Research Note 84-115

COMMAND CONTROL GROUP BEHAVIORS
FINAL REPORT - OBJECTIVE 1
A METHODOLOGY FOR AND IDENTIFICATION OF COMMAND CONTROL GROUP BEHAVIORS

AD-A145 690

Joel M. Reaser
Science Applications, Inc.

Steven Stewart
Army Research Institute

Roland V. Tiede
Science Applications, Inc.

Submitted by

Stanley L. Halpin, Chief
ARI FIELD UNIT AT FORT LEAVENWORTH, KANSAS

and

Jerrold M. Levine, Director
SYSTEMS RESEARCH LABORATORY

DTIC
SEP 1 7 1984

DTIC FILE COPY

U. S. Army
Research Institute for the Behavioral and Social Sciences

August 1984

Approved for public release; distribution unlimited.

This report, as submitted by the contractor, has been cleared for release to Defense Technical Information Center (DTIC) to comply with regulatory requirements. It has been given no primary distribution other than to DTIC and will be available only through DTIC or other reference services such as the National Technical Information Service (NTIS). The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

84 09 14 043

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: Research Note 84-115 / 2. GOVT ACCESSION NO.: AI43 690	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): A Methodology for and Identification of Command Control Group Behaviors	5. TYPE OF REPORT & PERIOD COVERED: Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Joel M. Reaser, Steven Stewart, Roland V. Tiede	8. CONTRACT OR GRANT NUMBER(s): MDA903-81-C-0254
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Science Applications, Inc. 1710 Goodridge Drive McLean, VA 22101	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 2Q162717A790
11. CONTROLLING OFFICE NAME AND ADDRESS: U.S. Army Research Institute for the Behavioral Sciences	12. REPORT DATE: August 1984
	13. NUMBER OF PAGES: 175
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, distribution unlimited.

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

18. SUPPLEMENTARY NOTES

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

command and control
automated data processing
decision making
team behavior
individual behavior
Tactical information flow
Behavior modeling
Combined Arms Tactical Training Simulator
Command Control Group behavior

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

This report provides the results of the first year's research of a three-year effort to identify the individual and multi-individual non-procedural skills exhibited by battalion command control group members and the commander/staff as a whole. In this project a model of command control group behavior was applied to identify and quantify four general categories of behavior. A methodology was developed for use at the Combined Arms Tactical Training Simulator (CATTS) at Ft. Leavenworth, Kansas. Extensive recordings were

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) made of battalion commanders and their staffs as they underwent training at the facility "fighting" a highly realistic computer-assisted war game. The methodology was effective in distinguishing between groups in three of the four areas. Preliminary results show that both procedural and non-procedural, individual, and team behaviors contribute to overall team performance.

DTIC
COPY
INSPECTED

A-1

COMMAND CONTROL GROUP BEHAVIORS -- OBJECTIVE 1
A METHODOLOGY FOR AND IDENTIFICATION OF COMMAND CONTROL GROUP BEHAVIORS

BRIEF

This volume describes the results of the first year's work on the first objective of the Study, COMMAND CONTROL GROUP BEHAVIORS. Two companion volumes describe the work done on the second two objectives.

Purpose:

The overall purpose of this objective is to identify the individual and multi-individual non-procedural skills and the team behaviors exhibited by battalion command control group members and the commander/staff as a whole. A second but equally important purpose is to develop a methodology for identifying the latter types of behavior in both battalion C^2 group and other than battalion C^2 group contexts, i.e., a generalizable methodology.

First Year Focus:

Review and analyze the video/audio tape sets of three CATTS exercises as a means for initial methodology formulation and to identify what, if any audio/visual hardware modification/additions, etc., may be necessary in order to capture "better data" for more detailed study and analysis. Also, design and develop a probe system during this preliminary phase. This system, in conjunction with the improved audio and video recording capabilities recommended and acquired, should make it possible to capture more relevant behavior. Additional data will be collected from three potential sources, viz., naturally occurring CATTS exercises conducted with Regular Army units, Reserve and National Guard groups, and ad hoc command groups that have been constituted from several different participants pools. Thus, both intra- and inter-group analysis is possible.

Method:

The following steps were undertaken to achieve the first year focus:

- Existing tapes were reviewed and analyzed.
- Improved instrumentation was recommended and implemented.
- A panel of experts in the field was convened.
- A research plan was prepared and submitted.
- A model of C^2 group behavior was developed.
- Hypotheses were generated from the purpose of the research and reduced to testable statements and data requirements.

- o Data collection techniques, to include a probe system, were developed.

- o Data were collected.

- o Data were reduced and analyzed.

- o Preliminary conclusions were formulated.

Preliminary Conclusions:

Based on the first-year effort, it is recommended that the following steps be taken to improve the viability of CATTS as a C^2 group behavior laboratory and to facilitate its use in reaaching Objective 1.

- o Carry out as many, preferably all, of the proposed long-term improvements to provide the following capabilities:
  - Follow two key players at all times with voice-activated mikes and filter all audio recordings.
  - Record and replay video in all three locations played in CATTS (TOC, JTOC, and Trains).
  - Produce selected excerpts for analysis and feedback.
  - Provide the capability to record and synchronously replay the tactical situation, both player and controller.

- o Tighten up the administration of CATTS by:
  - Adhering to realistic JTOC move times and communication restrictions
  - Removing the CRT display from the JTOC
  - Strict enforcement of rules restricting player access to unauthorized CATTS facilities until completion of training.

- o Extend the data extraction methodology to collect the data needed to calculate Streufert's "Complexity Measures" and to implement more sophisticated measures of C^2 group behavior derived from the time stream data inherent in CATTS.

- o Extend the model inherent in the first-year methodology to show the conceptual interrelation among: combat outcomes; C^2 group performance measures; complexity measures; and the behavioral, information processing measures.

- o Implement and exercise the extended methodology to demonstrate the correlation among: combat outcomes; proposed group performance measures, complexity measures; and behavioral measures.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF TABLES

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

This is one of three reports prepared as a result of the first year's work on the 3-year study of "Command Control Group Behaviors." This report documents the conduct and results of the work on Objective 1.

1. GENERAL

1.1 Purpose

The overall purpose of this objective is to identify the individual and multi-individual non-procedural skills and the team behaviors exhibited by battalion command control (C^2) group members and the commander/staff as a whole. A second but equally important purpose is to develop a methodology for identifying the latter types of behavior in both battalion C^2 group and other than battalion C^2 group contexts, i.e., a generalizable methodology.

In this project, a model of command-control group behavior was applied to identify and quantify four general categories of behavior. A methodology was developed for use at the Combined Arms Tactical Training Simulator (CATTS) at Ft. Leavenworth, Kansas. Extensive recordings were made of battalion commanders and their staffs as they underwent training at the facility "fighting" a highly realistic computer-assisted war game. The methodology was effective in distinguishing between groups in three of the four areas. Preliminary results show that both procedural and non-procedural, individual and team behaviors contribute to overall team performance.

2. BACKGROUND

The Statement of Work takes the position that: It is increasingly being stated that the success of U. S. forces on future battlefields against our most probable enemies will depend upon factors other than the sheer numbers of personnel and weapons we now have at our disposal. The command and control (C^2) process is one such factor where deficiencies invite catastrophy, but where performance increments can provide substantial force multiplier effects. Clearly, every effort should be made to ensure that C^2 process performance increments are realized.

One fundamental information need involves determining what team behaviors, as distinguished from individual or multi-individual behaviors in a group setting, contribute to the performance of command group members and/or the group as a whole. Many of these behaviors have been identified in previous research. However, many of them, perhaps the most important ones, have not. For example, a Defense Science Board Task Force Report (1975) has pointed out the importance of team training, and thus team performance, to the effective functioning of the force. However, it went on to say that very little is known about what actually constitutes effective team behavior, even though so much time and money is expended within the DOD for training in the team context, e.g., tank crew training, CPXs, FTXs, etc. Ascertaining what the dimensions of effective team performance are with respect to command groups is an objective of this project. Greater knowledge of all these parameters will facilitate the development of effective C^2 training procedures and systems as well as functional requirement specification for battlefield automation and its configuration to support the tactical C^2 process.

Obviously, team behaviors do not completely account for C^2 performance. They are one of a number of variables which contribute to the overall battlefield outcome as is pictured in Figure 1. Nonetheless, they are certainly a contributing factor and it is the goal of this research to identify and quantify the important C^2 behaviors.

3. TECHNICAL APPROACH

The steps carried out during the first year of the project are presented in Figure 2.

3.1 Develop a Conceptual Framework

The first step was to develop a conceptual framework. Tiede (1980) developed such a model based on several projects to analyze and simulate division-level command and staff operations. This basic model has been modified and extended.

The model considers the command-control team as a decision node in a tactical information system and was refined to describe five categories of behavior: input processing behaviors, pre-decision processing behaviors, decision process behaviors, post-decision processing behaviors, and output processing behaviors (see Figure 3).

The node receives inputs, transforms and stores data, and generates outputs. The individuals within the node perform processes which accomplish the information processing function. They receive the incoming messages, verify them, tag them for internal disposition, and input them into the appropriate data bases (manual at battalion, automated and/or manual at higher echelons). The next process is to prepare the data for inclusion in decision-making processes. This includes sorting data elements, associating data elements which are related to each other (in time, by area of the battlefield, or by type) and arranging them into meaningful patterns.

