements;

(3) Performing, or have performed, the following activities of a long-term research program;

(a) development of Outline Test Plans for all experiments,

(b) analysis of experimental results,

(c) development of appropriate fire suppression models;

(4) Controlling and managing activities of the total research program (i.e., specifying what should be done);

(5) Coordinating and integrating the efforts and results of the research activities;

Figure 6 is a schematic plan of the SRO research program activities. The ten short-term activities described in section 4.1, and development of a detailed plan for conduct of a long-term research program should be conducted in a two-year period. The short-term activities are listed below for easy reference:

*ST-1	Evaluate and enrich ASAP study
*ST-2	Critical evaluation of behavioral fire suppression models
ST-3	Parametric analysis of assumptions in fire suppression models
ST-4	CDEC experimentation
ST-5	AT gunner "signals" experiments
*ST-6	Investigate experimental approaches for long-term research program
ST-7	Analyze "quick fixes"
ST-8	Training guidelines and devices
ST-9	Combat veteran questionnaire studies
ST-10	Intelligence studies on role of fire suppression in foreign forces

Given the recommended initial staffing of the SRO noted below, the asterisked short-term activities are to be performed by the SRO staff during the initial two-year period and the remaining activities tasked to other agencies. Although the development of recommendations regarding the long-term research program and an associated plan for it are also the responsibilities of the SRO, it is recommended that the parametric analysis[1] (even though it is integral to fulfilling these responsibilities) be tasked to another agency in order to minimize the number of SRO staff members for the first two years.

1We estimate that this will require approximately eight man-years of effort.

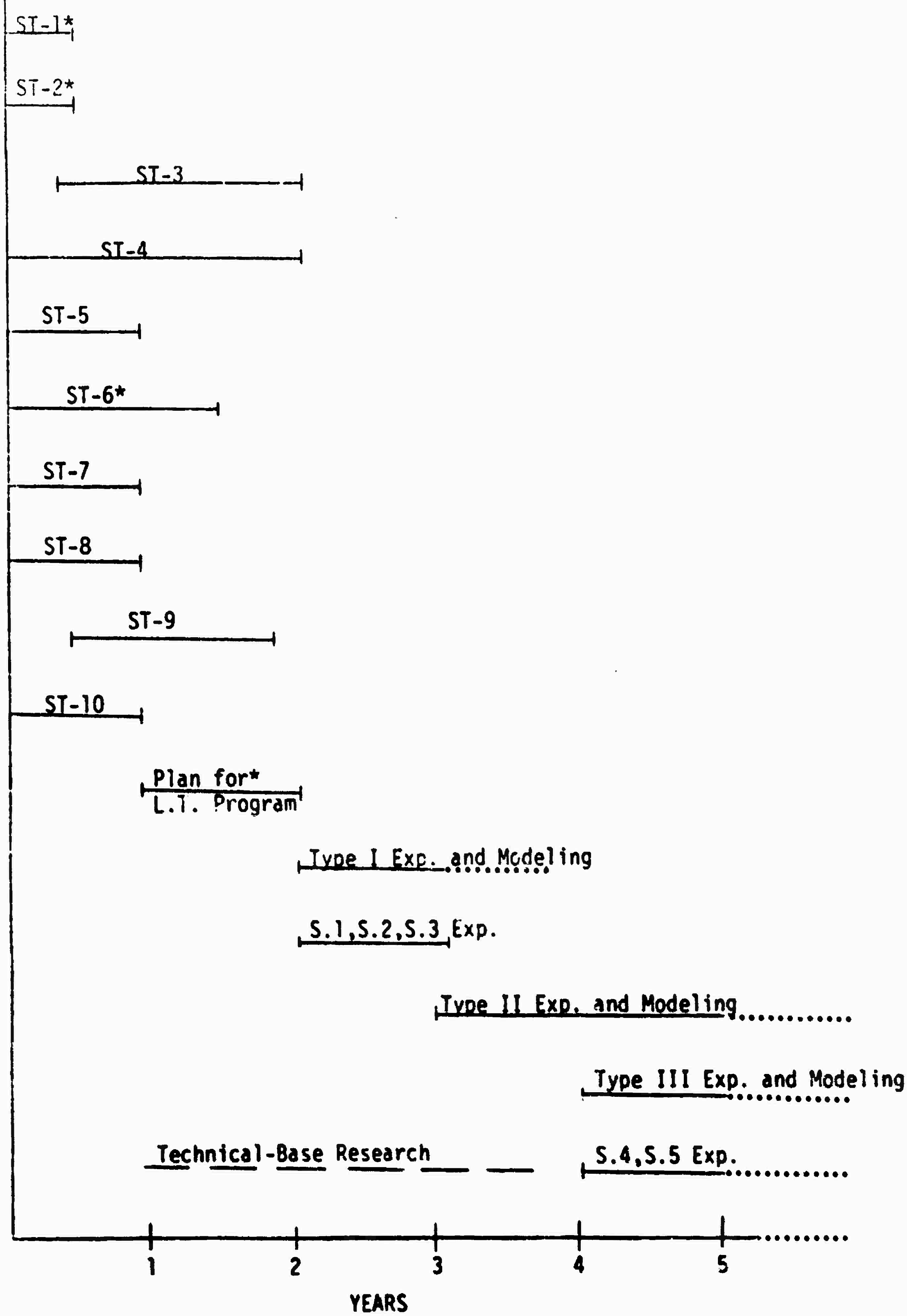

FIGURE 6: PLAN OF SRO AND PROGRAM ACTIVITIES

The effort should be closely monitored and, if necessary, directed by the SRO. Additionally, it is anticipated that the SRO will have to be supported by 2-3 man-years of effort from other agencies to accomplish the ST-6 activity.

Assuming the long-term research program is feasible and justified, figure 6 also contains a sequence of the principal categories of research required as described in section 4.2. Rationale for this sequence is summarized in section 4.2.6. It is anticipated that the research program will probably extend beyond the five years shown in the figure. Requirements for the indicated technical base research are discussed in section 5.2.

Table 6 contains the recommended staffing of the SRO for the first two years of the research program. This nucleus of seven professionals is considered the minimal essential for the conduct, control, and management of the short-term research program and development of a comprehensive plan for a long term program. It is estimated that approximately 15 professional man-years from other agencies will be required to support the first two-year's activities, excluding ST-4 and ST-5. It is assumed that these will be performed by CDEC as part of its existing fire suppression experimentation program.

TABLE 6: SRO Staff Requirements

Title	No. Reqd.	Grade	Experience/Capability Level
Chief	1	Colonel (06)	Combat Arms
Behavioral Scientist	2	TBD (Civilian)	1 - Expert[1] 1 - Journeyman[2]
Operations Research	2	TBD (Civilian)	1 - Expert 1 - Journeyman
Statistician	1	TBD (Civilian)	Journeyman
Physicist	1	TBD (Civilian)	Expert
Administrative Support	2	TBD (Civilian)	1 - Secretary - steno 1 - Secretary - clerk

[1] An "expert" is defined to be a professional who has 10-20 years of experience and can advance the state-of-the-art in his discipline and/or can creatively structure and perform studies and draw comprehensive (including surprising) conclusions and insights from them. He will probably have a PhD level of education.

[2] The "journeyman" is defined to be a professional who has 3-5 years of experience and can use state-of-the-art methods in his discipline, understand new advances, and can perform studies with minimal guidance from more senior professionals. He will probably have a PhD or be an exceptional MS graduate.

CHAPTER 5

QUICK FIXES AND OTHER THOUGHTS ON FIRE SUPPRESSION

Previous chapters presented a description of fire suppression processes and the structuring of a derivative research program. This chapter contains some related material regarding quick fixes for reducing fire suppression on command-guided anti-tank weapon systems and other ideas related to fire suppression.

5.1 Quick Fixes

Associated with the development of highly effective command-guided anti-tank weapon systems such as TOW, DRAGON, CLGP, has been an increasing concern that required exposure to track a target would subject the gunner or forward observer to suppressive fire which would result in a large number of aborts. A number of recent attempts to reduce these suppression effects include the use of body armor, tactical deployment to fire from behind a parapit, and mounting the system on armored vehicles. This section presents a number of additional "quick fixes" which we suggest be examined further for their technical feasibility, operational feasibility, costs, and operational value.

1. Optical Guidance to Avoid Suppression Effects

Up until the present, it has implicitly been assumed that anyone who fired a direct fire weapon would necessarily be exposed to enemy direct fire, and was therefore subject to being suppressed by that fire. The only serious attempt to get around this is the use of armor to provide protection. The principal protection afforded an infantryman in the open is his ability to make use of the terrain and of dug-in positions in lieu of armor. While this provides concealment and the same kind of protection as armor, it does not allow him to search freely for targets or fire his weapon while remaining protected from all suppressive enemy fire.

For the first time, now, in our optically-guided munitions, the technology basis exists to allow an infantry soldier to deliver precision (direct) fire munitions on target without having to expose himself to enemy suppressive fire. This rather significant change in the potential situation does not appear to have been recognized, and thus far no requirements have been established to explore the exploitation of this possibility.

The key to this new operational possibility, i.e., the ability to fire a precision (direct) fire weapon without being exposed to suppressive fire, lies in recognition of the fact that optically-guided munitions only require the infantryman to establish and maintain an accurate line-of-sight to the target. He does not have to aim the launch tube with this accuracy, as he does have to do in firing a rifle. This allows use of a periscope-type device to allow the gunner to search for targets and then to track them without having to actually expose himself to suppressive fire in the process. The important thing to recognize is that because of the use of optical guidance of the munitions, the periscope not only allows the gunner to acquire targets without exposing himself, but also allows him to aim and deliver his fire without exposing himself. The gunner's role is entirely optical, and the periscope displaces the optical path so that the gunner can function without being exposed.

Up to the present time, the use of a periscope in land combat was more or less as an extra gadget that allowed an individual to look at a scene without being exposed. Unfortunately, it did nothing to let a fighting man carry out his basic mission, which is to deliver fire on the enemy. As a consequence, the periscope was just extra weight to carry around that was only partially useful and, in a practical sense, not really effective. It did not protect the gunner because when it came time to deliver direct fire, he had to expose himself anyway. We believe that now with the advent of optically-guided direct fire munitions this situation has been drastically revised, and the significance of the periscope not only for target acquisition but for munitions delivery has become a practical and important reality. The periscope allows the gunner to remain protected from enemy direct fire weapons while he is able to fire at the enemy. It counters the enemy's fire suppression capability.

The two most obvious types of weapons which can make use of periscope-type aiming are TOW and CLGP, or some adaptation of these. It is a straightforward if somewhat substantial engineering task to modify TOW so that the weapon is fired from a position significantly above the gunner and the gunner views at his eye level, but by means of a periscope sees a field-of-view as though his eye level were several feet higher. This would allow TOW gunners to remain on the reverse slope of a hill or in a dug-in position behind an embankment and attack approaching tanks without being exposed to direct fire by the tanks. This type of mechanism would also be particularly useful in the TOW systems mounted on the M113, and would allow the gunner to retain the protection of the APC while firing the TOW.

In the case of CLGP, the projectile fire is, of course, indirect, but from the point of view of the laser designator operator, he is putting direct "fire" of the laser designator on the target. In this case in particular, it is clear that the use of a periscope both for use in surveillance and target tracking and for use in directing the laser beam would allow the gunner to keep under cover and immune from the enemy direct fire while designating his target. He would view through the periscope, track the target through the periscope, and "fire" his laser designator with the laser beam passing through the telescope.

The technology for adapting a periscope system to provide immunity against direct fire for the TOW gunner or laser designator operator is well established and only needs a decision for its exploitation. A number of different formats for this exploitation are possible. These range from the most straightforward, in which the laser designator simply operates through a tall (collapsible) periscope, to a whole new weapon system concept of a lightly armored, high speed vehicle firing a TOW-type weapon in a slightly indirect fire mode with periscope viewing, in which case the vehicle would fire from defilade position in an anti-armor role. The vehicle would be lightly armored with a large engine and able to sprint between protected positions. It would acquire and track targets through its periscope in a fully defilade position. It would fire TOW at a slight elevation so as to clear the protective embankment, and then the TOW tracker viewing through the periscope would capture control of the missile, bring it down to the periscope-to-target line-of-sight, and guide it to the target. Any number of different concepts making use of periscopes to allow direct fire while retaining the protection of an embankment or reverse slope are possible. All of them offer an immunity from enemy direct suppressive fire.

2. Rate-Aided Tracking to Maintain Track during Suppression Interrupts

The concept of rate-aided tracking has been investigated for several fire control systems such as Stinger Alternate and Pave Spike where manual tracking may be interrupted due to terrain loss of the line-of-sight or temporary loss of man-in-the-loop operation. In this case, the system "memorizes" the angular rates as the target is tracked and applies that bias to the system, the man acting as a continuous corrector for the actual instantaneous rate. If the manual track is interrupted, the system continues to track at the last bias value. This concept should have direct application to command guided and laser designated weapon systems where suppression could be a frequent cause of track interruption.

3. Rapid Target Pin-pointing to Counter Suppression Weapons

The rapid pin-pointing of enemy fire could provide an important method of neutralizing the adverse effects of suppression. It could also provide the means of bringing rapid counterfire to bear. The Army-ARPA MIT HOWLS program is evaluating emerging technologies such as charge-coupled devices (CCD), IR detectors, Moving Target Indicator (MTI) radars, unattended ground sensors (UGS), to effect real time location of hostile weapons. The HOWLS program should be examined in detail to determine which elements might provide quick fixes for rapid target pin-pointing, particularly CCDs for motion detection and IR sensors for flash detectors.

4. Decoys to Divert Suppressive Fire

It appears to be well recognized that suppressive fire is most effective when delivered against an acquired suppressee rather than randomly dispersed over an area. Coupling this with information that

(a) the launch signature of DRAGON and TOW provide significant stimuli for "pin-point" acquisition, and

(b) based on some of the results from the DRAGON OT-III tests, it appears that crews of vehicle targets can acquire the missile in flight and respond with fire prior to missile arrival,

suggests that additional stimuli on the battlefield would reduce the effectiveness of a fixed amount of suppressive fire. Accordingly, consideration should be given to the development of inexpensive, rapidly deployable, "decoy" systems that will stimulate the firing signature (and possibly the missile flight) of DRAGON and TOW. Such decoys could be proliferated along defensive positions, and perhaps keyed to actual firings, for the purpose of diverting suppressive fire from actual systems.

5. Training in Signal Estimation and Risk Assessment

The performance of DRAGON and TOW gunners may be improved if they were able to more accurately assess the risk associated with suppressive fire. Current data seems to indicate that the primary stimulus determinants of suppressive reactions are:

a. Proximity of incoming rounds to the individual.

b. Loudness of the projectile signature.

c. Volume of incoming rounds to the individual.

d. Type of weapons system employed against the individual.

e. Unique projectile or weapons system signature.

f. Visual and auditory signature associated with the impact of the projectile.

The relationship of these characteristics with P_k is not immediately obvious, and these characteristics may not completely describe all of the important stimulus variables. However, they do suggest some implications for immediate emphasis in training. In general, it appears that DRAGON and TOW gunners, and more generally that ground-combat trainees, would profit from more experience with incoming live fire with feedback under safe conditions, than is presently provided. (While there was a good reason to replace the old known distance method of marksmanship training with TRAINFIRE involving pop-up targets at various ranges, the trainee lost the experience of being near incoming live fire while performing his duties of pulling and scoring targets in the pits.)