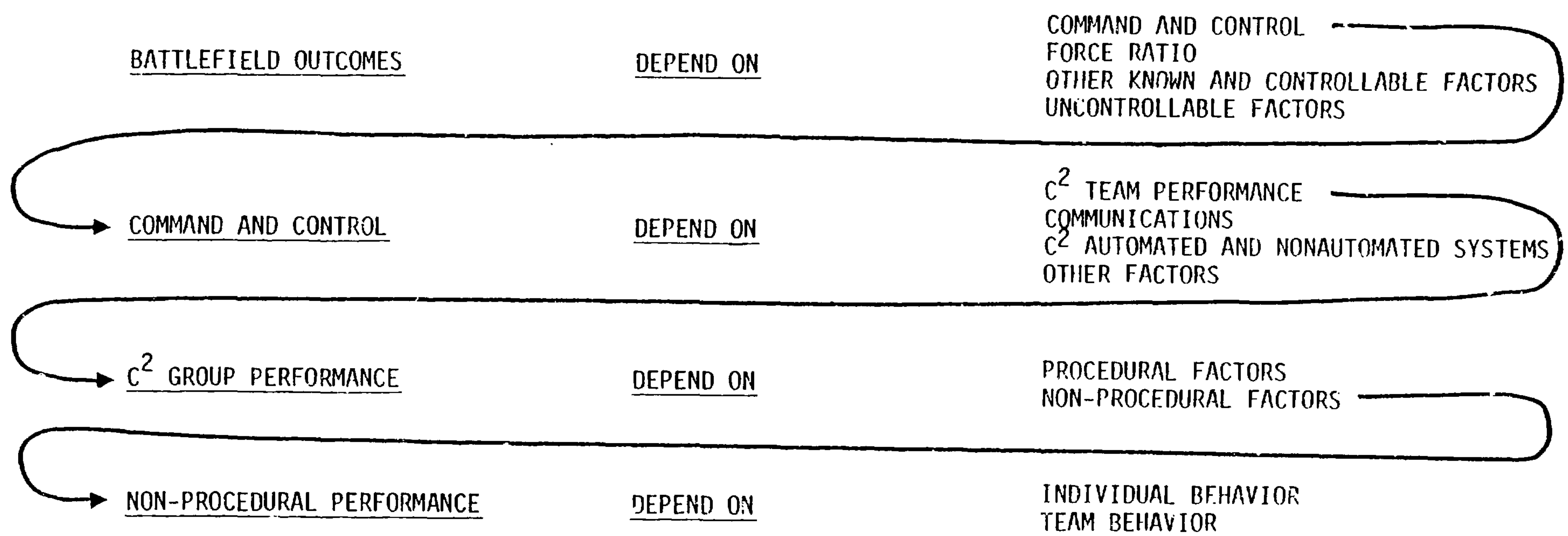


FIGURE 1. THE ROLE OF C^2 TEAM BEHAVIORS IN CONTRIBUTING TO BATTLEFIELD OUTCOMES

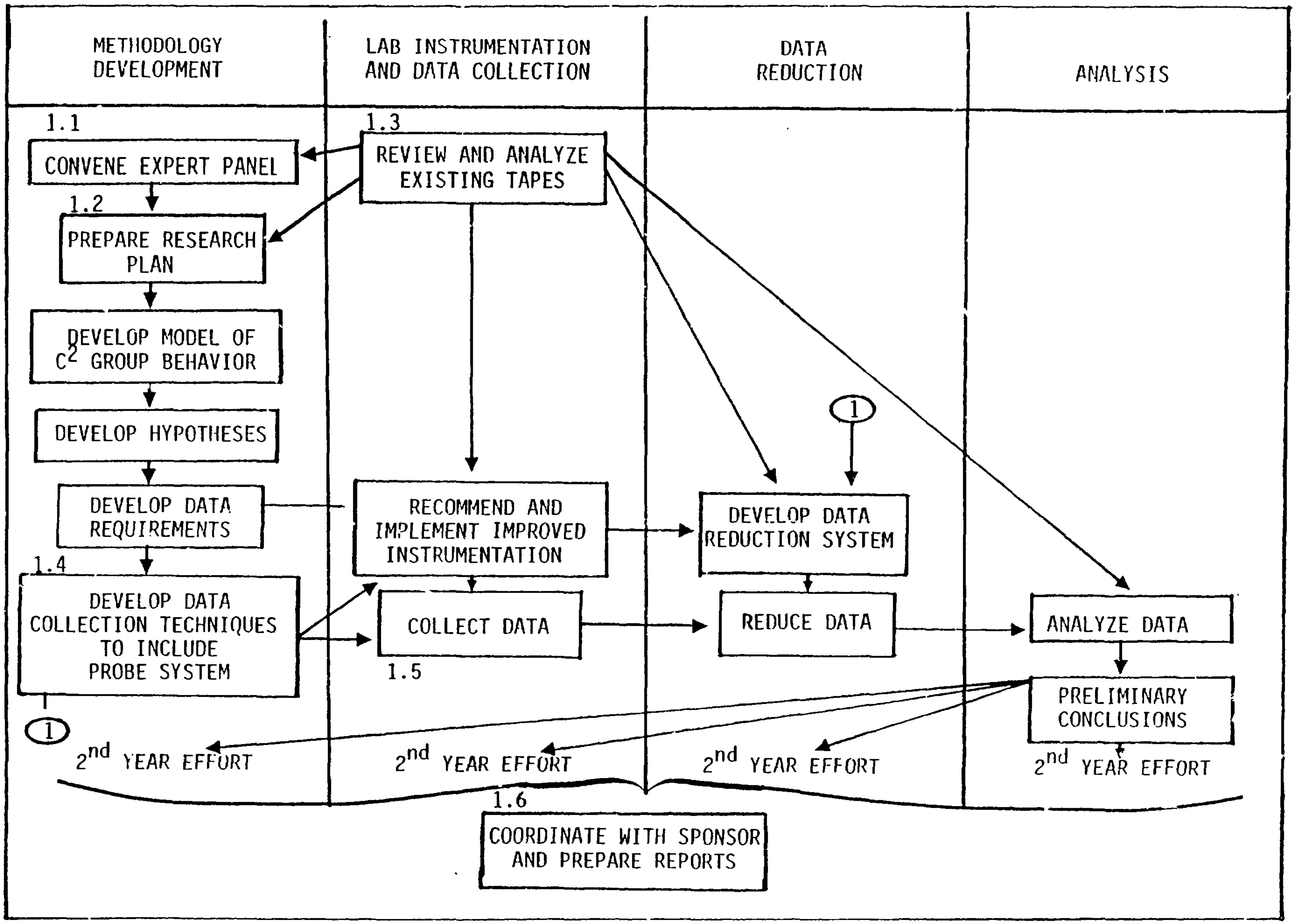


FIGURE 2. FLOW OF FIRST YEAR TASK ACTIVITIES FOR OBJECTIVE 1

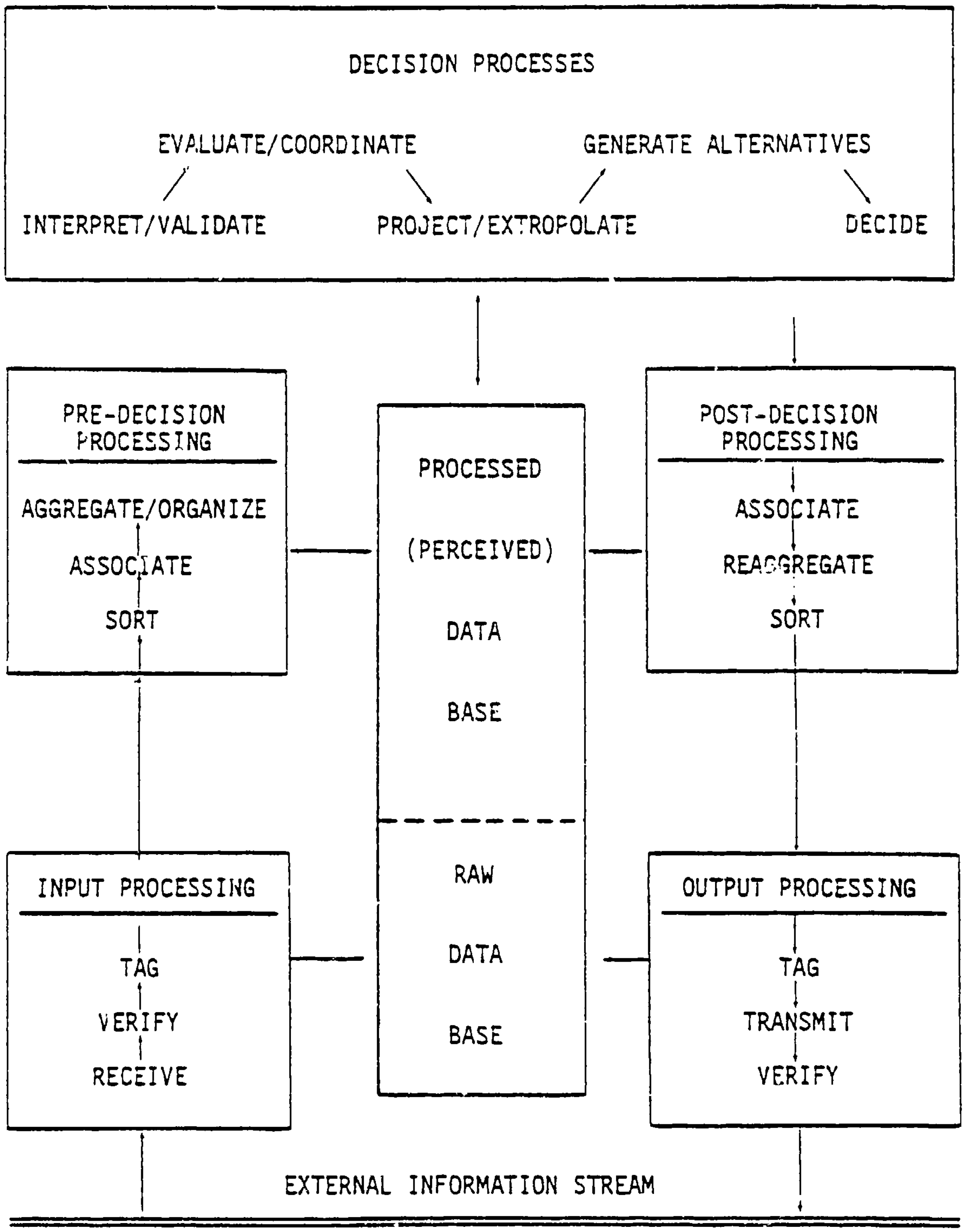


FIGURE 3. MODEL OF COMMAND CONTROL GROUP BEHAVIOR

The decision process involves the use of these data patterns stored on the group's collective, perceived data base. Patterns are interpreted in relation to the mission, evaluated, and projected into the future under different sets of assumptions. Alternatives are generated for the decision maker to consider, and he makes the decision.

At division-level, this process occurs repeatedly as data are processed through the G staff sections and then to the commanders. At battalion, the processes can all occur within a single room or tent. Nonetheless, the basic model applies, regardless of echelon.

The tasks performed range from simply writing down an incoming message and relaying it to someone, up to weighing a set of complex alternatives and deciding on one. As one goes from the lowest level process to the highest, several things are true: 1) the lower level tasks are easily taught and can be defined into fairly standard procedures for training individuals how to perform the task or for specifying how automation can perform the task. These lower level tasks are referred to in the project as "procedural" behaviors; 2) the higher level decision process behaviors are not easily taught and are difficult or impossible to prescribe as a standard procedure. These are referred to as "non-procedural behaviors." The distinction between procedural and non-procedural is not absolute. In part, this is because, as we learn more about a process, we can "procedurize" previously non-procedural behaviors. However, in general, non-procedural refers to the more cognitive, decision, or thought processes.

Referring back again to the differences between organizational levels, at division-level, groups of people perform what, at battalion level, may very well be performed by one person -- in his head. This has implications for research methodologies as will be discussed below.

The purpose of Objective 1 deals with two dimensions of behaviors as shown in Figure 4. The model was extended during the first year to take into account all four cells -- procedural vs. non-procedural and individual vs. team behaviors. Individual behavior is accounted for in two ways: 1) especially at battalion, and frequently at other echelons, single individuals perform all the activities within one or more of the five levels of behavior; 2) the model can be extrapolated downward to describe the functioning of a specific individual as well as a team.

	Individual & Multi Individual	Team
Non-Procedural	1	2
Procedural	3	4

FIGURE 4. COMMAND CONTROL GROUP BEHAVIORS TO BE STUDIED IN THE PROJECT

3.2 Generate Research Hypotheses

The next step involved the generation of hypotheses which could be tested. The general hypotheses came directly from the stated purpose of Objective 1 of the project. They are:

- Hypothesis 1: Procedural behaviors contribute to effective team performance; non-procedural behaviors contribute to effective team performance.

  Discussion: This research is directed at discovering not whether one or the other is important, but to attempt to quantify the relative importance of both. It is clear that a command control group cannot perform effectively without efficient and effective handling of incoming and outgoing messages (procedural). Similarly, the group cannot complete its mission without good and timely decision making and the effective coordination of the team members (non-procedural).

- Hypothesis 2: Individual behaviors contribute to effective team performance; team behaviors contribute to effective team performance.

  Discussion: Teams have a structure in which the individuals in each grade must coordinate and contribute their specialization to the group effort. However, the individuals in the team can, to some extent, improve overall team performance by improving their individual performance.

  A team, especially a military team such as a command group, has certain properties which differentiate it from an ad hoc group and thereby make it more effective than a group. These properties, as identified in previous research, include a) pre-defined roles for members, b) structured paths of communication, c) awareness of team members of that structure, d) recognition of a team mission and its importance, and e) need for coordinated efforts by team members. Other variables which have been found to be related to team performance are ability to adjust and sensing of overload of other members, i.e., the ability to adapt effectively as conditions require.

3.3 Develop Quantification Methodology and Instrument the Laboratory

3.3.1 Quantification Methodology

Development of the methodology required:

- Reducing general hypotheses into testable statements
- Developing a data collection plan.

3.3.1.1 Measures of Command-Control Group Behaviors

There are four categories of behavior measurement which were needed to determine the impact of those behaviors. Figure 5 shows those categories and the measures selected for each category.

Additional analysis was also performed to determine whether groups differed in the way in which they allocated specific jobs to specific individuals or sections. This issue is critical to the structure and function of the staff. As a preliminary measure of "division of labor," a ratio was developed between the number of cognitive/decision type activities which were carried out and followed by output processing by the same individual (i.e., is the staff officer directly handling the radio or phone lines as well as deciding how to conduct the battle?). This analysis also showed differences between groups with some very tentative indications that, during the execution of the battle, traditional division of labor peaks at an intermediate value.

The analysis of flow matrices and initial computations derived from them showed definite differences between groups on a series of the measures and showed that the data transfer type classification was detecting differences in activities between groups.

Although the number of groups for which a complete set of data were collected was not large (N = 11), more sophisticated statistical procedures were also carried out in an attempt to get a preliminary assessment of the relative contribution of different categories of behavior. These very preliminary data showed that, of the four types of behavior presented in Figure 5, the measures used for team procedural and non-procedural behaviors showed some correlation with the criterion measures of performance.

Hypothesis 2

Hypothesis 1	Individual - Multi-Individual (IMI) Behaviors	Team (T) Behaviors
Non-Procedural (NP) Behaviors	Interpersonal Style in Communicating	Adherence to Organizational Structure Allocation of Team Human Information Processing Resources Time Required to Effect a Decision Pattern of Intra TOC Communications
Procedural (P) Behaviors	Reaction Time Adherence to Communications Procedures	Turnaround Time Communications Mode

FIGURE 5. CATEGORIES OF MEASURES FOR EACH TYPE OF BEHAVIOR

NPT Behavior Measures

The set of measures chosen as indications of team non-procedural behaviors included:

- Adherence to organizational structure -- Did the team maintain role specialization, that is, did higher level team members stick to higher level processes and did staff sections adhere to their designated functions? What differences did it make? In this first year, only one measure was taken to quantify this factor; this was a "division of labor" measure which indicated the ratio of processes in which higher level team members not only performed the high level cognitive process but also personally handled the transmissions of a message resulting from that process.

- Allocation of team human information processing resources -- A second non-procedural measure is the level of human resources which the team devoted to lower level versus higher level processes, i.e., what is the workload level committed to simply receiving and transmitting messages versus the performance of higher level cognitive processes? To measure this factor, a proportion was computed based on the number of messages processed versus the total number of information processing steps carried out.

- Time required to consummate a solution -- As an overall measure of the team's ability to bring to bear an effective response to a presenting problem, the total time from presentation of the problem to evidence of an effective response was measured. As with other variables, there are a number of intervening variables which will affect this time. (A solution to this particular issue is a goal of the second year of the project.) However, the total time was used as a first approximation.

- Pattern of intra-TOC communications -- Another non-procedural team behavior is the number of sections or individuals who actually participate in the decision process and the patterns of interactions between them. This pattern describes several features of a team's operations, e.g., it identifies the sections or individuals usually relied on and whose information, insight, or experience is most useful or most valued; it shows differences between teams in terms of the numbers of communications which occur before an effective solution is reached. There were two measures used as indicators of this behavioral variable -- the number of sections included in the decision process and the number of pairs of sections active in the process.

NP-IMI Behavior Measures

- Interpersonal style of communication -- Another non-procedural behavior is the manner in which members of the team interact on an interpersonal basis, i.e., are they supportive and cooperative or negative and non-supportive? Observers were asked to judge this dimension on a three-point scale.

P-T Behavior Measures

- Turnaround time -- One aspect of procedural behavior is following the general rule for conciseness and brevity in radio/telephone communications. This is one of many areas where, for the sake of efficiency, the Army has developed highly stylized procedures. As one measure of the team's behavior in performance of these procedures, the average time per communication between individuals was computed.