At present little is known about the ability of an untrained soldier to judge the distance of an incoming round. A training situation could be easily arranged, as has been done at CDEC, which would give soldiers the experience of sensing incoming rounds at varying distances. By providing immediate feedback of miss-distance, the soldier could learn the auditory characteristics of rounds passing at different distances. Such a training exercise should first be run to obtain normative data on the accuracy of judgments as training begins and to determine how judgmental accuracy improves with practice and feedback. If significant improvement occurs, a training program could be developed for general use in Advanced Individual Training in the Combat Arms. Soldiers who have become familiar with incoming fire and have learned at least a little about how to judge its distance should be able to assess risk more accurately and behave more appropriately under suppressive fire.

A similar program could be instituted to develop training in identifying and distinguishing between incoming fire from a number of different weapons of varying signatures and calibers. Such training would help the soldier in assessing risk in terms of his ability to identify hostile fire of greater or less potential danger to himself.

While it is probably not necessary to demonstrate experimentally that the greater the volume of incoming fire the greater is the risk perceived by the soldier, the matter of volume of fire should be taken into account in the kinds of training exercises suggested above. The masking effects of loud noise in his area will, no doubt, have an effect on the trainee's ability to distinguish between incoming rounds, both in terms of miss-distance and the type of weapon delivering the fire. Therefore, the exercises should be run under conditions of relative quiet and with various levels of simulated battlefield noise. Skills in discrimination developed in quiet will need to be practiced and strengthened under conditions of increased ambient noise.

In developing these kinds of training programs, use should be made of experienced combat veterans for two purposes: (1) to determine how accurately they can discriminate, in order to set some tentative norms or goals for the training of inexperienced troops, and (2) to learn from them the particular characteristics of the stimuli (principally auditory) which they use in making their discrimination. This information would be most useful in developing the content of the training programs.

While the suggested training exercises can be accomplished in the field, using live ammunition and suitable terrain with proper bunkers and foxholes emplacements, it would be worthwile to investigate the possibilities for simulation through motion pictures and sound effects. The development of an indoor simulated situation would provide on all-weather capability for training and would be especially useful when terrain for training is limited, as is usually true with National Guard and Reserve Components.

5.2 Miscellaneous Ideas

1. Technologies Base Research

Suppression is a comples behavioral phenomenon. A significant aspect of the "suppression problem" is the lack of an adequate technological base. An understanding of human behavior in the suppression process requires creative research ideas, innovative approaches and new theoretical constructs leading to developments whose direct applicability may not be immediately obvious. Clearly we believe a short-term research program is worthwile. We believe a long-term research program may be worthwhile. Both the long-term and the short-term research programs have specific relevance to the problem of fire suppression and are intended to assist in its solution. It was recommended that research efforts be initiated and directed by TRADOC.

Additional research efforts are required to address areas in which there is lack of knowledge or a weakness in the technological base required to support a TRADOC suppression program. The broad areas include:

(1) The effect of non-traumatic stress on performance.

(2) Human performance in situations involving physical danger.

(3) Behavioral analyses of risk perception and risk taking in real-world situations.

(4) The perception of environmental uncertainty and its relationship to performance.

(5) Behavioral study of the impact that different environmental conditions (i.e., day vs. night) have on fire suppression.

This research would have general relevance to suppression and would focus on the formulation of scientific principles and the identification of parameters. Scientific advances in these areas have the potential to provide innovative approaches and new theoretical constructs concerning the processes underlying suppression. These would simplify and facilitate the TRADOC suppression program and increase the likelihood of producing useful information.

Programs in the technological base are generally initiated by developing agencies. In the absence of current programs in the areas indicated above, TRADOC should recommend and support the initiation of such research.

2. Development of an Artillery Fire Suppression Index for TACFIRE

TACFIRE, as currently programmed, computes artillery fire missions only on the basis of the probability of a kill (P_k) for a given target. The definition of fire suppression suggested in this report provides a conceptual basis for developing an artillery fire suppression index which could be used in conjunction with P_k in computing fire missions. This should result in a more efficient allocation of artillery fires.

Suppression effects can be measured as a change in performance capability caused by signals from delivered fire. The degree of fire suppression effects are associated with the joint probability distribution of the random variables which describe the amount of the changes in performance capabilities over time. A suppression index could be computed based on the changes over time in certain general performance capabilities such as mobility, firepower, etc. Supplemented with analogous measures of shock effects, this index would be a measure of the non-lethal effects of artillery fires. This index could be incorporated into the calculation of fire missions in several ways. For example, a useful standard time interval for suppression/shock effects could be determined and computations based on:

a. degradation in a given performance capability appropriate to the target, such as mobility/firepower, or more generally;

b. degradation in combat power estimated using engagement simulations.

The suppression index would be a function of target, situation, and performance capability. The calculations likely to be involved in using this index could readily be performed on TACFIRE.

Successful development of this concept might result in a reduction in the amount of firepower (overkill) computed for given fire missions and in more effective artillery fire.

3. "Flesh-Testing" the Bushmaster Round

It is our understanding that the Bushmaster round has been tested for lethality effects by the Ballistics Research Laboratory, but that this testing has been against paper targets. Such tests are not a realistic means of assessing damage producing capabilities of the round and we believe that consideration should be given to flesh- or gelatin-testing to generate better information. The Army has excellent records of the results of similar tests with other types of munitions that allow one to extrapolate the animal results to the anticipated type and severity of injury caused by a given round or munition to man. This extrapolation is possible because of the variety of clinical medical data on injuries caused by such munitions in prior conflicts. We believe this information will be useful in the context of a fire suppression program for the following reasons:

(a) Discussions with military officers have suggested that a weapon is suppressive if it is perceived as capable of causing death or serious injury. If potential adversary forces are contemplating use of a BUSHMASTER type round, it would be useful from a suppression training point of view to assess the death and injury producing potential of such a round realistically.

(b) Although we are not familiar with its technical details, we understand the BUSHMASTER round is a projectile of about an inch in diameter which fragments like a small grenade when it is detonated by striking some object. The projectile may have a total velocity that is the sum of its initial muzzle velocity and the velocity of the platform from which it is fired (less, of course, the loss of velocity during its time of flight). When such a moving projectile detonates, the velocity of fragments may vary considerably as a function of the angle from the line of flight. It, therefore, appears most desirable from a suppression design viewpoint to determine the injury produced by the fragments to animal tissues situated at different distances from the point of detonation and at various angles from the line of flight, measured from the point of detonation. The pattern of lethality or injury may be quite different ahead of and behind the point of detonation, which could have an influence on the suppressive effect of such a round.

APPENDIX A

TERMS OF REFERENCE

APPENDIX A

TERMS OF REFERENCE
AD HOC WORKING GROUP ON

FIRE SUPPRESSION

1 November 1974

1. BACKGROUND:

In recent years the Army has invested extensively in field experimental facilities, computerized combat assessment models, and war gaming techniques for the purpose of weapon system evaluations and analysis of force development issues. While these resources do provide improved methods for evaluation of tactics and materiel, the effects of suppression are generally ignored or not quantified. This lack of accounting for the effect of suppression in the models and field experiments is causing serious difficulties in the cost and operational effectiveness evaluations of present and future weapon systems.

A priori, the suppression phenomena has a significant direct effect on the attrition that may be expected to occur in small unit combat activities (since it decreases both the firer's and target's attrition capabilities) and may have an equally important indirect effect by interfering with the observation, movement, and communication activities in a battle. The inability to model these suppression effects credibly reduces the realism of cost effectiveness evaluations of a broad spectrum of proposed maneuver unit and fire support weapon systems and provides little guidance to the design of appropriate suppressive fire characteristics into such weapon systems. Although there is a history of studies, modeling, and experiments associated with this suppression phenomena, the mechanics of generation of suppression and the resulting degradation in individual soldier and unit performance is not satisfactorily understood.

Accordingly, there appears to exist a need for a structured program of experiments, analyses, and modeling activities that will lead to a means of estimating the performance effects of suppression as a function of the generating mechanism, target characteristics, terrain type, and target activity. Some preliminary efforts to develop such a program were recently initiated by the Training and Doctrine Command (TRADOC).

2. TERMS OF REFERENCE:

The ASAP committee should provide scientific guidance to this program by:

(1) Briefly reviewing and assessing some of the past suppression research activities.

(2) Clarifying some of the definitions associated with the process.

(3) Defining and/or clarifying objectives of a research program.

(4) Within time and resource constraints, outline the structure of the research program.

3. TERMINATION:

The Chairman of the Ad Hoc Group is requested to conclude his efforts at the earliest possible date. A final report should be submitted not later than 1 June 1975.

APPENDIX B

MEMBERSHIP LIST

DEPARTMENT OF THE ARMY
ARMY SCIENTIFIC ADVISORY PANEL
Washington, D.C. 20310

1 November 1974

Membership
AD HOC GROUP
on

Fire Suppression

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APPENDIX C

AGENDAS FOR VISITS TO CDEC AND CACDA

DEPARTMENT OF THE ARMY

Headquarters
US Army Combat Developments Experimentation Command
Fort Ord, California 93941

ITINERARY

AD HOC GROUP ON FIRE SUPPRESSION
Army Scientific Advisory Panel
Washington, D.C.

15 - 17 January 1975

ADMIN OFFICER: CPT Cook
TRANSPORTATION: Sedan
ACCOMMODATIONS: VIP 1, 2, 3
PURPOSE OF VISIT: Suppression Discussion

TIME	EVENT	LOCATION OR TRANSPORTATION	SPONSOR
	Wednesday, 15 January 1975		
TBA	Arrival	TBA	
	Thursday, 16 January 1975		
0800-0805	Commander's Orientation	Bldg 2917, Rm 1	Cdr
0805-0825	AD HOC Group Orientation	Bldg 2917, Rm 1	Dr. Bonder
0825-0845	Command Briefing	Bldg 2917, Rm 1	DCSPPA
0845-0915	Experimentation Synopsis	Bldg 2917, Rm 1	DCSEX
0915-0945	Instrumentation Briefing	Bldg 2917, Rm 1	DCSI
0945-1000	Break	Bldg 2917	SGS
1000-1115	Suppression Briefing	Bldg 2917, Rm 1	DCSPPA
1115-1120	Enroute Flagpole	Sedan	SGS
1120-1205	Enroute HLMR Army Airfield	UH-1H	CDEC Avn Section

ITINERARY For AD HOC GROUP ON FIRE SUPPRESSION (Continued)

TIME	EVENT	LOCATION OR TRANSPORTATION	SPONSOR
1205-1210	Enroute Hacienda	1/4 Ton	SGS HLMR
1210-1300	Lunch	Hacienda	Spt Bn
1300-1305	Enroute Field Headquarters	1/4 Ton	SGS HLMR
1305-1325	HLMR Briefing	Fld HQ	SGS HLMR
1325-1330	Enroute Instrumentation Support Command (ISC)	1/4 Ton	SGS HLMR
1330-1400	Briefing and Tour of ISC	ISC	DCSI
1400-1415	Enroute DUCS Field Site	1/4 Ton	SGS HLMR
1415-1520	Briefing and Observe DUCS Trial	DUCS Fld Site	DCSEX
1520-1535	Enroute HLMR Army Airfield	1/4 Ton	SGS HLMR
1535-1620	Enroute Flagpole	UH-1H	CDEC Avn Section
1620-1630	Enroute Quarters	Sedan	SGS
1630-	Open in Quarters		
	Friday, 17 January 1975		
0800-0830	Executive Discussion	Bldg 2917, Rm 2	Dr. Bonder
0830-0900	Suppression Results to Date	Bldg 2917, Rm 1	DCSEX
0900-1000	Current and Future Suppression Experiments	Bldg 2917, Rm 1	DCSPPA
1000-1015	Break	Bldg 2917	
1015-1130	Suppression Discussion	Bldg 2917, Rm 1	DCSPPA
1130-	Termination		

CORRECTED COPY

US Army Combined Arms Combat Developments
Activity
Fort Leavenworth, Kansas 66027

SUPPRESSION AD HOC GROUP
ARMY SCIENTIFIC ADVISORY PANEL
12-13 February 1975

NAME	ITINERARY	BILLET
Dr. Seth Bonder		Ramada Inn
Dr. David L. Fried		Ramada Inn
Dr. Meridith Crawford		Ramada Inn
Dr. H. L. Ley		Ramada Inn
Mr. Edward G. Swann		Ramada Inn
Dr. Edgar M. Johnson		Ramada Inn
LTC J. R. Broome		
LTC R. A. Ross		

ACTION OFFICER: MAJ Edward J. Burke, CCS, 5595

- -

TIME	FUNCTION	BY WHOM GIVEN	PLACE
	Tuesday, 11 Feb 75		
	Arrive Leavenworth		
	Wednesday, 12 Feb 75		
0800-0815	Welcome/Administration -- CCS Dir		Grant Auditorium
0830-0900	Ad Hoc Group Purpose/Comments -- Dr. S. Bonder		Grant Auditorium
0900-0915	Comments/Welcome -- DCDR CACDA, MG W. R. Wolfe, Jr.		Grant Auditorium
0915-1200	TRADOC Suppression Effort -- CCS Dir/COA Dir		Grant Auditorium
1200-1300	Lunch		FLOOM

TIME	FUNCTION	BY WHOM GIVEN	PLACE
1300	AR, FA, and IN Perceptions of Battlefield Suppression and Curient Modeling Effort -- CCS Dir/COA Dir		Grant Auditorium

Thursday, 13 Feb 75

0800-0930	Executive Session -- Dr. S. Bonder		Classroom 7 Bell Hall
0930	Discussion as required -- Dr. S. Bonder		Classroom 7 Bell Hall

APPENDIX D

WORKING NOTES DESCRIBING SUPPRESSION AS REPRESENTED IN THE DYNTACS, ASARS, CARMONETTE, AIRCAV5-BONDER/IUA, BLDM, AND AIDM COMBAT MODELS

These notes were prepared by Dr. Lee Jacobi of Vector Research, Incorporated, as part of a TRADOC sponsored project to improve the representation of fire suppression in the AMSAA Improved Differential Model (AIDM). They are reproduced here with permission of the author.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES

CHAPTER D.I

INTRODUCTION

These notes describe in some detail the assumptions, implementation techniques, and miscellaneous topics related to the suppression models currently implemented in the following combat models: DYNTACS, ASARS, CARMONETTE, AIRCAV5-BONDER/IUA, BLDM, and AIDM. The notes were compiled as background material for the development of new suppression models for the version of AIDM currently operational at the TRADOC Systems Analysis Activity (TRASANA). In order to facilitate development of an accurate and thorough presentation of these models within a very limited time, much of the material was extracted verbatim from the reports listed in the bibliography (Appendix A). The reader is cautioned that these are working notes only; more formal use or reproduction is not advised without careful verification of the source material or without permission of the authors noted in Appendix A.

These notes are divided into five chapters in addition to this introductory one. Chapters two, three, four, five, and six describe the current DYNTACS, ASARS, CARMONETTE, AIRCAV5-BONDER/IUA-BLDM, and AIDM suppression models, respectively. Figure 1 summarizes the representation in these combat models of several important suppression characteristics.

MODELS / CHARACTERISTICS	DYNTACS	ASARS	CARMONETTE	BONDER/IUA	BLDM	AIDM
MECHANISMS CAUSING SUPPRESSION	FRONT NEAR MISSES NON-DAMAGE HITS MOBILITY-KILL HITS K-KILLS	NEAR MISSES DIRECT HITS -KILLING -NON KILLING	NEAR MISSES	FIRE RECEIVED	FIRE RECEIVED (SPECIAL TREATMENT FOR NON-LETHAL HITS)	CASUALTIES
PROCESSES AFFECTED (SUPPRESSEE)	NON-FIRING DETECTIONS FIRING COMMUNICATIONS (FDC)	MOVEMENT FIRE OBSERVATION COMMUNICATIONS	FIRE MOVEMENT OBSERVATION	FIRE OBSERVATION BEING ACQUIRED	FIRE OBSERVATION BEING ACQUIRED	FIRING
LEVELS OR STATES OF SUPPRESSION	LONG-TERM SHORT-TERM	SEVERAL STATES	"PINNED-DOWN" PARTIALLY NEUTRALIZED -EVASIVE ACTION -PROCEEDING WITH CAUTION (BUTTONED-UP)	SUPPRESSED UNSUPPRESSED	SUPPRESSED UNSUPPRESSED	SUPPRESSED UNSUPPRESSED
DURATION OF SUPPRESSION	INPUT CONSTANT	INPUT CONSTANT	INPUT CONSTANT	INPUT CONSTANT	WEAPON DEPENDENT INPUT CONSTANT	EXPONENTIAL
FACTORS INFLUENCING LEVELS	MISS DISTANCE	NEW: F-KILL, EXISTING STATE OF SUPPRESSION OLD: NUMBER OF ROUNDS, ROUND TYPE, AVERAGE MISS DISTANCE	SUPPRESSEE TYPE NUMBER OF ROUNDS IN Δt ROUND TYPE	NONE	NONE	NONE
FACTORS INFLUENCING DURATION	MISS DISTANCE STATE OF SUPPRESSION SEVERITY OF HIT	MAXIMUM CURRENT LEVEL OF SUPPRESSION	MOVEMENT OUT OF AREA OF IMPACTS	SUPPRESSEE TYPE	SUPPRESSEE TYPE	NONE
ELEMENTS AFFECTED BY SUPPRESSION	ALL BUT AH'S	ALL	ALL	ALL BUT ARTY	ALL BUT ARTY	ALL BUT ARTY

FIGURE 1. SUMMARY OF SUPPRESSION CHARACTERISTICS AS REPRESENTED IN VARIOUS COMBAT MODELS

CHAPTER D.11

THE DYNTACS SUPPRESSION/NEUTRALIZATION MODEL

Chapter 11 provides a detailed description of the assumptions implemented in the DYNTACS suppression/neutralization model. Section A serves as a general overall description of the model. Section B describes a target suppression calculation. Finally, Sections C - E discusses the impact of suppression on the intelligence model, the counter-battery lethality model, and the helicopter operations model, respectively.

A. GENERAL DESCRIPTION

An important effect of fire delivered upon enemy positions is the neutralization of enemy weapons which temporarily blinds them and restricts their ability to engage in firing activities. Armor vehicles are forced to button-up and enemy weapons receiving fire seek cover to avoid being destroyed. Also, the smoke and dust created by the fires may limit the visibility of the enemy weapons. When in a neutralized state, the enemy weapon is incapable of observing the friendly force. By neutralizing enemy weapons during an attack, a maneuver unit may close with the enemy position without being harassed by enemy fire, or, in a defensive engagement, neutralization of the attacking forces may permit the defenders to break up and destroy the attacking units.

Generally, this concept of neutralization is represented in DYNTACS as follows:

When one weapon fires at another, it may suppress that weapon even though it fails to kill it. (There are four general kinds of suppression possible in DYNTACS: suppression due to (1) a near miss, (2) a hit which incurs no damage, (3) a hit which incurs a mobility kill, and (4) a hit which incurs a total kill.) DYNTACS allows both direct and indirect fire weapons to suppress targets but the techniques for determining suppression differ between direct and indirect fire weapons.

Direct fire weapons can only suppress a vehicle if they score a hit, thus producing only "secondary" suppression. Once a hit has been scored, the suppression interval depends on the severity of the hit. If a round causes enough damage to inflict either a maneuver or firepower kill, the damaged vehicle is suppressed for 2 minutes. If the round causes no damage to the target, then the target is suppressed for only 5 seconds. These suppression times represent the best estimate distilled from the cumulative experience of the members of the DYNTACS tactics and doctrine committee. They are not based on concrete information.

The artillery produces primary suppression as well as casualities, and has a suppression ellipse associated with each firing pattern.

The dimensions of this ellipse depend on gun dispersion in the battery, the sheaf used, the artillery projectile used, and the ballistic dispersion of the round. The dimensions are specified as input. When a volley of artillery is fired, the expected impact points are calculated. The neutralization ellipse is then placed over the center of mass of the expected impact points. Any vehicles or elements inside this neutralization ellipse are suppressed. Blue artillery is credited with the capability to suppress threat weapons for 5 seconds. Threat artillery can suppress Blue weapons for 3 seconds. As with the direct fire weapons, the values both for the size of the suppression ellipse and the duration of the suppression are the best estimates of individuals from the artillery school.

In general, however, two neutralization time intervals are recorded for each considered weapon element, i.e., the current and previous neutralization time intervals. As additional rounds impact in the vicinity of the element, these neutralization time intervals are either enlarged, or a new interval is generated causing the current interval to become the previous interval and the previous interval to be dropped. If the neutralizing round occurs during the current interval, the current interval is increased in length. If the neutralizing round impacts after the end of the current interval, a new current interval is established. The previous interval is always extended back to the beginning of the battle.

These neutralization time intervals are updated when an element sustains a neutralizing round. Since the length of the neutralizing period is provided as input, the neutralization period can be varied for the type of round by either the Firing or Artillery Models.

B. TARGET SUPPRESSION CALCULATION

In the DYNTACS target suppression calculation, the height and width of a target silhouette are used to compute the probability of hit by integrating a bivariate normal distribution over the exposed silhouette. It is assumed that near misses impacting to the sides and above the target, with respect to the firing vehicle, do not suppress the target. However, it is assumed that near misses in front of the target cause suppression due to flying debris. The relevant distance in front of the target is defined as that which would cause suppression if hit. This distance in front of the target, the range between firer and target, and the height of the firer are used to compute an equivalent vertical distance that is added to the bottom vertical target dimension to account for the probability of suppression. Since a target is automatically suppressed if it is hit, the additional vertical dimension for suppression is added to the bottom of the normal uncovered vertical target dimension to compute the probability of suppression.

A random number is compared to the probability of hit plus the probability of suppression to test for suppression. If a target is suppressed it may also be hit so the same random number is tested against the probability of hit to determine the hit status of the target.

C. IMPACT OF SUPPRESSION/NEUTRALIZATION ON THE INTELLIGENCE MODEL

When the intelligence model checks the neutralization status of the current element, it examines the time interval for the previous event that the current element was unneutralized. Visual detections can be acquired and retained only during this unneutralized period. The model examines the neutralization times for the current element and designates the beginning and end of the time interval that the current element was not neutralized. The visual detection model determines whether any enemy elements were detected in this time interval, the last interval available for search.

When the current element fired in its previous event and is unneutralized, the firing activity prevents any search for undetected weapons, but the current element can retain its already detected weapons.

Since a neutralized observer is incapable of observing enemy weapons, each weapon detected before the neutralization period has its detected status reduced to a state called "approximate knowledge". The only exception is when the neutralized observer fired in his previous event and his target is uncovered, then it is assumed that the firer keeps his sights directed at the target. Also, since the neutralized observer cannot acquire an enemy weapon while neutralized, a waiting pinpoint acquisition computed for the observer while he was unneutralized is deleted. Finally, if the current element was neutralized during a part of its previous event, visual search can occur only during the unneutralized period.

D. IMPACT OF SUPPRESSION/NEUTRALIZATION ON THE COUNTERBATTERY LETHALITY MODEL

As a result of counterbattery directed fire, two types of neutralization may be inflicted on the elements of a firing battery. The first type of neutralization, short term, involves neutralization from which the battery element may recover during the course of the battle. The second type, long term neutralization, involves damage to the element which removes it for the remainder of the battle.

Short-term neutralization results from a projectile impact which causes little if any actual physical damage, but its effects are sufficient to cause a temporary suspension of activity. A neutralization time associated with short-term neutralization is computed as a function of the distance of projectile impact from the battery element position, and projectile type. Specification of the projectile type reflects the various lethality characteristics of different types of projectiles. Two input radii of neutralization about the weapon locations within the battery are associated by the model with two input neutralization times dependent on projectile type, for the short-term neutralization time calculation. The inner radius is associated with the maximum short-term neutralization time. The extreme short-term neutralization times reflect a separate vulnerability level for the fire direction center (discussed below). The neutralization time for an individual weapon is computed assuming the projectile impacted within the short-term neutralization zone.

Long-term neutralization is the result of physical damage to some element of a battery which is irreparable within the time frame simulated by DYNTACS. The neutralization time (analogous to a total kill) associated with this type of effect is a large positive number.

When the projectile impact point is within the long-term neutralization zone of a battery element for that projectile type, the element is removed from the battle. The assumption is made in the model that the aim points of the battery firing weapons are not altered due to a neutralized weapon, although no projectile is fired by the neutralized weapon. When the neutralization period for a weapon passes, indicating the neutralization is short-term, the impact point from the projectile fired by the weapon is used in damage assessment.

The elements of the battery consist of the weapons and the fire direction center (FDC) which represents communication. Neutralization of the individual weapons prevents them from performing any firing activity during the neutralization period.

If all the weapons within a battery are simultaneously short-term neutralized, the current fire mission of the battery is aborted. A new mission can be selected after the neutralization period has elapsed. If all the weapons within the battery incur long-term neutralization, the activity of the entire artillery unit is suspended for the duration of the battle (becomes a casualty).

In order to reflect the proximity of a projectile impact to an element in the battery for computing lethality, the two radii are applied to the specific points which describe neutralization zones. The inner radius describes the area where projectile impact results in long-term neutralization or permanent suspension of the element's activities (a total kill). The area between the inner and outer radii circles represents the zone where projectile impact results in short-term neutralization of the battery element's activities. Beyond the outer radius no lethality effects will be suffered by the battery element. The dimensions of the two radii are variable depending upon the impacting projectile type.

a. <u>FDC Neutralization</u>

Short term neutralization to an FDC merely disrupts the communication processes for the length of the neutralization period. No disruption of forward observer (FO) activities or battery firing is realized, except that ward observers may not communicate their requests. Long-term neutralization results in the eventual removal of the battery unit from the battle since the FDC becomes permanently inactive, and no FO communications may be processed. The battery continues to fire all missions already on the fire request list except those missions specified as fire adjustment missions. If the battery is firing a fire adjustment mission when the FDC is neutralized, the mission is terminated. Scheduled fire activity is not affected.

Neutralization to an FDC may occur under two unique circumstances relative to counterbattery fire. The fire occurs when the FDC is not actively communicating with a forward observer. The second occurs when the FDC is communicating.

When an FDC is not processing a communication, the lethality model inactivates the FDC immediately. The calculated neutralization time is the time interval during which the fire direction center cannot process missions. The neutralization time for a long-term neutralization is a large positive number, greater than any time simulated by DYNTACS. The short-term neutralization time is a time which will presumably occur during the battle. The times are determined from user supplied data and, therefore, may be represented by any range of neutralization times. The next event of the FDC occurs at the time corresponding to the end of the neutralization interval. This rem the FDC from the battle for the specified length of time. At the end of the neutralization, the FDC may again process communications. For long-term neutralizations, the end of the neutralization period is never reached so that the FDC is permanently removed.

When the FDC is active, that is, when communication is in progress, a different procedure is used to represent the neutralization. Because communication is in progress, a check is made to determine if a forward observer is also involved in the process. If so, communication time between the FDC and the FO is assumed minimal, and it is, therefore, also assumed that the actual communication would not be interrupted by the neutralization. Hence, when communication is being processed by the FDC, the neutralization period begins immediately following that communication. To represent this, it is necessary for the FDC to actually neutralize itself during the communication event.

The counterbattery lethality model, therefore, determines a neutralization time for the FDC and stores it for future reference by the FDC model. As in the case where the FDC was inactive when the neutralization time has expired, the FDC resumes a wait status for the next fire request.

If an FDC receives neutralization while a neutralization to the FDC is currently in effect, the counterbattery lethality model compares the two neutralizations and determines the final neutralization time. If an FDC is long-term neutralized and receives a more recent neutralization of long-term or short-term type, no processing is required. Hence, the cases which require consideration are those involving an FDC which is short-term neutralized, and which receives another short-term neutralization or long-term neutralization. When a short-term neutralized FDC receives another short-term neutralization, the resulting neutralization will either end at the same time as the original, or at a later time because it is assumed that the neutralizations overlap. When the final time has been determined, the FDC's clock is changed to the time of the combined neutralizations.

If an FDC receives a second short-term neutralization while a communication is pending, and before the first neutralization has been affected, the time until the next event becomes the new neutralization time. When the FDC completes the communication and initiates neutralization, the resulting neutralization is, therefore, the combination of both neutralizations.

When the FDC is short-term neutralized and receives a long-term neutralization, the neutralization is extended from short-term to long-term. If communication is pending and a long-term neutralization is received subsequent to a short-term neutralization, when the FDC completes communication and initiates the neutralization, a long-term neutralization results.

b. FO Neutralization

The activities of forward observers associated with an artillery fire direction center which has been neutralized are directly affected by the neutralization of the center. Moreover, the effects produced are dependent upon the type of neutralization inflicted.

Short-term neutralization merely inconveniences the forward observers since communication with the center is interrupted for the duration of the neutralization period. Hence, the FO attempts to place his fire requests with other artillery units through the fire support coordinator until his communication with the affected center is restored.

The FO model determines that the FDC is temporarily neutralized. The FO then communicates his fire request to the fire support coordinator, FSC. The FSC examines the possible receivers for the fire request and assigns it to another artillery unit if possible.

Long-term neutralization to a fire direction center, in effect, disassembles an artillery unit. The communication processes between the battery and the FO's cease to function. The firing battery continues to fire all fire for effect missions and scheduled fires, but all fire adjustment missions which require active involvement with an FO are removed from the fire request list. This includes the mission presently being fired by the battery. At this time, all forward observers which were involved in communication with the FDC are returned to target selection status. When the battery has completed the remaining mission, the artillery unit becomes permanently inactive.

The FO model, as in the short-term neutralization case, realizes that the FDC is neutralized during an FO's communication and relays requests throught the FSC. The FSC is assumed to have the knowledge that an FDC has become permanently removed from the battle. The FSC then attempts to reassig the forward observers connected to the object FDC to other artillery units. If this reassignment fails, the FO's involved will be eliminated from the bat

The data describing the fire pattern of counterbattery missions consist of range and deflection dimensions for determining individual shell impact points in a volley and for describing the neutralization area associated with the impact.