- Communications mode -- The mode of communication is another procedural behavior of the team. For most products defined by the FMs (e.g., FM101-5, FM 30-5, and similar documents), there is also a prescribed mode of communication, usually written, by which sections interface with each other. For non-prescribed communication, the mode selected is usually the most convenient. In battle, often there may be only one mode available. At battalion, as played at CATTS, practically all communication is either face-to-face or radio, and there is no decision to be made by the player; the mode is determined by the location of the player at the other side of the communication. For example, in this case, the mode between the commander and staff members is determined by the commander's choice to "play" from the JTOC or remain in the TOC.

P-IMI Behavior Measures

- Reaction time -- There are classes of events that occur which should result in prompt specific reaction. These events are procedural, i.e., events from which individuals in the team are trained and for which the measurement of performance is simply the time required to react to the event. One such event in the command control group is communications jamming by the enemy. As an indication of performance in this type of behavior, the time required to respond to the jamming was recorded.

- Communications formatting -- A second measure of procedural, individual/multi-individual behaviors was whether communications were carried out in prescribed format, complete, and transmitted without error. In the case of battalion, communications are almost always by voice. Therefore, a communication rating was used which required observers to judge whether voice communications were sent and received completely, in standard form, and error free.

3.3.1.2 Behavior Measurement

The next step was to develop the procedures needed to collect data for the measures which had been identified. The general methodology had been established by the designation of CATTS as the laboratory facility. CATTS has, as part of its integral equipment, an audio and video taping capability which could be used to record the exercises for subsequent detailed analysis. (The specific set up and improvements made to it are discussed in paragraph 3.3.2 below.)

The measurement problem was, therefore, to develop a procedure which would: 1) elicit behavior from the group, and 2) record and measure the differences in behavior between groups and over time for the same group.

After reviewing the first several months' exercises, it was decided that no special procedure was needed to elicit behavior. The natural flow of the game presented numerous challenges to the group which could be sampled to measure behavior. There also appeared to be a natural ebb and flow of the simulated battle which provided a natural change in the situation which could be measured in terms of battle intensity or information processing demands on the group. Therefore, the only active attempt made to inject challenges (or "probes") into the game was the jamming of communications. During the exercises included in the analysis in this report, jamming was introduced approximately 20 minutes after the start of the battle and the team's ability to reestablish communications was measured.

In order to record and measure the team's behavior, two behavioral sequences were selected as samples of each group's behavior. The first was just mentioned -- response to jamming. In the context of the situation, this probe was taken at what was considered a moderate level of battle intensity, i.e., contact had been made but heavy engagement had not begun. The second sample was taken during high intensity, i.e., the sample started with the imminent engagement of enemy tanks and ended with the first kill of an enemy tank.

The first sample was used to measure procedural behaviors; the second to measure both procedural and non-procedural behaviors. The activities in the first were a sample of the rote completion of previously defined procedures. The behaviors in the second included initial input of the challenge (sighting of enemy tanks), pre-decision processing of the information (association and aggregation of that message with other data on the enemy's activity), decision processes (interpretation of the fact that an enemy counter-attack was underway and decision as to the response), post-decision processing (formulation of the orders to maneuver units), and output processing (transmission of messages to upper and lower echelons).

The two behavior samples provided a set of specific data elements to quantify these behaviors. The set selected for this pilot effort appeared to be those that were the easiest to extract and apply.

3.3.1.3 The Criterion Measures

One of the advantages of the CATTS facility is that a wealth of simulated battle information is available to be used to track the success or failure of the command control group to achieve its objectives. The computer used to calculate battle outcomes keeps track of equipment and personnel status and location for each platoon level unit. Losses inflicted by weapons system, location, and time and replacements by type and time are all recorded. In addition to the computer-generated data, the game controllers, who are permanent-duty staff for CATTS, also provide a series of ratings on the performance of the teams.

For the preliminary analysis in this first year, five computations based on the computer-generated data were used as criteria along with the average controller's ratings of overall team performance. The computer-generated indices were: measures of relative losses between friendly and enemy forces, changes in overall combat ratio at the beginning and at the end of the training exercise, and computational variations on these data.

3.3.2 The Research Laboratory -- CATTS

A high-fidelity, computer-driven, battalion-level simulation coupled with audio/visual recording technologies provided the laboratory for this research project. The Combined Arms Training Simulator (CATTS) is the most sophisticated device of its kind in the Army. It has the capacity to train mechanized and light infantry and armored battalion commanders and staffs in combined arms operations. The CATTS does this via a computer which contains math models and a digitized terrain data base which can realistically portray the movements of both friendly and enemy units, engagements of these units, weather, and use and input of smoke, as well as a host of other variables which can affect the outcome of the battle. The command group, operating within a realistic mock-up of a Tactical Operations Center (TOC) equipped with a normal complement of communications equipment, interface with their "troops" through professional controllers role playing subordinate (company) commanders. The company commander controllers enter the battalion staff's orders into the computer where the battle is simulated. An opposing force controller enters directives for the operation of the enemy units and the computer provides him, as well as friendly controllers, "feedback" vis-a-vis the status of the battle. The friendly controllers relay appropriate portions of the computer's feedback to the battalion commander and staff, and their reactions are "plugged" back into the battle. Both Mid-East and European terrain data bases are available.

The command group's TOC is equipped with cameras and microphones wired into a video recorder and a multi-channel audio tape recorder. The latter is capable of recording simultaneously all communication transmissions on all simulated ratio nets available to the command group. Thus, it is possible to obtain complete audio and visual records of the command group's activities during the conduct of entire exercises. This is currently being done where there is no objection on the part of the participating command group (most do not object). The primary data base available for use in satisfying the first objective will be sets of audio and visual tapes of three entire battalion command group CATTS exercises.

The video and audio records made it possible to visit and revisit both intra- and inter-command group behavior in order to develop insights into what non-procedural individual and multi-individual skills and team behaviors are necessary for more efficient and effective functioning of the command group as a whole.

As part of the project, the initial recording system was evaluated and a series of improvements was made. The improved recording system was installed in September 1981 and included the following improved components:

- 5.5 mm lenses to provide a wider span of vision of the TOC
- 6-hour video recorders to reduce tape handling and to improve video quality
- Improved noise filtering microphones to enable audible recordings of command group conversations
- Audio feedback controller to filter out background noise in improved audio recordings.

In addition to these hardware improvements, other data collection procedures were also implemented:

- Exercise diary recording to record major events as they occurred with references to the time code and tape counters
- Tape library procedures for recording and cataloging all video/audio tapes used for each exercise
- Documentation procedures to collect hard copy documentation on each exercise (sequence of scenarios to be used, participating unit, results of other scoring).

Figure 6 portrays a systems view of CATTS showing its principal components, their basic functions and the gross information flow. CATTS is a highly dynamic model and a number of separate event sequences are being generated. Four of these are of direct interest. One of these is the time stream of planned events emanating from both the planning and supervising functions and marked 1. The second is the time stream of actual events produced by the combat model and marked 2. The other two time streams of interest exist only inside the player element. One is the time stream of events perceived by the players as a result of reports of selected events relayed by the controllers, labeled 3 in the figure. The fourth is the entire ensemble of behaviors generated by the players, labeled 4. These time streams are also related to four variables of interest: ultimate criteria, intermediate criteria, independent predictors, and moderators. The effort during the first year has been concentrated largely on time streams 2 and 4 -- in fact, almost exclusively on