E. IMPACT OF SUPPRESSION/NEUTRALIZATION ON THE HELICOPTER OPERATIONS MODEL

While performing either preplanned or immediate support missions within DYNTACS, aerial vehicle teams may deliver neutralization fires, destruction fires, or combined fires. The first of these fires is intended to reduce the combat efficiency of the enemy by hampering the fire of his weapons, reducing his freedom of action and movement, and reducing his ability to inflict casualties. Neutralization fires may also be delivered for protection while engaging a point target with destruction fires.

The model assumes that aerial vehicle elements have available two classes of weapons as follows:

(1) destructive (point) fire weapons, generally consisting of direct-fire missiles; and

(2) suppressive (area) fire weapons, including such weapons as machine guns, rockets, etc.

Each aerial vehicle element may have up to six ammunition types available. The class of each weapon-ammunition category is specified as input as either suppressive or destructive fire ammunition.

a. Target Selection

The first phase of the target selection procedure is to determine, for each element in the specified aerial vehicle section, the total number of destructive and suppressive weapons currently available for employment by the aerial vehicle section. The assumption is made that, during a single firing event, an aerial vehicle element can employ no more than one destructive weapon and no more than two suppressive fire weapons. The actual limitations on an aerial vehicle are specified as input.

The second phase of the target selection procedure is to determine the best complex of enemy ground targets for engagement by the aerial vehicle section. The maximum allowable radius of the circle utilized to describe the boundaries within which a ground target complex will be attacked is specified by input data for an aerial vehicle section having a given number of suppressive and destructive fire weapons currently available. The most desirable combination of the number of destructive fire weapons and suppressive fire weapons for the selected complex is then determined by the model.

b. The Firing Model

During the movement phase of a helicopter attack to and from the main weapon firing point, suppressive fire may be employed by the vehicles to hinder attempts for return fire. A given helicopter may be assigned to fire suppressive fire, a main weapon fire, or both, hence, the two types of weapons may be employed by each vehicle.

The first type of weapon consists of rapid fire weapons which are used for suppressive fire. These weapons fire a number of projectiles in one burst, and several bursts may be fired during one firing mission by each weapon. Types of rapid fire weapons are distinguished by input data. During one firing mission an aerial vehicle may employ two different types of rapid fire weapons. The number of bursts fired by such weapons depends on the type of rapid fire weapon and the time allotted for suppressive fire. The time alloted to suppressive fire is predetermined and is dependent on the phase of the attack.

A neutralization time for the target is determined each time a hit occurs. The determination of a hit and kill is dependent on the number of rounds fired within the burst.

An attack mission for a section is divided into two phases. Phase one of the attack consists of prior suppressive fire and all point fire executions by the section. Phase two consists of all suppressive fire after the point fire.

During each phase an element may be called on to fire a maximum of two weapons, either two suppressive fire weapons or a suppressive fire weapon and a point fire weapon.

During phase one of a direct fire attack, a helicopter may fire according to one of the following doctrines:

(1) multiple bursts from one suppressive fire weapon at one target,

(2) multiple bursts from two suppressive fire weapons at either one or two targets,

(3) single shot from a point-fire destructive weapon preceded by multiple bursts from a single suppressive fire weapon, both weapons fired at same target.

Phase two of the attack allows suppressive fire to be delivered after the delivery of point destructive fire.

During attack phase two, a helicopter may fire according to one of the following doctrines:

(1) multiple bursts from one suppressive fire weapon at one target, or

(2) multiple bursts from two suppressive fire weapons at either one or two targets.

If multiple weapons are fired, each may be assigned to a different target, or they may all fire at the same element. If there is no point fire there may be as many different targets as there are suppressive fire weapons assigned. If the vehicle is to fire a point fire weapon, any assigned prior suppressive fire will be directed at the same target. Suppressive fire following point fire may be directed at any target element including the point fire target if there was point fire by the vehicle.

The primary target of the attack is the target assigned to the point fire and to the after suppressive fire weapons, if this type of fire is to occur. The secondary target is the target for any prior suppressive fire or for the second suppressive fire weapon if no point fire is assigned.

Target assignments for an element may be changed between phases in the event that the target becomes a casuality or a new threat situation is perceived. It is also possible that a point fire weapon will not be fired at the end of phase one because the target element becomes a casualty during prior suppressive fire.

CHAPTER D.III

THE ASARS SUPPRESSION MODEL

Chapter III discusses the assumptions and techniques employed in the ASARS suppression model. Section A serves as a description of the determination of the suppression level. Sections B - E relate the impact of suppression on ASARS' intelligence, communications, movement, and firing submodels, respectively. Finally, Sections F and G briefly mention the measures of effectiveness used in the analysis of the suppression model output, and the sensitivity of the suppression model, respectively. Recently received notes describing a new ASARS suppression model appear as Appendix B to this report.

A. DETERMINATION OF SUPPRESSION LEVEL

When the current element has fired small arms at an enemy element, there will be some suppressive effects for elements within a certain input miss distance. These effects are modeled in terms of the level of suppression produced and by the duration of that level.

A suppression level L is defined by its effects upon the element's ability to perform three functions, i.e. the element's ability to move, fire and observe. When little suppression has been produced these functions are not greatly affected. For example, at the minimum level the element's aim error may increase only 5 percent, its detection time may increase only 10 percent, and its rate of movement may not change at all. At the other extreme, when the element is totally suppressed, i.e. at the input maximum allowable level, then it will not be able to perform any function whatever. How long each level lasts is determined by input, and is dependent upon the mode of the battle. As a result, these effects may be short-lived for an element in an assault relative to an individual in fire and movement.

To compute the level L produced in the current event, the model considers the number of rounds fired, the weapon type fired, and the average miss distance of the rounds by inputing a matrix of values for L, dependent upon these variables. Hence, the current model is deterministic. However, through this matrix approach, the model's sensitivity to suppression is easily determined and controlled.

Finally, if the element was already suffering suppressive effects at level L when it was again fired upon, then its new level must account for the previously produced effects. So, the model first computes a new level L_2 considering the suppression factors of the current firing; that is, L_2 is independent of L_1. Then, levels L_1 and L_2 are combined to yield the overall level L where L will be the maximum of L_1 and L_2. Subsequently, the element will be suppressed for the duration associated with level L.

B. IMPACT OF SUPPRESSION ON THE INTELLIGENCE SUBMODEL

The current element's target detections are updated at the beginning of its observation event in terms of its activities during its last event. One basic criterion for updating detections is its suppression level as follows:

(1) If the current element fired in its last event and was not totally suppressed for observation at the end of the event, certain detection levels are maintained if both terrain and vegetation LOS exist.

(2) If the current element fired in its last event but was totally suppressed for observation at the end of the event, detection levels are reduced.

(3) If the current element did not fire in its last event and was not totally suppressed for observation, the detection level is similarly reduced.

(4) If the current element did not fire in its last event and was totally suppressed for observation at the end of the event, only certain detection levels are reduced.

The procedure for determining the observation event time is as follows: If the current element is suppressed for observation for a portion of the maximum observation event time, it will observe for that portion of the event time at a reduced capability for observation; and if no detection is made during this portion of the event, it will observe for the remainder of the maximum event time with no degradation in observation. However, if a detection is made in the first portion of the event, the remaining event time is not utilized. Thus, the time to detect a target is adjusted to account for any reduced observation ability due to suppression by fire.

The possible combined information suppression situations (states) are:

(1) Suppressed only,

(2) Non suppressed or non casualty of any type, or

(3) Non casualty or a movement casualty or suppressed.

C. IMPACT OF SUPPRESSION ON THE COMMUNICATIONS SUBMODEL

As back up to voice communications, fire team, squad and platoon leaders can communicate by arm and hand signals provided the transmitting and receiving elements are not unduly suppressed and line of sight exists between/among communicating elements.

D. IMPACT OF SUPPRESSION ON THE MOVEMENT SUBMODEL

Training and motivational factors relating to movement are not simulated directly in the ASARS II Battle Model but do have a secondary influence. For example, the lowest level at which movement is totally suppressed is a stored variable. If the combatants are well trained and highly motivated, then, a large input value of this variable will ensure that movement is seldom suppressed.

E. IMPACT OF SUPPRESSION ON THE FIRING SUBMODEL

The firing submodel determines the suppressive effects of the current element's fire on a target. To describe these effects, the model relies both on input weapon characteristics and on situation dependent variables generated within other submodels. Each firer-target situation is specified by factors such as the suppression level of the firer.

The firing model also allows for the interruption of firing. One consequence of the interrupted firing activity is illustrated by the following potential situation: A prepares to fire at B but is interrupted; next, B fires and hits A; consequently, A suffers a high suppression level and misses B when he resumes firing. Had A not been interrupted while preparing to fire, he might have hit B and thus prevented himself from being hit. Hence, interrupted events eliminate the possible bias which could arise from ignoring the disadvantage of weapons requiring frequent reloading or a time-consuming aim procedure. If an element is interrupted while preparing to fire during the current event, then he will resume his activities from the point at which he was interrupted when he next becomes current. The total time required for the firing activity is the sum of the aim time, load time (when required), and the time utilized during the actual firing procedure.

a. Selection of Potential Suppression Targets

Only elements within a specified input miss distance can be suppressed by the fire. In order to eliminate elements from consideration, the total delivery error of the weapon must first be computed. In particular, the horizontal and vertical aim errors, respectively, are computed and corrected by factors which increase the horizontal and vertical aim errors as a result of varying degrees of suppression for the firer.

In addition, a weapon can only be effective within a given range. All elements beyond this range are immediately out of contention as potential suppression targets.

Finally, elements not within the hit sector above but within a sector of certain width oriented from the firer to the aim point are later examined for suppressive effects resulting from the fire.

b. Computation of Hits

The individual elements which were found to be in the current element's hit sector are examined individually for specific hit effects. If there are no hit sector targets, the model records the target-round miss distances and proceeds to examine suppression targets.

Once a round has hit a target, it will no longer be considered except for suppressive effects. That is, a round can hit at most one body part of one target. When all rounds have been considered, the suppressive effects of the fire on a given element are determined.

If the element has been hit, then he will be suppressed to the maximum degree allowed in the simulation. This is necessary since a hit element does not necessarily become a casualty nor are any casualty effects instantaneous. As a result, a wounded element must somehow become at least temporarily incapacitated, and this is accomplished by means of suppression.

If the element was not hit, then the suppressive effects are determined by considering the total number of rounds fired, the average miss distance, and the weapon fired. When all hit sector targets have been examined, the model proceeds to consider the suppression sector targets.

c. Hand Grenade Model

When the current element (C.E.) is firing a fragmentation round at a visible assigned target, the model determines whether or not a direct hit was scored. If a hit has been scored, the target is suppressed. If a direct hit did not occur, then all enemy elements within a certain radius of effects about the point of impact of the round with the ground plane will suffer wounding effects from the fragments.

To determine these effects, the height of the target's presented area, which is not covered with respect to the point of impact, is computed. If the target is not totally covered, then it has been hit and is consequently suppressed.

These wounded elements are suppressed to the maximum degree. Suppression effects are also computed for enemy elements beyond the effects radius but within a certain input distance.

Finally, if the target is a foxhole with an overhead cover, the suppressive effects produced by firers within the target's viewing sector are independent of the cover over the foxhole.

F. MEASURES OF EFFECTIVENESS USED IN THE ANALYSIS OF THE SUPPRESSION MODEL OUTPUT

The M.O.E. utilized to analyze the model output is the percent of total time that Blue (Red) elements are suppressed at any level with respect to observation, movement, and fire, individually, as a result of Red (Blue) fire. The term "at any level" means at a suppression level greater than 0.

G. SUPPRESSION MODEL SENSITIVITY

The model was found to be extremely sensitive to small numerical changes in suppression criteria and more so with respect to the duration of the suppressive effects than to the value of the suppression level.

CHAPTER D.IV

THE CARMONETTE SUPPRESSION/NEUTRALIZATION MODEL

Chapter IV discusses the assumptions and techniques utilized in the CARMONETTE Suppression/Neutralization model. Section A serves as a general description and summary of the suppression/neutralization model. Later sections discuss the model in more detail. Section B outlines the suppression activities represented in CARMONETTE with respect to the periodic assessment of neutralization, and to infantry, mechanized and artillery activities. Section C briefly mentions the impact of suppression on weapons characteristics. Section D classifies the various types of combat units in the model by fire response class. Section E briefly discusses the impact of suppression on movement. Section F lists the kinds of suppressive firing commands utilized in CARMONETTE. Finally, Section G serves as a glossary of CARMONETTE suppression-related terms.

A. GENERAL DESCRIPTION OF THE CARMONETTE SUPPRESSION MODEL

CARMONETTE provides for two levels of suppression, "pinned down" and "partially neutralized" (proceeding with caution, taking immediate evasive action, buttoned up). Dismounted infantry and open vehicles may be "pinned down." Dismounted infantry, open vehicles, light armor, heavy armor, and aircraft can be "partially neutralized" by either direct or indirect fire.

A "pinned down" unit does not fire, move, or conduct surveillance and retains only nearest grid square intelligence. A "partially neutralized" ground unit conducts surveillance and fires its weapons with reduced accuracy, moves at a lower speed, and requires twice as much time to aim its weapons. Aircraft (helicopters) drop to treetop level when fired upon unless they are guiding a missile to a target. If the helicopter is guiding a missile, it will drop to treetop level after the missile impacts.

In addition to many other factors, suppression is a function of the number and caliber of rounds impacting in an area over a designated time interval. In one study the designated time interval used was 90 seconds. When determining suppression, the actual number of such rounds is divided by the neutralizing effect of the ammunition before checking a suppression threshold table. Hence, neutralization is defined for each class of ammunition by giving it a number (weight) representing how much more neutralizing one round of that class is than one rifle round. The neutralization weights for each type weapon (or effect) per round fired are inputs to the model. The length and width of the impact areas for indirect fire weapons (artillery and mortars) are also inputs to CARMONETTE. The impact area for direct fire weapons is one grid square. When the sum of the indexes of all rounds passing a non attrited target exceeds certain prescribed levels, the respective types of suppressive activity (proceed with caution, seek cover, and total suppression) are imposed for the specified time interval. These suppression or neutralization thresholds which must be exceeded for a unit to be considered pinned down or partially suppressed due to direct or indirect fire are computed by the model based on the number of rounds per neutralization interval required to cause a unit to respond to the fire - also an input.

Other input data include target-priority lists. There are separate target-priority lists for the Red side and the Blue side. When a unit is given a suppressive-fire order it can search for targets not only in the target square, but also in nearby squares. This distance of search is measured in meters from the center of the target square. For example, a machine gun unit may be told to suppress a designated target square but also to fire at targets if found within 200 m of the square. This number, the suppressive-fire area, is selected for each side and included in the target-priority list.

B. CARMONETTE SUPPRESSION ACTIVITIES

The suppression activities represented in CARMONETTE are those related to the periodic assessment of neutralization and to infantry, mechanized and artillery activities.

1. Periodic Assessment of Neutralization

The number of rounds impacting in the vicinity of a unit during a neutralization interval is calculated. Rounds received some time ago will not be important to the unit as far as its neutralization is concerned. Thus, during every neutralization period the rounds fired at the unit several intervals ago are erased from its memory, and the unit will only respond to the rounds fired at it in the more recent intervals. Furthermore, a unit that has moved from one grid square to another will not be concerned about the rounds that impacted near it in its previous location, and thus at the boundary-crossing event those rounds that landed in the previous grid square are erased from its memory.