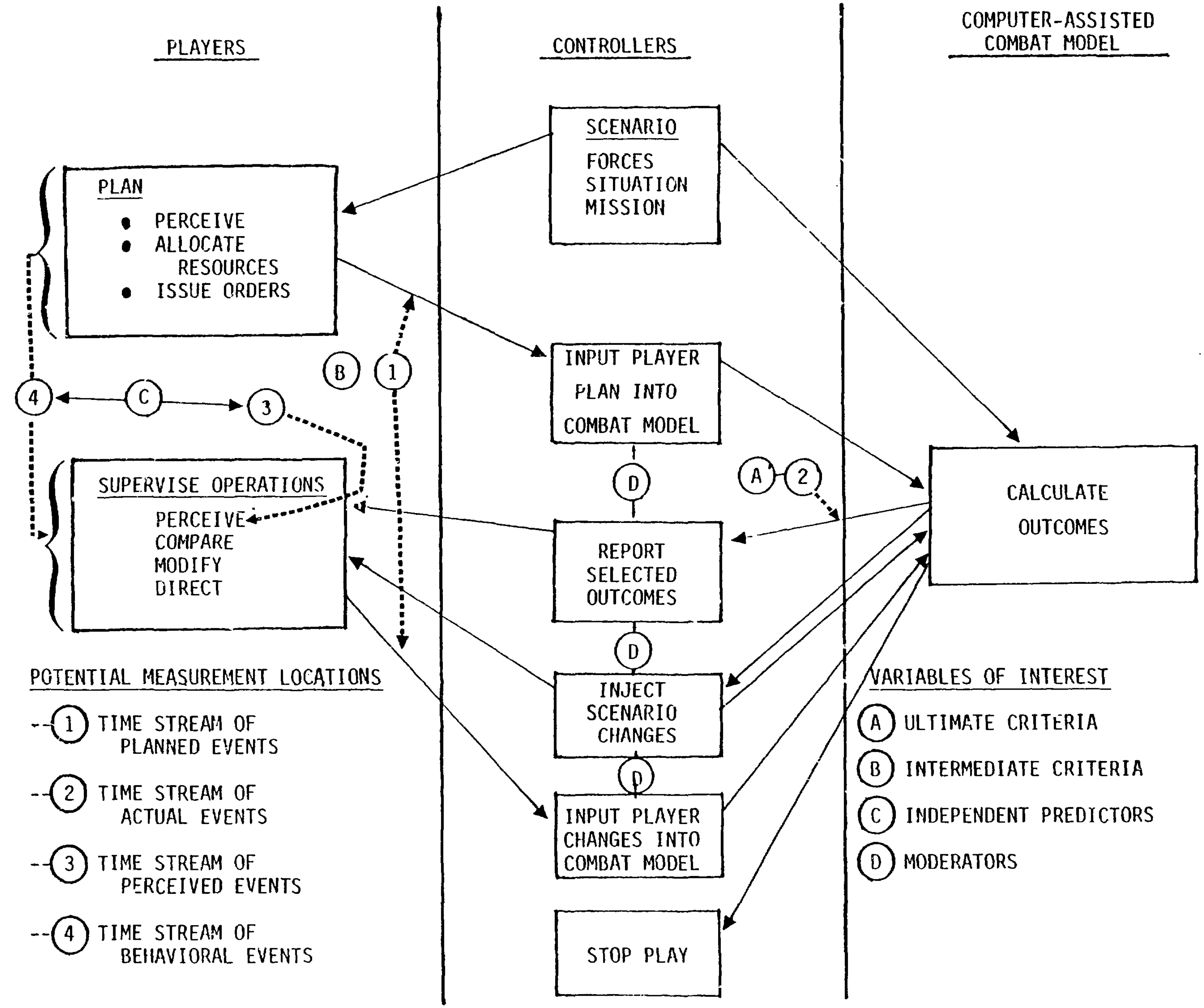


FIGURE 6. A SYSTEMS VIEW OF THE CATTS LABORATORY

the technical problems involved in collecting time stream (4) data in the laboratory and means for reducing these data from the tapes on which they were collected.

3.4 EXERCISE RECORDINGS AND DOCUMENTATION

Recordings were made of all exercises conducted at CATTS from May 1981 up to the present time. However, the recordings on the first 3 months were made on the equipment originally available and were inadequate for detailed analysis. During August through December, recordings were made of seven units which were part of a controlled design experience, and it was these exercises that were chosen for analysis to provide the preliminary data for the first year. The seven units each played four battle scenarios -- two attack and two covering force, one each on two terrains -- Europe and the Middle East. Thus, there was a total of 28 possible exercise-days. Each day included several hours of planning and several hours of "fighting."

3.5 REPLAY AND BEHAVIORAL ANALYSIS

There were two stages in the analysis. First, the behavioral data from the observer collection sheets were reduced and analyzed. Second, those behavioral data were correlated with the criterion measures -- controllers ratings and the computer-generated, simulated battle status data. This section covers the first of these steps.

3.5.1 Replay Facility

In order to replay the exercises, a system has been designed and installed to make replay and analysis as efficient as possible. The system consists of:

- 6-hour video recorders with full control key pad to provide easy manipulation of the video recordings for search, play, and replay of behavioral sequences to be rated

- Microcomputer-based behavioral rating recording system to facilitate recording and analysis of observers' ratings of individual, multi-individual, and team behaviors

- Digital time code/character generator equipment to display the game time on the video screen and on the digital display for the audio recorder (this allows synchronization to the second of audio and video recordings)

- A portable 8-track audio recorder with audio and digital recording capacity to permit re-recording of audio sources and digital game time transport to an observer laboratory.

In addition to this hardware, the following software and procedural components have been developed or are near completion:

- Observer ratings software to prompt the observer to enter the data needed for each observation on each observation task

- Microcomputer-to-mainframe interface software to allow edited observer ratings to be passed directly to the larger computer and merged with other data for subsequent statistical analysis

- Library procedures for recording and cross-referencing audio reels, video cassettes, data disks, and hard copy documentation for each exercise

- Data editing/merging routines for editing and merging the observer ratings, data collected from other sources, and the game status statistics.

3.5.2 Replay and Behavioral Analysis Procedures

Each exercise was first replayed to identify the exact start time and end time for the behavioral samples. These samples were then given to the panel of observers who observed, classified, and rated the C^2 behaviors of the team related to each of the samples described earlier in paragraph 3.3.1.2.

Two data collection forms were designed for use by research team observers. The high battle intensity form required the observers to provide a detailed information flow audit trail by making a series of entries each time any individual in the TOC communicated with anyone else regarding the tactical event. Codes were developed for senders-receivers, mode of communication, quality of sender and receiver communication, type of communication, style of interaction, and the start and end times of the communication.

All these codes were straightforward coding tasks except the type code. This latter code was designed to permit inference of the information activities as classified by the model from the communications. The code provided data regarding the incidence and pattern of exchange among the players of both higher and lower cognitive processes. In order to correctly classify a conversation, the observers had to listen to the conversation, take into account the content of the conversation and roles of the individuals involved and the data which those individuals had received prior to the conversation. By comparing the data "in" with the data "out", the observer could infer what, if any, processing had taken place.

The moderate battle level intensity form simply recorded the game time jamming was initiated, the time at which it was recognized as a problem, the time at which successful communications were re-established, and the observer's rating of the group's success in re-establishing communications.

4. ANALYSIS

The data reduction and analysis which were undertaken during this first-year pilot eeffort were much more in the nature of a feasibility test and demonstration of what kinds of analysis might be undertaken with the data being collected than an effort to "prove" the hypotheses or to derive hard experimental evidence. Although some tentative findings have been developed, it must be remembered that they are based on a tiny segment of the total behavior that led to the combat outcomes and controller ratings of group performance. There are, furthermore, grave reservations concerning the validity of the criterion measures used for the analysis.

The data considered for the analysis were: 1) the data collected by observers reviewing the probes, and 2) combat outcome data (and controllers' ratings) being generated by the CATTS computer. These data provided the basis for calculating the totality of variables included in this analysis. These variables are listed in Table 1.

Table 1. VARIABLES INCLUDED IN THE PRELIMINARY ANALYSIS

CRITERIA VARIABLES	Controller ratings of team overall performance (higher ratings = better performance)
	Loss exchange ratio (higher scores = better blue performance)
	Relative exchange ratio
	Surviving maneuver force ratio differential
	Change in combat ratio
	Weighted force measure

INDICATOR VARIABLES	The time required to determine the need to switch channels during jamming
	The time required to successfully re-establish communications
	The jamming-induced communication difficulty of the exercise (1 = bad, 2 = good)
	The degree of success the team had in successfully re-establishing communications in response to enemy jamming (1 = "experienced less difficulty than most" to 3 = "experienced more difficulty than most")
	Number of nodes which received probe-related transmissions (7 major nodes)
	Number of nodes which sent probe-related transmissions
	Number of pairs of nodes which communicated probe-related transmissions (26 possible pairs)
	Ratio of above to total possible
	Total time in minutes for probe to be completed
	Average length of each probe-related transmission
	Proportion of each mode of communication used for probe-related transmissions (CFTF -- face-to-face, CRTO -- radio/telephone, CRTL -- radio/telephone with speaker)
	Average quality of sender communications (1 = "good" to 6 = "poor")
	Average quality of receiver communications
	Ratio of each type of data transfer related to the probe
	Average style rating (sender and receiver) for probe-related transmissions (1 = "hostile" to 3 = "supported")

The analysis of these variables was carried out in two steps. First, the data were tabulated for each exercise. The tabulations were used to determine: 1) if the rating scales, the classification system, and other measures were detecting any differences between the groups; and 2) a preliminary attempt was made to verify the descriptive analysis from step (1) and make an initial attempt to measure the relative contribution of the types of behavior.

The statistical analysis consisted of computing Pearson product-moment correlations between the variables. This matrix was inspected and the data for suspect correlations was plotted; then, stepwise regressions were performed and, in some cases, a curve-fitting program was used to establish the best curvilinear formulation of the relationship between predictor and criterion. Of the 28 one-day exercises considered as the set for analysis, one exercise was not conducted and several had little data. The correlations were computed on a pair-wise (rather than observation-wise) deletion basis since few exercises (i.e., observations) had all data available. The correlations were, therefore, based on n's which ranged from the middle to upper teens.

There are preliminary indications that both procedural and non-procedural behaviors and both team and individual behaviors are related to overall group performance, but these must be heavily caveated for reasons stated in the following discussion.

5. DISCUSSION

Based on the first year's experience, a number of observations are pertinent with respect to the instrumentation of both the recording and observation laboratories, the administration of CATTS exercises, and needed extensions to the methodology.

5.1 The Laboratories

Although significant improvements were made in the instrumentation for recording and observing CATTS exercises, a number of additional capabilities are still required to improve the viability of CATTS as a C^2 group behavior laboratory. These include:

- The ability to follow at least two key players by means of voice-activated microphones
- Noise filtering of all audio recordings
- The ability to record and replay video in all three CATTS locations (TOC, JTOC, and Trains)

- The means to produce selected, synchronized excerpts from the multiple taped recordings for analysis and feedback to players

- The ability to record and synchronously replay the tactical situation presented to the controllers and that maintained by the players.