2. Infantry Activities

In the simulation of employment of weapons, infantry units that are armed with machineguns can be given a command for final protective fires. In this event the path of the projectiles is traced to determine whether any enemy units are passing through the cone of fire. If enemy infantry units are passing through the cone of fire they may be pinned down or partially neutralized.

3. Mechanized Activities

Mechanized units react to hostile fire in three distinct ways. Heavily armored units cannot be pinned down and only a state that may be described as "buttoned up" is provided. This state can be caused to occur when a sufficient volume of either direct or indirect fire falls in the vicinity of such a unit. Lightly armored units such as APCs and scout cars may also be caused to button up under either direct or indirect fire and, in addition, the lightly armored units that are troop carriers may dismount their troops if a sufficiently high volume of direct fire is received. Unarmored vehicles and jeeps act in a way that is consistent with their lack of armor and can be pinned down or will attempt to evade the fire in the case of lesser amounts of indirect or direct fire.

4. Artillery Activities

The two types of fire missions that artillery and mortar units can be given are scheduled fires and on-call fires. During scheduled fires a particular grid coordinate is commanded to be fired on for a period of time. The on-call fire mission causes the artillery to await calls from the units that are given the capability of calling artillery. In this case the calling unit provides the coordinates and the amount of fire to be delivered. All units that are in the area under artillery attack have the rounds included when the neutralization calculation is made.

C. THE IMPACT OF SUPPRESSION ON WEAPONS CHARACTERISTICS

When the neutralization weight of each round fired is indicated, one tank round is considered more devastating or demoralizing than one rifle round. Thus, this neutralization weight is an integral multiple of those for weapons that have the lowest neutralization weight of one. The accuracy of all weapons is given in standard deviations as a function of the degree of firer neutralization.

D. CLASSIFICATION OF UNITS BY FIRE-RESPONSE CLASS

Fire response class is used to describe a unit's response to hostile fire. Thresholds are used to indicate the response of each of these classes of units to three kinds of fire: severe, a combination of direct and indirect fire; moderate direct fire only; and moderate indirect fire only. Dismounted infantry or units of unarmored vehicles respond by being pinned down or slowed down or by taking evasive action.

A pinned down unit does not move. It may have a reduced ability to acquire or retain target information and may fire infrequently. It makes maximum use of the available cover. This is not done for other classes because it is presumed that vehicle exposure cannot be reduced.

A unit under moderate direct fire will proceed cautiously if it is acting on a move command with its ability to acquire or retain target information and to fire reduced, but not so much as if it were pinned down.

A unit under moderate indirect fire responds by moving as rapidly as possible to the next square if it is acting on a move command.

The neutralization interval is the period of time over which incoming rounds will be considered to affect the behavior of a unit. The response of a unit to hostile fire will be determined by comparing the thresholds for response with the actual number of rounds (adjusted by the neutralization weighting factors) fired during the neutralization interval into the square the unit occupies.

E. THE IMPACT OF SUPPRESSION ON MOVEMENT

In those situations when a unit is out of ammunition or being suppressed by indirect fire, it will travel as fast as physically possible. When a ground unit is receiving hostile direct suppressive fire, it will automatically be ordered to travel at the slowest rate for its mobility class.

F. TYPES OF SUPPRESSIVE FIRING COMMANDS

The kinds of fire that may be ordered are:

(1) Suppressive fire at a certain grid square, or

(2) Suppressive fire at a certain grid square while moving.

The movement doctrines previously discussed are used for those units that do not have the phrase "while moving" in their firing command. An order for suppressive fire always includes the condition that there are no pinpointed targets available. If no pinpointed targets are available the unit will fire suppressively into the target square.

G. CARMONETTE SUPPRESSION GLOSSARY

Evasive action. The response to hostile direct fire or moderate indirect fire by ground units who receive enough rounds per neutralization period.

Neutralization interval. A period of time over which the incoming rounds will be considered to affect the behavior of a unit and to be applicable to both sides and all fire-response classes.

Neutralization-interval rounds received. The evaluation of the number of incoming rounds in a neutralization interval considered to affect the behavior of a unit.

Neutralization weighting factor. An arbitrary weighting of each round based on the demoralizing effect of that round, e.g., if a rifle round is assigned a weight of 1, then a tank round may be assigned a larger weight.

Rounds received per neutralization period. An enumeration of the number of incoming rounds of ammunition at a unit during a neutralization interval done in order to consider the behavior (reaction) of the unit.

Pinned down. A description of a unit that is under severe fire and does not move, resulting in a reduction of its presented area, a very low target-acquisition rate, a short retention of target information, and a low and infrequent rate of fire from the unit.

Suppressive fire area.

The selected integral multiples of grid squares in each direction from the designated target grid square for delivery of artillery unit fire and entered on the target-priority lists for each side.

CHAPTER D.V

THE AIRCAV5-BONDER/IUA-BLDM SUPPRESSION MODELS

Chapter V discusses the assumptions and techniques utilized in the AIRCAV5-Bonder/IUA-BLDM Suppression Models. Sections A and B describe the AIRCAV5-Bonder/IUA direct-fire and indirect-fire suppression models, respectively. Section C briefly discusses the BLDM suppression model.

A. DIRECT-FIRE SUPPRESSION MODEL

The AIRCAV5-Bonder/IUA Model treats direct-fire suppression using the modeling assumptions of the ATMIX version of the IUA simulation. The parameter values used in the program for probabilities of suppression and times suppressed were derived from the ATMIX data files. The program logic assumes that a Blue weapon is subject to suppression by any round fired at a target associated with the same route as the given weapon, except that attack helicopters (AH's) are subject to suppression only by rounds fired at AH's, and ground weapons are subject to suppression only by rounds fired at ground weapons. A Red weapon is subject to suppression only by rounds fired at members of its own weapon type. The input suppression probabilities are functions of round type and target weapon type. If a weapon is suppressed, it does not fire for an input period of time which is a function only of the weapon type.

Red rounds are divided into three suppression classes. The Red rounds in each suppression class fired at each axis during each DT are accumulated for rounds fired at aerial units and for rounds fired at ground targets. The average number of rounds per route in each class is computed as the total number for the axis times the reciprocal of the number of routes on the axis. This number is multiplied by a factor representing the suppression probability. The number of surviving weapons in each group (Blue or Red) that is suppressed during the current time increment is computed and stored. For a Blue group, this number is computed at the end of the time step. For a Red group, this number is updated each time the group is fired at.

Direct fire suppression probabilities for Red rounds against Blue ground weapons are pre-set in the program logic, but the user can specify suppression probabilities of rounds against AH targets. The suppression probabilities for Blue rounds fired by ground weapons are functions of the round type alone, but for rounds fired by AH's the user can specify the suppression probability as a function of weapon type, target type, and cover. The number of time steps that non-ADW ground weapons are in the suppressed state is fixed in the program logic. For AH and ADW types, however, the number of time steps weapons spend in the suppressed state can be specified by the user. The time of suppression parameter is based only on the type of round and type of target.

At the beginning of each time increment, the total number of suppressed weapons of each group is updated and summed over the number of 10 second time increments (up to some maximum number) that that group can be suppressed. The number of weapons in a given group which is capable of firing is the number of unsuppressed weapons, but since suppressed wapons are not assumed to take cover, they may be attrited. For each group attrition of suppressed weapons in the current DT is computed, stored, and printed out together with the number of previously suppressed survivors in a particular group.

Both AIRCAV5 and the program from which AIRCAV5 was developed (ATMIX5) compute acquisitions of Blues on the basis of unsuppressed targets, but then allow both suppressed and unsuppressed Blue weapons to be attrited. An exception in AIRCAV5 was made in the case of AH units. Since suppressed weapons are not assumed to remask any earlier than they would if not under fire, both suppressed and unsuppressed AH's are subject to acquisition while they are in their firing positions. However, a suppressed weapon is still able to acquire targets for future engagement.

1. Required Input Data

Three types of input data are required by AIRCAV5:

(1) The number of time increments a suppressed weapon of a certain type remains in the suppressed state given it is suppressed (legal values are 0 to 4 increments),

(2) The suppression probabilities for rounds fired by AH or other type weapons, and indexed on weapon type, cover status of target, and target type, and

(3) The probabilities of suppressing an AH or any other weapon type with a round of a certain suppression class.

The three classes of rounds with respect to suppression are large caliber APDS rounds, large caliber explosive rounds, and small caliber rapid-fire rounds.

B. INDIRECT-FIRE SUPPRESSION MODEL

Indirect fire from artillery is played for both sides in the AIRCAV models. Input data includes the suppression probability (due to artillery) or fraction of weapons of each type which will be suppressed by artillery fire, given that the weapons are within the artillery concentration.[1]

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[1] Given that a group of certain type weapons is under artillery fire, the group can utilize only this fraction of its attrition rate.

The logic assumes that 80 percent of Red defenders are covered by Blue preparatory fire concentrations and 60 percent of Blue defenders are covered by Red preparatory fire concentrations.

The expected number of rounds to kill is computed by incorporating an artillery suppression factor for suppressive effects of artillery on the firing group.

1. The Artillery Suppression Index

The target weapon group exposure and firing weapon group artillery suppression index runs from 0 to 5. The cover codes have the following meanings:

0 - target is fully covered,

1 - target is in hull defilade,

2 - target is fully exposed,

3 - same as 0, but observer is under artillery fire,

4 - same as 1, but observer is under artillery fire, and

5 - same as 2, but observer is under artillery fire.

C. THE BLDM SUPPRESSION MODEL

The BLDM suppression model is the same as that of AIRCAV5 with the additional capability of representing the situation in which non-lethal hits cause suppression. The suppressed state may last varying lengths of time with certain probabilities.

CHAPTER D.VI

THE CURRENT AIDM SUPPRESSION MODEL

Chapter VI discusses the assumptions for techniques utilized in the current AIDM suppression model. Section A briefly summarizes the assumptions of the model. Section B describes the required inputs to the main suppression calculation. Finally, Section C discusses the main suppression calculation currently performed within the AIDM model.

A. SUMMARY OF ASSUMPTIONS

Within the AIDM, only that fraction of the survivors in a given firer group which is not suppressed may cause attritions or be the subject of pinpoint acquisitions. However, both suppressed and unsuppressed fractions of a given group of survivors may be acquired by non-pinpoint means and attritted.

B. REQUIRED INPUTS TO THE SUPPRESSION CALCULATION

To calculate the total fraction of a given group of survivors that are currently suppressed, the model utilizes two basic factors:

(a) The expected fraction of casualties, f. The value of f for a given group is calculated within the model as the ratio of the total number of casualties of all types (i.e., mobility only kills plus firepower only kills plus total kills) to the number of survivors at the end of the considered time interval.

(b) Human factors coefficient, ρ. The value of this coefficient represents the aggregate of effects of human factors and other intangibles relating to morale, leadership, tactical situation, fear:danger ratio, and so forth. Use of certain values implies conditions resulting in higher suppression levels than the threat would typically elicit: inexperienced troops, for example. If conditions are such that lower than typical suppression levels will occur, as might be the case in a crucial defense by veteran troops, then other values of ρ are appropriate. Values of ρ are determined from input.

C. THE MAIN SUPPRESSION CALCULATION

Given the model inputs, f and ρ, s, the fraction of a given weapons group suppressed during the considered time interval, is given by the equation

$$S = \exp|\beta|/(\exp|\beta| + 1),$$

where

$$|\beta| \equiv \text{Absolute Value of } \beta,$$

and

$$\beta = 10 \exp\left[\rho(1-f)^2/f\right] - 5.$$

The probability (μ) that a group once suppressed remains suppressed at least one more time interval is also calculated as follows:

$\mu = \exp(-DT/\overline{T})$ where DT is the length of the time interval, and $\overline{T}$ is the mean duration of the suppressed state, given as input.

The fraction currently suppressed (S'_T) is updated each time interval as the sum of the fraction becoming suppressed during the time interval under consideration (S) plus those fractions still suppressed and which became suppressed during previous time intervals (S_T) according to the relation:

$$S'_T = S + (1-S)S_T\mu .$$

S'_T is then the factor which multiplies the current number of survivors within a given weapon group to obtain the fraction of that weapon group which are currently firers.

APPENDIX D.A

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APPENDIX D.B

NOTES DESCRIBING NEW ASARS SUPPRESSION MODEL

Developed by Captain John Riddell - USAIS

A. OLD MODEL IN ASARS

(1) Look-up table of coefficients developed for only 6 weapons, therefore limited capability to address different weapons.

(2) Large "look-up" matrix. Used up storage.

(3) No capability for indirect fire weapons. Only direct fire.

(4) Can't handle simultaneous events.

(5) States - or factors - deterministic (no variability).

B. OTHER SUPPRESSION MODELS

(1) Expected value models. Not treated stochastically.

(2) States are too restrictive.

C. CRITICAL ASSUMPTIONS OF ASARS SUPPRESSION MODEL

(1) Suppression is a reaction to perceived danger. The model plays reactive suppression.

(2) Perception of danger is a constrained ($0 \leq S \leq 6$) random function of real danger. A measure of real danger is probability of kill (P_K). Both of these assumptions are based on the Litton study.

D. STEPPING THROUGH THE MODEL FOR AN ELEMENT

(1) Time t_1: Event = $(t_1 - t_o)$

(a) The previous state of suppression (S_o) is equal to 0. $S_o = 0$.

(b) The index of probability of kill ($P_{K_{i_o}}$) for the event ($t_1 - t_o$) is equal to 0. $P_{K_{i_o}} = 0$

(c) The model searches for danger (i.e., rounds fired at the element). Computes the probability of kill (P_{K_1}) using the AMSAA routine "Individual Soldier Model" by Dr. H. Fallin.

$$P_{K_1} = (P_H) \times (P_{K/H})$$

(d) A new or current index is computed ($P_{K_{i_1}}$).

$$P_{K_{i_1}} = 1 - (1 - P_{K_{i_o}})(1 - P_{K_1}).$$

EX: Since: $P_{K_{i_o}} = 0$

Then: $P_{K_{i_1}} = 1 - (1-0)(1-P_{K_1})$

$= 1 - 1 + P_{K_1}$

$P_{K_{i_1}} = P_{K_1}$

(e) The model again searches for danger. It computes the probability of kill (P_{K_2})

$$P_{K_2} = (P_H) \times (P_{K/H})$$

Another current index is computed ($P_{K_{i_2}}$)

$$P_{K_{i_2}} = 1 - (1 - P_{K_{i_1}})(1 - P_{K_2})$$

(f) The model again searches for danger: It computes the probability of kill (P_{K_3}).

$$P_{K_3} = (P_H) \times (P_{K/H})$$

Still another current index is computed ($P_{K_{i_3}}$)

$$P_{K_{i_3}} = 1-(1-P_{K_{i_2}})(1-P_{K_3})$$

(g) And so it goes until the end of the event (t_1-t_o). The last updated current index of probability of kill of the event is denoted as $(P_{K(t_1-t_o)})$.

(h) The critical assumptions (C) imply that the state of suppression (S) is a function of perceived danger and that perception of danger is a constrained random function of P_K. In this case $P_K \equiv (P_{K(t_1-t_o)})$. Therefore, we can say that the state of suppression for the event (t_1-t_o) is:

$$S_{(t_1-t_o)} = g[P_{K(t_1-t_o)}]$$

(i) In order to account for the "randomness" of suppression, the above equation is performed in two steps.

<u>Step 1:</u> The value $(P_{K(t_1-t_o)})$ uniquely determines a binomial parameter $\hat{p}$. This determination is made through the following function:

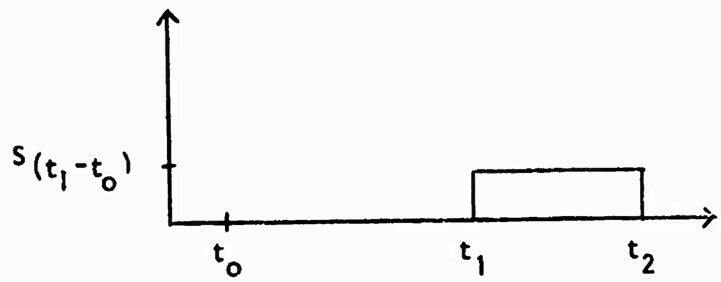
$$\hat{p} = a + b\ln (P_{K(t_1-t_o)})$$

<u>Step 2:</u> The value $\hat{p}$ then defines a binomial $B(\hat{p}, n=6)$. This binomial then is used to generate a state of suppression $(S_{(t_1-t_o)})$. The state is a random

variable. Monte Carlo methods are used to sample from the binomial in order to obtain $(S(t_1-t_o))$. This is represented as

$$B(\hat{p}, n=6) \rightarrow (S_{(t_1-t_o)})$$

(j) A plot of suppression versus time is:



(2) Time t_2: Event = (t_2-t_1)

(a) The previous state of suppression (S_o) is equal to $(S_{(t_1-t_o)})$.

(b) The index of probability of kill $(P_{K_{I_o}})$ for the event (t_2-t_1) is reset to 0.

$$P_{K_{I_o}} = 0$$

(c) Steps (1c) through (1g) are repeated for the event (t_2-t_1) to obtain a current index of probability of kill of the event denoted as $(P_{K(t_2-t_1)})$.

(d) Before we determine a state of suppression directly using $(P_{K(t_2-t_1)})$ we must maintain some form of continuity with the previous state of suppression which is $S_{(t_1-t_o)}$.

(e) Assume the state of suppression of the previous event decrease by a multiple of 1/2 during the event (t_2-t_1). The state of suppression for the previous event is then 1/2 $S_{(t_1-t_o)}$.

(f) This value $[1/2\ S_{(t_1-t_o)}]$ randomly defines a binomial estimator $\hat{p}'$. The resultant binomial is $B(\hat{p}', n=6)$.

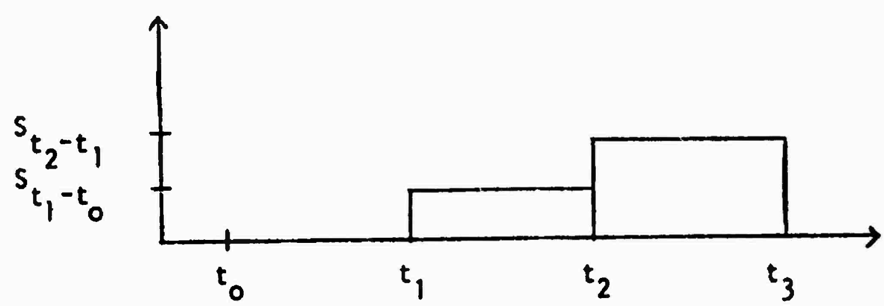
(g) The value $\hat{p}'$ uniquely defines a probability of kill of the previous event which has "decayed" by 1/2. This probability of kill is denoted as $(P'_{K(t_1-t_o)})$.

(h) The results of step (2d) and (2g) are combined to form a revised probability of kill for the event (t_2-t_1) denoted as $(P^*_{K(t_2-t_1)})$.

$$P^*_{K(t_2-t_1)} = (1-(1-P_{K(t_2-t_1)})(1-P'_{K(t_1-t_o)})$$

(i) Follow steps (1h) through (1i) to determine the suppression state for the event (t_2-t_1). This is called $(S_{(t_2-t_1)})$.

(j) The plot of suppression versus time now becomes:



(3) For subsequent times for the battle, follow steps (2a) through (2j) making the appropriate changes in subscripts.

E. DEGRADATION OF PERFORMANCE BY STATE OF SUPPRESSION

The state of suppression, for each time event (t_i-t_{i-1}), determines which function (observe, move, fire) will be degraded and the interval ranking scale indicates how much that performance function will be degraded.

If Observation:

(a) Calculate the unsuppressed probability of detection.

(b) Reduce the probability of detection by a multiplying factor of (1 - value of the interval scale).

If Movement

(a) Reduce the average movement rate of the suppressed element by a multiplying factor of (1-value of the interval scale).

If Firing:

(a) Increase aiming error by adding an appropriate component of suppression error to the basic aiming error.

APPENDIX E

SUPPRESSION BY INDIRECT FIRE SYSTEMS IN THREE MODELS

(U) Suppression by indirect fire support systems is represented in three models. The Rand FAST-VAL is a battle simulation in which suppression is one of the secondary effects of firepower. A second model produced at Naval Weapons Center, models the production of suppression by explosive weapons and explicity combines suppression and incapacitation into ineffectiveness as a function of time. A third model produced at Mellonic Division, Litton Systems Inc., is an explicit function for suppression produced by indirect firepower. These three models are briefly described in the sections that follow. An evaluation of the models is not intended by this summary. References for each model are given at the end of each section for convenience rather than grouping them at the end of the appendix.

E.1 FAST-VAL Model

Introduction

(U) The Forward Air Strike Evaluation Model or FAST-VAL is a computer model of ground combat which includes the effects of supporting arms. The purpose of FAST-VAL is to measure the effect of air delivered weapons on the outcome of ground engagements of platoon to regimental size. FAST-VAL was developed at the Rand Corporation, under contract with the Air Force, by Jack Lind, K. Harris and Col. S. G. Spring, U.S.A. (Ret.). The project began in 1964 and ended with the publication of some 18 FAST-VAL reports in 1971. This research was intended to assist the Air Force in the selection of tactics, weapons and vehicles for use in close air support.

Model Overview

In the FAST-VAL model of a ground engagement an attacker advances toward a defender's position. As the attacker advances both sides can exchange small arms fire. The rates of firing for each side and rate of advance for the attacker are input step functions of attacker-defender separation and are degraded by casualties. Air, artillery and mortar delivered weapons can be employed by both sides according to an input schedule. During the engagement the combatants on each side have two possible postures or levels of protection available. Suppression is modeled by having personnel assume their lower posture if the casualty rate in their vicinity exceeds an input value. The casualties produced by small and supporting arms are calculated at the end of each simulation cycle. The simulation is halted when either sides cumulative casualties exceed their particular input defeat criteria.

Deployment and Maneuver

The initial deployment of both the defending and attacking units is defined using two independent grid systems of 100 ft. by 100 ft. squares. The input is then in the form of the number and type of personnel and equipments in each grid square. Deployment is handled in this manner so that aimpoints for supporting fires can be designated and their effects calculated. Input to the simulation is the separation of the opposing grid systems. The program calculates the mean separation between each unit and the forward edge of its respective grid. The sum of these 3 distances is then the initial separation between the attacker and the defender. Maneuver is then modeled in a one dimensional manner. The opposing units can now be thought of as two points separated by an initial distance. The attacking "point" simply moves directly toward the defending "point". As the attacker advances toward the defender he moves through different zones defined by distance to the defender. For each of these zones there is defined a maximum preplanned rate of small arms fire for the attacker and a maximum rate for the defender. For the attacker there is also defined a maximum preplanned rate of advance for each zone.

Break and Stop Criteria

The loser of a FAST-VAL engagement is the side which breaks first. The input break criteria used by Rand for the attacker and defender are respectively 30% and 50% cumulative casualties. However, the attacker can be stopped before crossing his final coordination line if his rate of advance is degraded by casualties to zero. The input function used by Rand degrades the advance to zero when casualties reach 23%. That the attacker cannot be stopped but must be broken once past his final coordination line simply reflects the finality of the last stage of an infantry assault.

Supporting Fire

Before or during the attack both units may be subjected to mortar, artillery and air delivered weapons. The type, timing, targeting and mode of delivery of this ordnance is closely controlled by the user.

Degradations

It is a basic FAST-VAL assumption that the maximum preplanned rates of advance and fire are degraded with cumulative casualties. This is accomplished by user defined functions. Based on the advice of their military consultants Rand has suggested a set of these functions, Ref. 16.

Posture and Suppression

The level of protection available to combatants is modeled by assigning two possible postures for the defender and two for the attacker. For instance, the defender might be either standing in a foxhole (his upper posture) or crouched in a foxhole (his lower posture). The attacker might be either upright or prone in average terrain. Posture is controlled by an input time table. However, if the casualty rate resulting from incoming supporting fires during a simulation cycle exceeds a user defined maximum (.01/minute/man was used by Rand) in a grid square the personnel in that square will assume their lower posture during the next simulation cycle. Suppression takes precedence to the input time table in determining posture. This model of suppression is independent of the effects of small arms fire.

Weapon Effect

The central theme of FAST-VAL is the effects of weapons on combat. Both small arms, organic to the infantry units, and supporting arms are employed in the model. The effects of both are considered but they are treated differently. The effects of small arms are simply modeled. Supporting arms are more elaborately modeled in keeping with the primary purpose of FAST-VAL. The effects of weapons are primary and secondary. Primary effects are destruction of targets and production of casualties. Secondary effects are degradation of rate of fire and degradation of rate of movement. Secondary effects are caused by all weapons through the production of casualties and by supporting weapons by the inducement of suppression. These degradations are applied to preplanned rates of fire and rates of movement.

Small Arms Effects

Input to the model is an array of expected casualties per burst for various zones (ranges) and target postures for the small arms of the attacker and a similar array for the defender. The method used by Rand to calculate these expected casualties is discussed in Ref. 8. It considers target acquisition probabilities, weapon delivery errors and the nature of the target. The total volume of small arms fire generated by one unit during a simulation cycle is assumed to be spread over the entire opposing unit.

The casualties produced by small arms are added to the casualties produced by supporting arms in each computational cycle. The casualties suffered by the unit then determine the fraction of the remaining force that is effective in the next period through input functions.

Supporting Arms Effects

The user preplans the mortar, artillery and air delivered ordnance by inputting a delivery schedule. This schedule specified the timing, mode of delivery, munition type and the grid square containing the aim point. By delivery mode is meant the combination of such factors as pattern definition, fuzing, air and ballistic errors, etc. For each combination of weapon type, delivery mode and target posture there must be input a particular Damage Function. This is an array which contains the expected damage not only in the grid square containing the aimpoint but in the surrounding grid squares. The target grid can be thought of as being overlaid with these damage functions; the probability in a particular grid square of surviving all incoming ordnance during a simulation cycle is just the product of the probabilities of surviving each incoming weapon during that interval.

The supporting arms effects degrade the rates of fire and rates of movement of the target force through the production of casualties and destruction of vehicles. On top of this, the suppressive effect of supporting fire independently degrades the performance. Thus for each cycle the supporting arms fire can produce both casualties and suppressed personnel in each cell of the battle. Suppression is produced if the casualty rate exceeds a threshold value input by the user. Associated with suppression for the infantry and the artillery are fractional capabilities for rate of fire and movement. These are fixed input values and apply to personnel of an infantry unit (platoon or company) or to a battery of artillery.

For example, consider an attacking company in a temperate zone in open terrain, 1000 yds. from its objective and not yet at the final coordination line. The company has sustained 20 percent cumulative casualties, and 40 percent of its riflemen and machine-gun crews are suppressed (i.e., if the upper posture, 40 percent of the men would have a casualty rate greater than 1 per 100 men per min., during the specified time interval). Then the company's rate of movement Figure E-1 (from Reference 16) is 60 X 0.51 X 0.51 = 15.6 yd/min. where the initial movement rate of 60 yd/min. is taken from Table 2; 0.51 is the percent reduction in movement rate due to casualties at 20 percent casualties, from Fig. E.1; and 0.51 is the percent reduction in movement rate due to suppression, also from Fig. E.1 (40 percent X 0.5 = 20 percent).

Figure E.1 is an example of the input functions used to describe the degradation of performance as a result of losses in the FAST-VAL model.

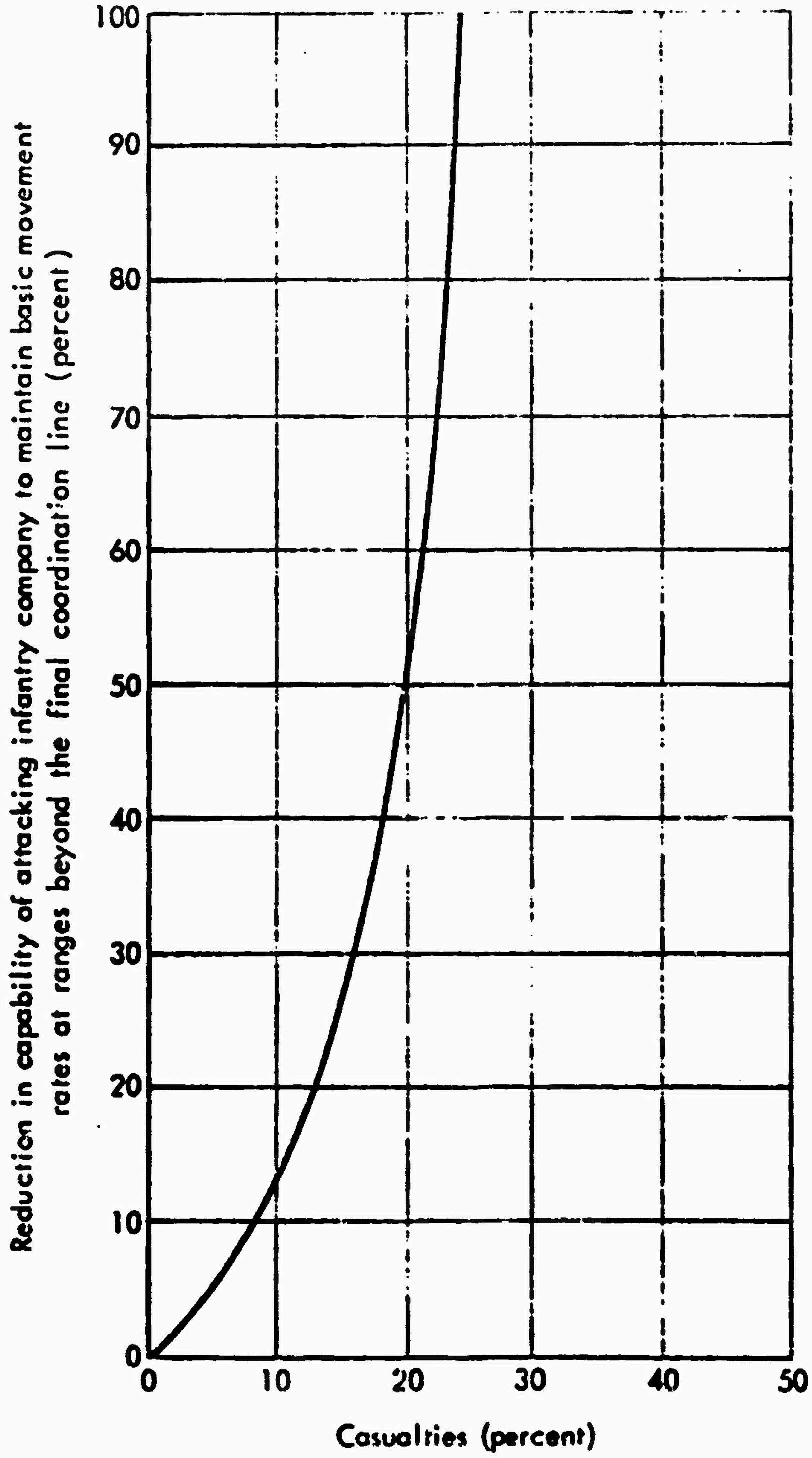


Fig. E.1—Relationship between casualties and the movement rate of an attacking infantry company

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E.2 Naval Weapons Center Model

Introduction

(U) The objective of the models described in this section was to provide a means for comparing the suppressive effects of various weapons explicity rather than aggregating those effects with others in the outcome of a combat simulation. The model development was part of a larger combat suppression study whose objective was to evaluate and develop design criteria for air delivered weapons used in suppression roles. Most of the larger study effort has been directed toward evaluating the capabilities of the Marine attack helicopters, because the fire support role is almost entirely one of delivering suppressive fire.