5.2 CATTS Administration

Although the cooperation provided by the CATTS permanent party has been outstanding, there are a number of administrative practices which, if rigidly enforced, would greatly improve the comparability of CATTS outcomes and hence the training value:

- The time and communication penalties associated with movement to the JTOC need to be rigidly and uniformly enforced

- Removal of the CRT display from the JTOC would produce a more credible decision-making environment and reduce the tendency to play the "game"

- Restriction of player access to unauthorized CATTS facilities until after completion of the exercise would greatly reduce uncontrolled variability in outcome.

5.3 Methodology Development

Even the limited data reduction and analysis accomplished during the first year pointed up several major deficiencies in the methodology which must be corrected. These may be summarized under three headings:

1) The criteria measures used were in themselves unsatisfactory and incomplete measures of combat outcomes. One criterion used was the controller rating which is, of course, a subjective rating not very tightly coupled to combat outcomes. The other five criteria were "objective" in the sense that they were computer-generated data (or mathematical manipulations thereon). However, these were all resource expenditure measures (principally casualties) whereas tactical missions have three dimensions: area, resources, and time.

2) There was much too wide a discrepancy between the time interval of probe during which behavior was sampled and the time interval which produced the combat outcome --

the former was a matter of minutes, the latter a matter of hours. Such combat outcomes were the result of hours of C^2 group behavior and innumerable uncontrolled variables.

3) There is too wide a gap between the individual processes identified by the C^2 group behavior model and combat outcomes. The methodology did not adequately address the question, "What difference does C^2 make?" The model needs extension so as to interrelate conceptually: information processes, C^2 group behavior and performance, and combat outcomes. Measures of C^2 group behavior and performance need to be developed for the experimental effort as well.

There are two concepts whose synergistic application would appear to provide the needed extensions to the methodology. One is the application of some of the decision theory concepts, specifically Streufert's Complexity Theory. This provides a set of measures of C^2 group behavior intermediate between individual processes and combat outcomes. The second concept makes more sophisticated use of the time streams identified in Figure 6 to develop measures of C^2 group performance as follows:

- Comparison of the time stream of planned events (decisions) 1 with the stream of actual events 2 gives a direct measure of the efficacy of the decisions.
- Comparison of the stream of actual events 2 with the stream of perceived events 3 provides a measure of the "slack" in the C^2 system.
- Comparison of the stream of planned events 1 with the stream of perceived events 3 gives a measure of the perceived need to take action at the time new decisions to act are made.

Furthermore, the characterization of decisions in terms of their complexity will also serve to focus attention on specific decisions whose combat outcome can be traced and to the individual processes involved in that specific decision making. This would simultaneously ease the "probe" problem and the time interval problem.

6. RECOMMENDATIONS

Based on the first-year effort in methodology development, instrumentation of CATTS, data extraction and analysis, and the preliminary findings and discussion, it is recommended that the following steps be taken to improve the viability of CATTS as a C^2 group behavior laboratory and to facilitate its use in reaching Objective 1:

- Carry out as many (preferably all) of the proposed long-term improvements to provide the following capabilities:
  - Follow two key players at all times with voice-activated mikes and filter all audio recordings.
  - Record and replay video in all three locations played in CATTS (TOC, JTOC, and Trains).
  - Produce selected excerpts for analysis and feedback to players.
  - Provide the capability to record and synchronously replay the tactical situation, both player and controller.
- Tighten up the administration of CATTS by:
  - Adhering to realistic JTOC move times and communication restrictions.
  - Removing the CRT display from the JTOC.
  - Strict enforcement of rules restricting player access to unauthorized CATTS facilities until completion of training.
- Extend the data extraction methodology to collect the data needed to calculate Streufert's "Complexity Measures" and to implement the analysis proposed in para. 5.3 above (measures of C^2 group performance).
- Extend the model inherent in the first-year methodology to show the conceptual interrelation among: combat outcomes, C^2 group performance measures, complexity measures, and the behavioral, information processing measures.
- Implement and exercise the methodology proposed in para. 5.3 above to demonstrate the correlation among: combat outcomes, proposed group performance measures, complexity measures, and behavioral measures.

SECTION 1

INTRODUCTION

SECTION 1

INTRODUCTION

This report documents the conduct and results of the work accomplished during the first year of effort on Objective 1 of the Study of Command Control Group Behaviors.

1.1 PURPOSE

The overall purpose of this objective is to identify the individual and multi-individual non-procedural skills and the team behaviors exhibited by Battalion Command Control (C^2) group members and the commander/ staff as a whole. A second but equally important purpose is to develop a methodology for identifying the latter types of behavior in both battalion C^2 group and other than battalion C^2 group, i.e., a generalizable methodology.

1.2 TASKS FOR OBJECTIVE 1

To achieve the objective, a set of tasks was identified in the Statement of Work and subsequently in the SAI proposal. These tasks, the source of the task statement, and the paragraph(s) in which they are discussed in this report are as follows:

Task	Source	Report Section
<u>First Year</u>		
1.1 Convene an expert panel to explore theoretical and methodological approaches	SAI Proposal	2.1
1.2 Prepare a detailed research plan	Contract Deliverable	2.2
1.3 Review and analyze the audio/video tape sets of three CATTS exercises	SOW	3.3
a) As a means for initial methodology formulation, and		2.3, 3.2
b) To identify what, if any, audio/visual hardware modifications/additions, etc., may be necessary in order to capture "better data" for more detailed study and analysis		3.3, 3.4

Task	Source	Report Section
1.4 Design and develop a probe system to capture more relevant behavior which has been stimulated by presentation of various "challenges" to the organization or its individual members. The task also will include preliminary development of the method of assessment	SOW	2.7.2
1.5 Collect additional data from naturally occurring CATTS exercises including regular, reserve, and ad hoc groups	SOW	4
1.6 Coordinate with the sponsor and prepare monthly and annual reports	Contract Deliverable	-
<u>Second Year</u>		
2.1 Collect additional data using alternative methodological approaches	SOW	
2.2 Quantify command group behaviors and the outcomes	SOW	
<u>Third Year</u>		
3.1 Determine the impact of the previously identified behaviors on command group effectiveness	SOW	
3.2 Implement and evaluate the methodology in other team contexts	SOW	

Figure 1-1 shows the flow of first year activities. Those activities included in the formal task statement above have been identified by placing the task number at the upper left corner. The column headings of Figure 1-1 are the basis for organizing the remaining sections of this report.

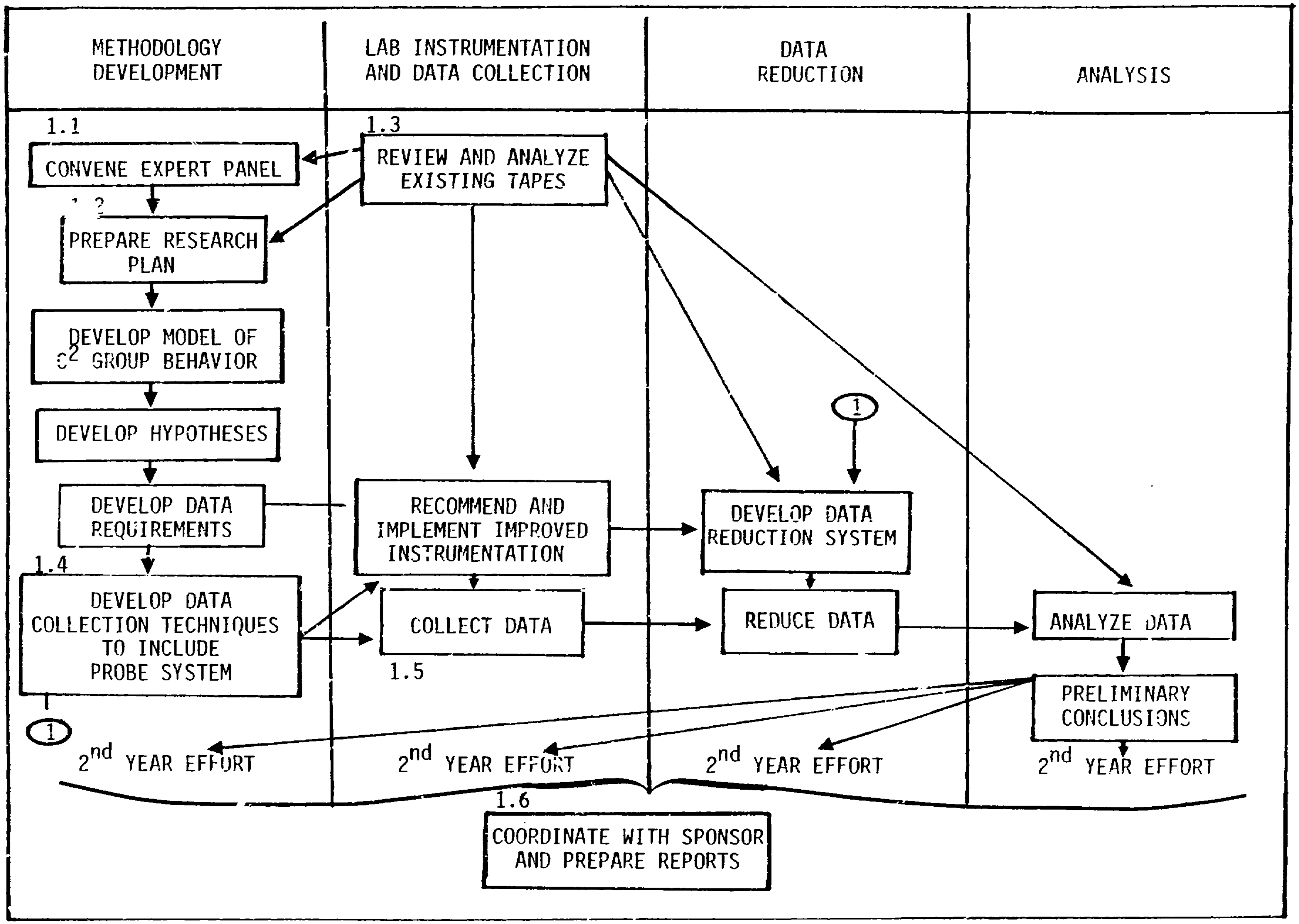


FIGURE 1-1. FLOW OF FIRST YEAR TASK ACTIVITIES FOR OBJECTIVE 1.

1.3 THE NEED

The first two paragraphs of the following have been extracted from the sponsor's Statement of Work for this study.

> It is increasingly being stated that the success of U. S. Forces on future battlefields against our most probable enemies will depend upon factors other than the sheer numbers of personnel and weapons we now have at our disposal. The command and control (C^2) process is one such factor where deficiencies invite catastrophy, but where performance increments can provide substantial force multiplication effects. Clearly, every effort should be made to insure that C^2 process performance increments are realized. This goal can be viewed as being comprised of two major elements -- a training development and a combat development component or objective. In the former, better methods, procedures, and systems can be developed to train commanders and staffs. In the latter, job aids, automation assists, and related computer system support can be developed to extend and enhance the commander's and staff's capabilities to accomplish those functions which they are called upon to perform in combat more quickly and accurately. These two generic types of efforts are being pursued by two Combined Arms Center (CAC) activities, the Combined Arms Training and Combat Developments Activities (CATRADA and CACDA), respectively. The ARI Field Unit - Ft. Leavenworth is conducting a research program to provide the human performance and behavioral information base which will enable these two activities to achieve these vital objectives more effectively and efficiently.
>
> One fundamental information need common to both objectives involves determining what team behaviors, as distinguished from individual or multi-individual behavior, are demanded and contribute to the performance of command group members and/or the group as a whole. Many of these behaviors have been identified. However, many of them, perhaps the most important ones, have not been identified. For example, a Defense Science Board Task Force Report (1975) has pointed out the importance of team training and, thus, team performance to the effective functioning of the force. However, it went on to say that very little is known about what actually constitutes effective team behavior, even though so much time and money is expended within the DOD for training in the team context, e.g., tank crew training, CPX's, FTX's, etc. Ascertaining what the dimensions of effective team performance are with respect to command groups is the key topic of this report and the goal of "Objective 1" of the project. Greater knowledge of all of these parameters will facilitate the development of effective C^2 training procedures and systems as well as functional requirement specification for battlefield automation and its configuration to support the tactical C^2 process.

Obviously, team behaviors do not completely account for C^2 performance. They are one of a number of variables which contribute to the overall battlefield outcome as is pictured in Figure 1-2. Nonetheless, they are certainly a contributing factor and it is the goal of this research to identify and quantify the important C^2 behaviors.

1.4 SYNOPSIS OF THE STATE OF THE ART

The following comments on the state of the art with reference to C^2 group research as well as those appearing in paragraph 1.5 appeared in the sponsor's statement of work for this study, but are so germane and complete as to warrant inclusion in the first year report.

The first objective is to develop and apply a methodology for differentiating the non-procedural individual and multi-individual behaviors from the team or synergistic behaviors in battalion command groups and determining their respective contribution to command group effectiveness. Ostensibly, it should be fairly easy to specify the individual behavior/tasks required by command group members as they manage the conduct of tactical operations. A good many of these individual tasks, as mentioned previously, have indeed been identified and are well documented in such Army publications as FMs 101-5 and 100-15 and ARTEPS 71-2, 100-1, and 100-2. Most, if not all, of the tasks contained in these documents, however, are what have been traditionally referred to as staff procedures or "hard tasks". As such, they, by and large, represent the mechanisms through which the command and staff management processes are operationalized and represent the kinds of tasks which current methodologies, e.g., TRADOC Pamphlet 350-30 (1975), can effectively address.

The fact that the art of command does not reside in the domain of hard skills has long been recognized. For example, Bloom and Farber's (1967) data indicated that "the 'art of command' is a phrase which serves to distinguish command from more specific military disciplines and professions. It is the application of techniques for organizing and using subordinate commanders and staff in such a manner that the commander can best fulfill his responsibilities for directing, planning, and supervising operations. The practice of the art is through the channels of the command process." Olmstead (1967), approaching the subject from a slightly different frame of reference and based upon his long working experience with Army commanders and staffs, concluded that: "There does not appear to be a single pattern of behavior which can be practiced so as to yield consistently the best organizational performance under all conditions." Thus, he felt that successful headship (and perhaps also staffship) should be viewed "as a process of adaptation to changing conditions," which requires both diagnostic and action skills, e.g., observation, analysis, assessment, prediction, etc., and intervention, strategy, manipulation of organization/environmental conditions, respectively. As intimated, these same principles should apply to all of the principal positions within the command group and not just to the commander *per se*. Each position has rather clearly articulated functions whose successful

BATTLEFIELD OUTCOMES	DEPEND ON	COMMAND AND CONTROL FORCE RATIO OTHER KNOWN AND CONTROLLABLE FACTORS UNCONTROLLABLE FACTORS
COMMAND AND CONTROL	DEPEND ON	C^2 TEAM PERFORMANCE COMMUNICATIONS C^2 AUTOMATED AND NONAUTOMATED SYSTEMS OTHER FACTORS
C^2 GROUP PERFORMANCE	DEPEND ON	PROCEDURAL FACTORS NON-PROCEDURAL FACTORS
NON-PROCEDURAL PERFORMANCE	DEPEND ON	INDIVIDUAL BEHAVIOR TEAM BEHAVIOR

FIGURE 1-2. THE ROLE OF C^2 TEAM BEHAVIORS IN CONTRIBUTING TO BATTLEFIELD OUTCOMES.

accomplishment demands more than the mere implementation of staff procedures.

The identification and quantification of multi-individual, non-procedural tasks and skills can be viewed as more or less synonymous with the problem of delineating and codifying individual non-procedural behaviors. That is, if one defines multi-individual training (or performance) as Wagner et al. (1977) do, it consists of nothing more than training (or the performance of) two or more individuals: 1) who are associated in a group context, 2) who may or may not be a part of a team, and 3) where the focus of the training and feedback is clearly on each individual's skills, activities, and products.

Although individual and multi-individual performance or training can be thought of as being more or less the same, they both differ substantially from what will be described here as team training or behaviors. Both Wagner et al., and Hall and Rizzo (1975), in relatively recent reviews of the team training literature, chose Klaus and Glaser's (1962, 1968) definition of a team as being probably the best available. According to them, teams have a relatively rigid structure, organization, and communication pattern; the task (equivalent to function as the latter term is used above) of each team member is well defined; and the functioning of the team depends upon the coordinated participation of all or several individuals. (Wagner, et al., rightly add that teams are goal- or mission-oriented and, thus, the specific context in which the team will operate must be considered.) Because of perennial confusion between what constitutes a "team" and a "small group," Hall and Rizzo went on to point out that "small groups", as opposed to "teams," have an indefinite or loose structure, organization, and communication pattern; task assignments which are assumed in the course of group interaction rather than designated beforehand; and group products which are a function of one or more of the group members involved depending upon the quality and quantity of their participation. Even though accepted definitions of "team" and "small group" differ, that does not necessarily rule out the possibility that "small group" research findings may have implications for understanding team performance. This issue was examined by the authors of both reviews cited above. In fact, Wagner et al. conceived team (training) research to be a part of the more general subject matter of small group research of group dynamics. After examining this larger field, the authors concluded that, although the area had produced literally thousands of studies and papers, most of them were only tangentially relevant to the team training research subgrouping. This view is consonant with the position taken herein.

There are selected, but certainly not new, issues that must be examined with respect to the team performance area as it relates to the work outlined here. Each of these is examined briefly in the following paragraphs.