(U) To evaluate a fire support weapon's suppressive capabilities, a mission model was developed that computes and records the suppressive effects throughout the mission time. In the model, the measure of effectiveness is the average fraction of the total mission time that the target is ineffective, where ineffectiveness is produced by either suppression or incapacitation of the personnel target.

Suppressed Target

(U) Suppressive effects are recognized by the ineffectiveness or nonperformance of the enemy personnel targets. The following combat functions for infantrymen are assumed:

1. Mobility
2. Observation
3. Firing
4. Communication

Attacking infantrymen need to perform all four functions; defenders perform all but the mobility function. A suppressed target would be unable to perform all or part of the required combat functions. In the modeling approach, the key function of the attacking infantryman is assumed to be mobility, and he can perform this function only if he is upright and can run. To perform effectively, the defending infantryman in the model is required to be able to observe and fire. To do this he must be able to look over the edge of his foxhole. He is considered suppressed when weapon effects cause him to crouch below the lip. The personnel target reduces his risk by increasing his cover. He does this whenever the danger measured or estimated over a short time interval exceeds some threshold. For modeling purposes, the time intervals for measuring the danger will be assumed to be equal to the minimum combat mission performance times.

Modeling Problem

(U) The suppression modeling problem has two major parts: The first is to predict the effects of weapon fire delivered in a short period of time. The second is to compute the expected effectiveness of particular weapons and tactics (including firing doctrine) over a mission. Each is modeled as a separate problem.

(U) The model for the first part of the suppression problem is called the weapon suppression model. It has to provide the probability of suppression and the expected recovery time for an (initially) unsuppressed target from the effects of a given number of weapons in a single time period. The model also must predict the effect of weapon fire on an already suppressed target.

(U) The second model, called the mission effectiveness model, uses the results of the weapon suppression model as an input. It computes the suppressive performance and mission effectiveness of a weapon system over a mission time. To do this it must be able to model transitions to and from suppressed states, because of the transient nature of suppression.

Target States

(U) The personnel target can be in one of the following three basic conditions: incapacitated, suppressed, or unsuppressed. Three different suppressed states have been assumed:

S_1 - lowest suppressed state, one Δt required for recovery

S_2 - second highest suppressed state, two Δts required for recovery

S_3 - highest suppressed state, three Δts required for recovery.

Three states are considered the smallest number that can be used to adequately represent the varied suppressive reactions.

(U) Altogether there are six mutually exclusive target states: one for incapacitation, three suppressed states, and two unsuppressed states. For modeling the following number code is used:

Code	State
0	U_1
1	U_2
2	S_1
3	S_2
4	S_3
5	K

An increase in the number of a target's state means (except for states U_1 and U_2) that his potential combat performance capability is lower because more time is required for recovery. The recovery time is assumed to be a discrete variable with three possible values. The values are multiples of a basic time period. The lowest suppression state has a recovery time of one period, the second a recovery time of two periods, and the third a recovery time of three periods.

(U) The states U_1 and U_2 are unsuppressed states that differ in the susceptibility to suppression. A target recovering from state S_1 passes through U_2 for one period during which his thresholds are raised one level. Thus he passes from U_2 to S_2 for the minimum suppression threshold.

Weapon Suppression Model (P_s Program)

(U) The measure of risk experienced by a target in a given period is given by the expected kill probability (P_k) of the weapons acting in that period. Suppression is assumed to occur in a given simulation when P_k exceeds a suppression threshold (P_K^T). The suppressive results or effects are measured by a probability of suppression (P_{s4}). To generate average or probabilistic effects, numerous firings are simulated.

(U) A different suppression threshold is defined for each of three suppressed states, S_i. The values of the thresholds for high suppressed states are higher.

(U) In the modeling, suppression is represented by changes in target cover. In the computation of P_k, the targets in the suppressed and unsuppressed states are represented by different amounts of exposed area, called cover functions because the exposed area is usually given as a function of several target weapon interaction variables (for example, range from target to impact and burst height).

(U) The P_s program is a Monte Carlo simulation that generates weapon impacts and computes the resulting incapacitation and suppressive effects. A Monte Carlo modeling approach is used because in the suppressive behavior hypothesized the personnel target reacts to actual weapon impacts and not to the probability of impacts at certain distances. To model the behavior, weapon impacts around the target are generated by taking samples from a distribution. The expected lethal effects of these weapon impacts are then computed. The suppression transition criteria are applied to the expected P_k to determine what and how much suppression is achieved. The simulation is then repeated a sufficient number of times so that stable average values are obtained. The results of the suppression model are inputs for the mission effectiveness model as well as providing some insight into the capability of the weapons directly.

Mission Effectiveness Model

(U) The fire support mission is modeled with the following characteristics:

1. The mission occurs in a series of time steps.
2. The target can be in one of several mutually exclusive states.

3. The process of fire support suppression involves transitions from one state to another.

A Markov chain model is used to capture the above features in a mathematical form. The major element of this model as used here is the development of a one-step transition model that defines the conditional transition probabilities between the different states.

(U) The values for the transition probabilities are determined by the weapon effects that occur within a given time. The weapon effects are given by the weapon suppression model.

(U) At any time the target state can be represented by a probability vector with six elements; that is

$$P(t) = \{P_0^t, P_1^t, P_2^t, P_3^t, P_4^t, P_5^t\}$$

where each of the P_i^ts is the probability that the target is in the ith state at the end of the t^{th} time segment. That is, $P_i^t = P(X_t = i)$. Initially the target will probably be in state 0, and the state vector is 1, 0, 0, 0, 0, 0. In the mission effectiveness model the targets state is assessed in each time period over the duration of the mission.

(U) The target state in a particular time period is defined by the complete set of possible transition probabilities. The transition probabilities are the conditional probabilities of the target going to a particular state after having been in a given state at the start. Since there are six target states, there are 36 possible transition probabilities. These can be represented by a 6 X 6 matrix of conditional probabilities (the Markov chain one-step transition matrix for the suppression process).

(U) To determine the target state, transition in the matrix must be made. Transitions rules for the Markov chain matrix are established. The rules can be summarized as follows:

a. There are 16 disallowed transitions. (For example a target in a suppressed state may transition upward only one state).

b. There are seven transitions from an unsuppressed state to a suppressed state (including K). These transition probabilities are developed from the weapon suppression model output. For these transitions the risk thresholds must be exceeded.

c. There are nine transitions from suppressed state to suppressed state, likewise dependent on the weapon suppression model.

d. There is one absorbed state. K remains K.

e. There is one allowable transition from a suppressed state to an unsuppressed state.

f. There are two transitions for unsuppressed states remaining unsuppressed. These rules are summarized in the following matrix in Figure E.2:

TO STATE

P = FROM STATE

	(U_1)	(U_2)	(S_1)	(S_2)	(S_3)	(K)
(U_1)	$1 - P_s^*$	0	$P_{s_1}^* (1 - P(K_1/S_1^*))$	$P_{s_2}^* (1 - P(K_2/S_2^*))$	$P_{s_3}^* (1 - P(K_3/S_3^*))$	$\bar{P}_k$
(U_2)	$1 - P_s^*$	0	0	$P_{s_1}^* (1 - P(K_1/S_1^*))$	(a)	$\bar{P}_k$
(S_1)	0	$1 - P_s^*$	0	$P_{s_1}^* (1 - \frac{\bar{P}_k'}{P_k} P(K_1/S_1^*))$	(b)	$\bar{P}_k'$
(S_2)	0	0	$\cdot - P_s^*$	0	$P_s^* - \bar{P}_k'$	$\bar{P}_k'$
(S_3)	0	0	0	$1 - P_s^*$	$P_s^* - \bar{P}_k'$	$\bar{P}_k'$
(K)	0	0	0	0	0	1

$$(a) = P_{s_2}^* (1 - P(K_2/S_2^*)) + P_{s_3}^* (1 - P(K_3/S_3^*))$$

$$(b) - P_{s_2}^* (1 - \frac{\bar{P}_k'}{\bar{P}_k} \cdot P(K_2/S_2^*)) + P_{s_3}^* (1 - \frac{P_k'}{P_k} \cdot P(K_3/S_3^*))$$

. Transition Matrix.

Fig E.2

Mission Effectiveness

(U) All the ingredients for computing mission effectiveness have been presented; the only remaining step is to incorporate them into an expression for computing the mission measure of effectiveness (MOE).

(U) The mission MOE (the fraction of the mission time that the target is ineffective from either suppression or incapacitation effects) is designated F_I. To compute F_I the target state in each period must be known. The target state for any period, t, is given by the target state probability vector P(t). This vector is obtained by multiplying the previous state vector times the transition matrix for the present period; that is,

$$P(t) = P(t-1) \cdot P(t)$$

To compute all the state vectors, the initial state vector and the transition matrix for each period must be known. The initial target state can be assumed, and the matrices are obtained from the output of the weapon suppression model.

(U) The expression for computing F_I over a mission of n time periods is given below:

$$F_I = \frac{1}{n} \sum_{t=1}^{n} (P_2^t + P_3^t + P_4^t + P_5^t)$$

where P_2^t, P_3^t, P_4^t, and P_5^t are, respectively, the probabilities that the target is in the first suppressed, second suppressed, third suppressed, and incapacitated states in the t^{th} time period. They are all obtained from P(t).

(U) If an area target is being attacked, an F_I is computed for each target cell. The overall mission effectiveness is the average of the target cell F_Is.

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E.3 LITTON Model

Introduction

(U) An explicit deterministic expression for suppression is the form of this model. An alternative version is suggested by the report and subsequent modifications to the model have been made by other agencies. This discussion is limited to the basic form.

Model

(U) Suppressed behavior is reactions that reduce individual or unit efficiency to fire, observe and move. Suppression, as expressed in the model, is the fractional efficiency or effectiveness of a target in its functions. Suppression, S, is given by:

$$S = \exp[B]/(\exp[B] + 1)$$

where

$$B = 10 \exp[-(0.04/p) \cdot (1-f)^2/f] - 5$$

f = expected fraction of casualties

p = human factors coefficient

The level of suppression is obtained as a numerical value between zero and one, inclusive. Multiplied by 100, it is interpreted as the percent of suppression to be expected, with values close to zero corresponding to low suppression and values close to one corresponding to high suppression.

Expected Fraction of Casualties

(U) The expected fraction of casualties is the principal variable in the model and embodies all of the relevant weapon parameters in a single parameter. Suppression depends directly on the incapacitating effect of the suppressive fire. The value of f may be determined by direct calculation or by use of tabular values. It is said to depend on the following parameters of the fire and target:

1. Size of area occupied by target elements.
2. Target element posture (standing, prone, in foxhole).

3. Target environment (open, marsh grass, forest).

4. Type of weapon battery.

5. Mode of fire.

6. Technique of fire (observer adjusted, Met +).

7. Volume of fire.

8. Fuze type.

9. Charge.

10. Range to target.

11. Angle of fall of projectile.

12. Miss distance (CEP).

The report is not explicit about the effect of suppression on posture. It also is not explicit about the time over which f is accumulated. These parameters are apparently to be user defined.

Human Factors Coefficient

(U) The value of this coefficient represents the aggregate of effects of human factors and other intangibles relating to morale, leadership, tactical situation, fear: danger ratio, and so forth; it has a nominal value of one. Use of values greater than one implies conditions resulting in higher suppression levels than the threat would typically elicit: inexperienced troops, for example. If conditions are such that lower than typical suppression levels will occur, as might be the case in a crucial defense by veteran troops, then a value of ρ less than one is appropriate. The human factors coefficient is influenced by a large set of factors. Dominant among these are the following:

a. Genetically determined factors.

b. Previous experience with similar threats and situations.

c. Habitual methods of coping with conflict situations.

d. Attitudes toward comrades, leaders, and cause.

e. Current physical and physiological condition.

f. Expectations of support, duration, orders, impact locations, etc

g. Ability to communicate with comrades.

These factors are difficult to quantify and, when quantifiable, are difficult to measure. There is little that can be stated with assurance about individual human factors. Even more intractable are the social factors such as morale, esprit, leadership, and role-playing.

(U) The range of values taken on by ρ is not specified, however the accompanying figure shows S calculated for different values of ρ lying between 0.5 and 1.5. In the report tabular values of S are given for ρ lying between 0.1 and 3.0.

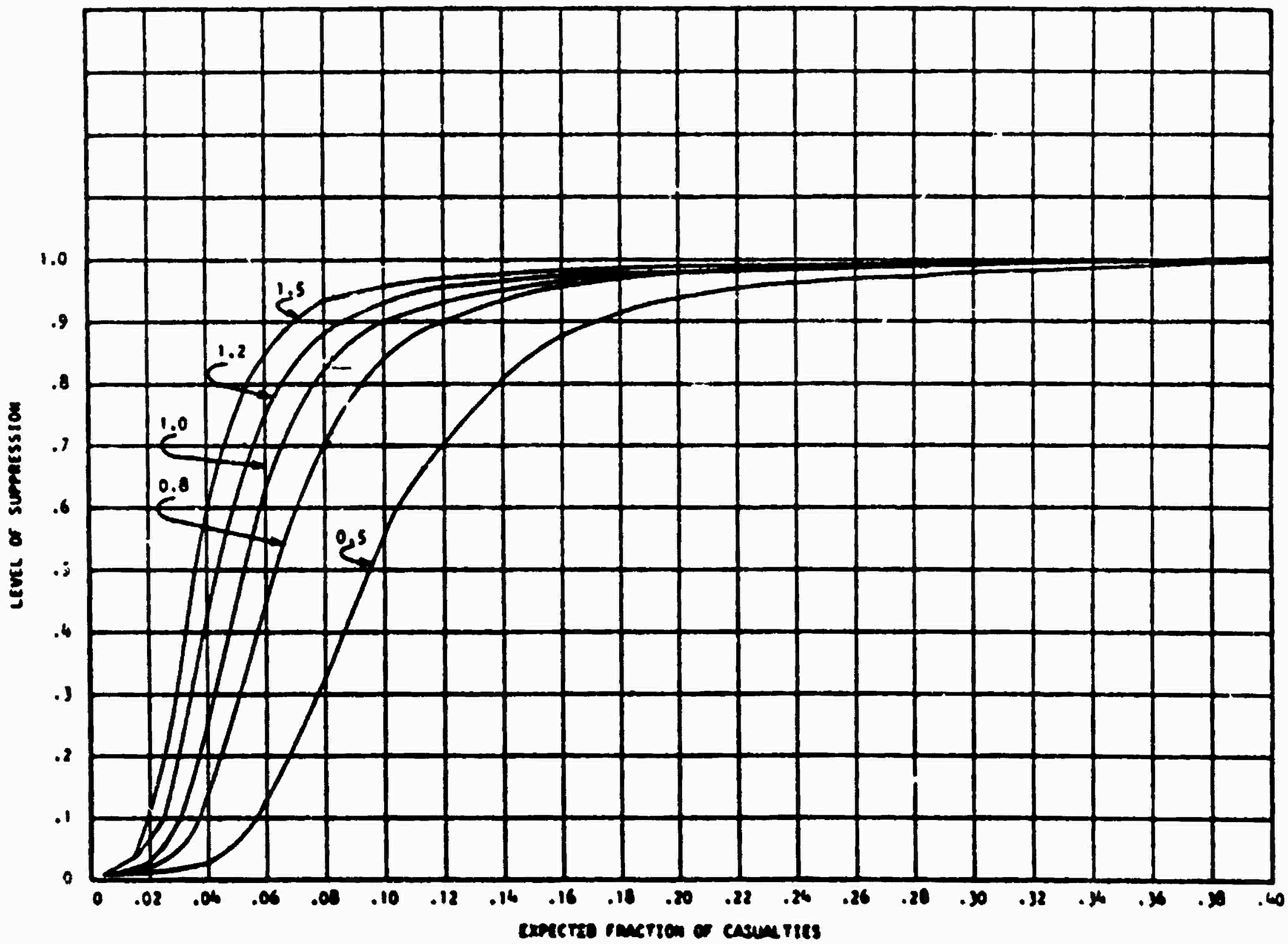

Figure E.3: Suppression Level as a Function of Expected Fraction of Casualties for Five Selected Values of the Human Factors Coefficient (from Ref. 1).

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APPENDIX F

DIFFERENCE BETWEEN ACTUAL AND PERCEIVED THREAT FROM A SUPPRESSIVE WEAPON[1]

[1]This appendix of the report was written by Dr. Marion Bryson, Scientific Advisor, CDEC, at the request of the ASAP working group chairman.

APPENDIX F

ON THE DIFFERENCE BETWEEN ACTUAL AND PERCEIVED THREAT FROM A SUPPRESSIVE WEAPON

Marion R. Bryson
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1. INTRODUCTION. In military combat each of two combatants attempts to gain an advantage by the optimum use of the personnel and hardware he has available. For simplicity, let us say the objective of the attacker is to occupy a position currently under the control of the defender. The objective of the defender is to prevent said occupation. At any given time, the probability of success for the attacker and the probability of success for the defender sum to unity. These two probabilities change over time due to action by the two sides.

One of the combatants, which may be either the attacker or the defender, will be designated the suppressor (Sr) for a particular action. The other side will be called the suppressee (Se). Sr will use his weaponry to cause Se to suffer casualties or to degrade the performance of his mission (suppress himself), or both. Let us assume that at time t, Se is alive and healthy but perceives a certain probability (maybe zero) that his state of being will not continue through the next Δ t interval of time. This probability is a function of the amount of protection Se chooses to afford himself during Δt. The subject of this paper is the relationship of the perceived probability of a change of state of health by Se to the actual probability of a change of state of health.

2. NOTATIONS.

Sr = the suppressor weapons system.

Se = the suppressee system.

t = time at which Se chooses an action.

Δ t = interval of time over which the action of Se continues before the next decision point.

x = a continuous variable representing state of suppression. If x = 0, Se if not at all suppressed, if x = 1, suppressee is completely suppressed.

$P_t(x)$ = Probability with which Se perceives his state of health will change in the next Δt if he takes action x at time t.

$C_t(x)$ = Correct probability that the health of Se will change in the next Δt if he takes action x at time t.

$w_t(x)$ = Probability Se ultimately wins the battle if he takes action x at time t.

3. ASSUMPTIONS.

a. If $P_t(x) > C_t(x)$ for some x, then $P_t(x) > C_t(x)$ for all x. Similarly for $P_t(x) = C_t(x)$ and $P_t(x) < C_t(x)$.

b. If $P_t(x) = C_t(x)$, then Se will choose that state of suppression x^* which maximizes $w_t(x)$.

c. If $x_1 > x_2 > x^*$ then $w_t(x_1) \leq w_t(x_2)$

d. If $x_1 < x_2 < x^*$ then $w_t(x_1) \leq w_t(x_2)$

From the above assumptions it follows logically that:

e. If $P_t(x) > C_t(x)$ then Se will take an action $x_1 \geq x^*$.

f. If $P_t(x) < C_t(x)$ then Se will take an action $x_2 \leq x^*$.

4. STATEMENT AND PROOF OF THEOREM.

Theorem: Unless $P_t(x) > C_t(x)$, it is never an advantage to Sr for $P_t(x)$ to be greater than zero.

Proof: 1. Assume the theorem is false. Then there is a value of $P_t(x)$ say $P_t^1(x)$ such that $0 < P_t^1(x) \leq C_t(x)$ and such that the action taken by Se based on the perception $P_t^1(x)$ is more advantageous to Sr then the action taken if $P_t(x)$ were zero.

2. Since the action taken if $P_t(x) = 0$ is the least suppressed state, the action taken for $P_t^1(x)$ must be a state of greater suppression.

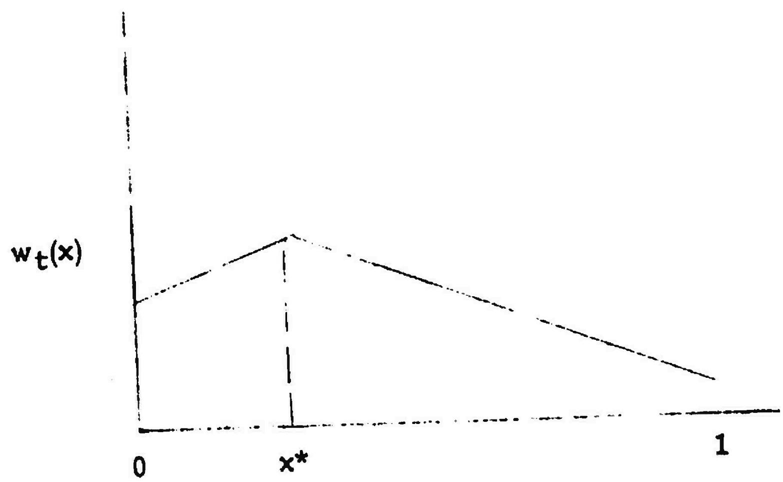
3. We may then call the state of suppression if $P_t(x) = 0$ the state x_1 and the state of suppression under $P_t^1(x)$ the state x_2 as in assumption d above.

4. Then by d, $w_t(x_1) \leq w_t(x_2)$.

5. This is a contradiction: no such value of $P_t^1(x)$ exists.

5. DISCUSSION.

The suppressee perceives a stimulus from a suppressor weapon. Based on this stimulus, he estimates the danger to his life from that weapon and takes an action as a result of this estimate. This action, he believes, will maximize his chance of winning the battle. (Any other objective function may be substituted for "probability of winning the battle" and the same argument holds.) If his perception of danger is correct, he will maximize his objective function $w_t(x)$ by taking the action x*. Graphically the relationship between the action x and the objective function is



Amount of Suppression (x)

If $P_t(x) > C_t(x)$ then Se will take an action x such that $x^* \leq x \leq 1$.

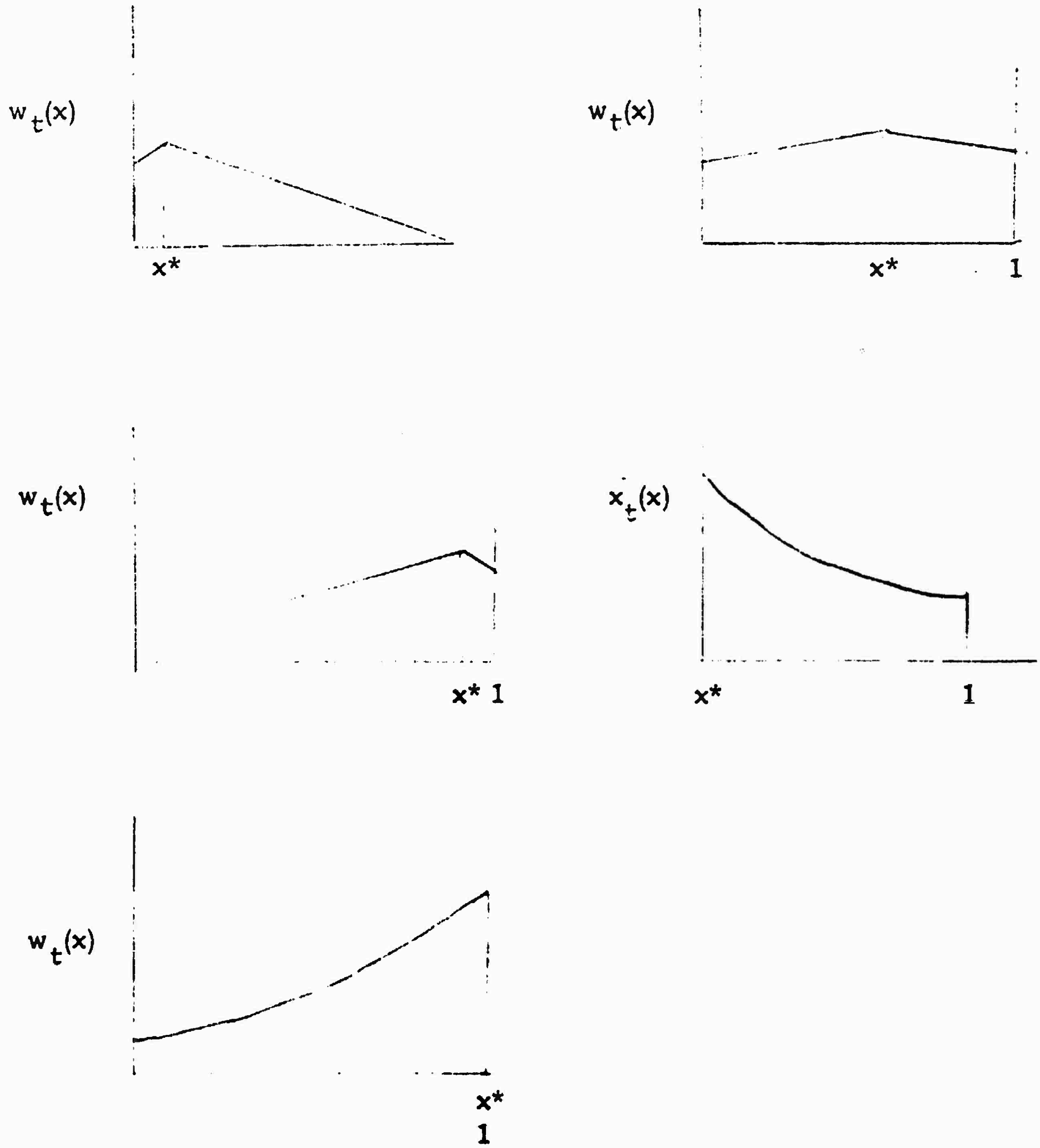
If $P_t(x) < C_t(x)$ then Se will take an action x such that $0 \leq x \leq x^*$.

- If Sr had complete control over $P_t(x)$, he would make it either 0 or 1 depending on which made $w_t(x)$ less.

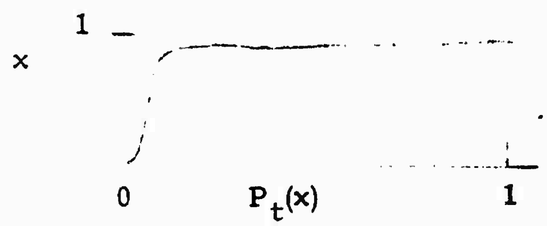
- Since Sr has, realistically, only partial control over $P_t(x)$, where in the range of possible values of $P_t(x)$ Sr has the greatest advantage depends upon the situation.

- Clearly, Sr never wants $P_t(x) = C_t(x)$.

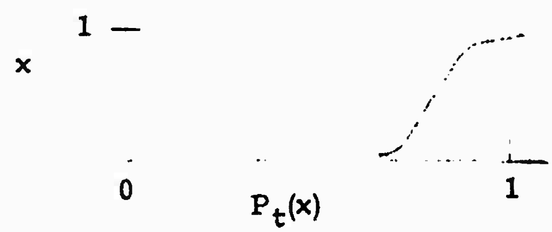
- It is probably worth some research to discover the optimum strategy for Sr under several situations depicted by the following sketches.



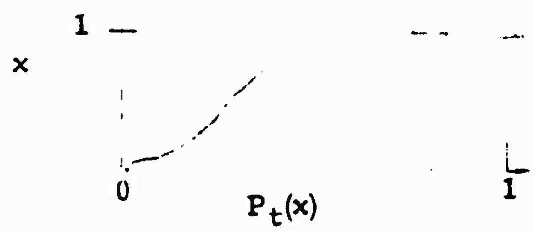
• For each $w_t(x)$ by x sketch there are several possible behavior curves. These curves will vary depending on the total battle situation. Some example sketches of action x plotted as a function of perceived threat $P_t(x)$ are as follows:



(If there is no other threat)



(If the other threat is great)



(A more usual combat situation)

• A completely different strategy for Sr may emerge if assumption b were changed to read,

"If $P_t(x) = C_t(x)$ then Se will choose a state of suppression which is greater than that which would maximize $w_t(x)$." (This is the conservative reaction or, more bluntly, the coward's response.)

• A similar strategy could be developed for the hero's response.

6. SUMMARY. If the U.S. Army is going to take an action as a result of the suppression program then this action must be to,

a. Improve our ability to respond in an optimum manner to suppressive fire.

b. Improve our strategy for delivery of suppressive fire.

c. Redesign our hardware so that its suppressive signature will cause the suppressee to behave in a manner more advantageous to us.

The relationship between perceived and actual lethality is key to all of these changes. Unless we understand more about it, we can't utilize the results of the suppression program to our ultimate advantage.

APPENDIX G

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At the request of the Commander, US Army Training and Doctrine Command (TRADOC), an ad hoc ASAP committee was organized to review and assess some of the past fire suppression research activities, clarify definitions, develop objectives of a scientific research program, and outline the structure of a research program. The committee's efforts focused on suppression that causes behaviors intended to lessen *risk* of incapacitation from firepower, rather than of actual incapacitation from firepower or confusion of the senses from non-firepower systems.

In the report, a detailed description of the processes (signal generation and attenuation; human sensory, perception, and behavior; and performance effects) that produce fire suppression is developed. This description is used as the basis for the operational definition of fire suppression and for the objectives of a research program. A structure and associated recommendations for a sequential study and research program is presented. Additionally, the report contains some "quick fixes" to reduce the effect of fire suppression on command-guided anti-tank systems and also a review of existing models of fire suppression.