First, command-control groups, whether they are at the battalion or the corps level, "fit" very closely the definition of "team" provided above. They have a relatively rigid structure, organization, and communication pattern; are definitely mission- or goal-oriented; the functions of each team member (with the possible exception of the commander) are fairly well defined; and the successful functioning of the group appears to be contigent upon the coordinated participation of all command group members, i.e., ostensibly, if and how well the mission is accomplished is a function of the successful integration of the personnel administration, logistics, intelligence and operations functions, and the orchestration of the force through subordinate commanders. As such, and because command groups by and large operate within the confines of emergent (as opposed to established) situations, they can be considered "organismic" in nature (Alexander and Cooperland, 1975). This distinction, as obliquely addressed above, is very important with respect to the study of command groups as teams. In investigations of team performance in established situations where the tasks, functions among team members and their equipment, and the general environment are relatively rigid, the quality and quantity of the teams' output were found to be functions solely of the competencies of the individual team members. Investigations by Horrocks et al. (1960), Briggs and Johnston (1967), and Klaus and Glaser (1960, 1965) are representative of those which have obtained such findings. On the other hand, investigations conducted within the context of non-static or emergent situations (e.g., Johnston, 1966, and Boguslaw and Porter, 1962) have found that the "quality" of the team's performance was more than the sum of the competencies of its members. In these situations which demanded interdependency among team members, the development of skills, e.g., the ability to effectively coordinate, that transcended individual competencies was necessitated in order for the group to function effectively.

A number of extra-individual or team competencies have been identified/investigated in the course of team performance's 20-year research history. Some of them, e.g., coordination, interaction, and cooperation, as Federman and Siegal (1965) point out, are ambiguous and lack concrete operational definitions which makes systematic investigation of them across researchers very difficult. There are others, however, which appear to be less ambiguous. These include team awareness (Kanarick, Alden, and Daniels, 1971) and orientation to team goals, error analysis, overload sensing, adjustment (coping) mechanisms, and reacting to emergent situations (Boguslaw and Porter).

The observed or hypothesized dimensions of collective team member performance, as opposed to performance idiosyncratic to the various members of the team, have been offered as exemplary of the kinds of variables which are thought to be related to the effective functioning of a team. As the relatively recent Defense Science Board Task Force Report (cited earlier) has pointed out, a real need exists to ascertain what actually constitutes the general elements of true team performance, and satisfying that need requires a viable methodology for identifying collective dimensions that may be common or unique to different kinds of teams, e.g., a command-control group as opposed to a tank crew.

Summary:

- Combat performance can be improved by improvement in "non-procedural behaviors" of command-control teams.

- Non-procedural behaviors are those which emanate from higher level decision processes which culminate in what is often referred to as the "art of command."

- Team behaviors are those which demonstrate effective coordination and synergistic effects of the individuals working in concert.

- Some specific team behaviors which have been shown to be related to performance include: orientation to team goals, error analysis, overload sensing, adjustment mechanisms, reaction to emergent situations.

1.5 INITIAL METHODOLOGICAL CONSIDERATIONS

The Defense Science Board Task Force Report, discussed in the preceding section, also identified some of the difficulties in conducting team research:

> This kind of R&D must be piggy-backed on operations in the field, large numbers of R&D personnel are required, the opportunities for data collection during the exercise are marginal, inferential statistics and psychometrics were not designed for this order of complexity, there are limited opportunities for repeated trials, the ultimate test of team training is combat, which cannot be simulated.

It is possible to look at these difficulties in a different way, and, in so doing, two fundamental kinds of problems emerge. First, teams or organizations, while in operaton, produce stimuli-pregnant environments, ones so rich that it is impossible during any given "snapshot" for a researcher, or a group of researchers for that matter, to absorb. Secondly, it is not necessarily inferential statistics or psychometrics *per se* which has impeded research progress. Rather, it is a *broader* methodological problem. Conventional social science approaches simply are not well suited for dealing with or explaining what is happening in environments like those which teams generate. Van Maanen (1979), in introducing a collection of articles dealing with alternate methodologies for the study of organizational behavior contained in a special issue of *Administrative Science Quarterly* (ASQ), summed up the methodolgical problem quite well:

> . . . Indeed, there seems to be a rather widespread skepticism surrounding the ability of conventional data collection techniques to produce data that do not distort, do violence to, or othewise falsely portray the phenomenon such methods seek to reveal. In particular, the overwhelming role played by the survey instrument in organizational research has led some observers to suggest that the field is becoming simply the study of verbally expressed sentiments rather than the study of conduct. To further refine our data analysis techniques, however, is not to improve the quality of the data which is, in the final analysis, at issue.

A specific challenge to conventional research approaches comes from Mintzburg (1979):

> What, for example, is wrong with samples of one? Should Piaget apologize for studying his own children, a physicist for splitting only one atom? A doctoral student I know was not allowed to observe managers because because of the "problem" of sample size. He was required to measure what managers did through questionnaires, despite ample evidence in the literature that managers are poor estimators of their own time allocation (e.g., Burns, 1954; Horn and Lupton,, 1965; Harper, 1968). Was it better to have less valid data that were statistically significant?

The Mintzburg article is only one of thirteen dealing with "qualitative" research approaches contained in the special issue of ASQ referenced above. Although methodologies other than those currently available for eking out more of the true meaning of individual, multi-individual, and team behavior are in their infancy stage, work in this area is ongoing and will be tracked during the course of this project. Also, Simon and Boyer (1970) have assembled a compendium of observational interactive analyses and other unobtrusive measures which differ in scope from those emerging methods discussed in the ASQ articles which still may be of some use.

As will be seen in the following sections, the conceptual model and methods for data collection and analysis have attempted to deal with these issues. The subsequent sections describe the specific tasks accomplished during the first year and describe the preliminary outcomes of the first year's data.

Summary:

- Live teams produce tremendous numbers of interactions and behaviors, each of which contributes in part to the team's performance.

- Research methodologies are needed which deal with a data-rich environment. Such methods should (a) be as unobtrusive as possible and (b) stress in-depth analysis and understanding of the process as well as collection of data suitable for traditional treatment.

1.6 GENERAL APPROACH

Command control groups are a complex system of humans, procedures, "machines" (automated and non-automated), and interfaces between them. The problem in Objective 1 is to identify and quantify the human dimension of this system. This problem must be addressed within the context of the overall system because it is the successful performance of the overall system which is the ultimate objective. An ancillary objective is to identify theoretically satisfactory behavioral dimensions of command group behavior. Since system performance is the primary objective, two things follow:

- The internal processes of the human component cannot be studied in and of themselves. The component internal processing characteristics can only be inferred from the component's ability to interface with other humans and machines. All components have input, processing, and output functions. While all components have these similar capabilities, they vary both in terms of the frequency of the activities and the content of the information with which they deal. The project purpose is to (a) quantify and identify (quality and frequency) the functions of the team and its member components and (b) further distinguish between the relative importance of procedural and non-procedural behaviors.

- The research methodology is focused more on pragmatic empirical relationships between the human component and system performance than on the evolution of group theory. Obviously, this is not to say that there is nothing to be derived from group process theory, decision theory, and information flow theory. However, there are some unique aspects of the military command group which reduce the number of variables applicable to much other group research. Those unique aspects are:

  - the high degree of structure, i.e., all battalion command groups have a BC, S1, S2, S3, S4, RTO, ALO, FSO and supplemental s[illegible];

- group structure is institutionally (organizationally) established

- there is a "life and death" dimension to the success or failure of the group.

These unique aspects yield a group which:

(a) rarely questions the role of the commander,

(b) practically never questions the structure of the group,

(c) is highly task-oriented,

(d) is less sensitive to the human dimensions since, when a particular human member fails or is eliminated, it is presumed that the organization can provide a replacement of roughly comparable capabilities.

With these aspects in mind, it is still the task to identify human group performance dimensions which relate to (i.e., contribute to) system success. The methodology chosen was one of analyzing in detail the activities of extant battalion command groups carrying out a computer-driven war simulation. All activities (e.g., voice communication, individual movements) for each simulation exercise were recorded using four video cameras, general area microphones, and recording "taps" into telephone communication lines through which the command group communicated with other echelons and with dispersed portions of the command group (JTOC and TRAINS). The methodology for the study was generally prescribed by the selection of the CATTS facility as the "experimental laboratory" for the project.

Given the advantages (as well as some limitations) of CATTS as the laboratory, the question remained as to what to observe and how to determine what behaviors are important out of all the thousands of individual actions that occur during each simulated battle exercise. As a starting place, the information flow model originally proposed was extended to apply to individuals as well as group information/ decision-making activities. Based on the model, preliminary operational definitions were developed for factors in team performance and for the distinction between procedural and non-procedural behavior. These operational definitions were then used to define a set of variables to be collected. Then a behavioral sampling methodology was developed to collect and analyze the resulting data. The data for all variables were not collected because of highly experimental nature of the methodology and even the evolutionary nature of the model. Nonetheless, the results of the first year support continuing along the currently proposed lines.

A behavioral sampling procedure for selecting a set of specific events was developed (referred to as a probe system). The probes were sequences of activity which had a definite starting point (e.g., receipt of a specific message) and a more or less specific ending point. The ending point is harder to define because the end point is, in general, a response to the message or action which initiated the starting point. However, the response may be:

- Combined as an action taken in regard to not only the specific message starting the probe but to other information messages;

- The failure to respond;

- The decision (voiced or not) not to respond.

Having selected the methodology and the initial focus of attention to apply to the methodology, the next decision dealt with what specific activities should be monitored. This was the most difficult decision because of the large number of potential activities which any group might exhibit. For example, human communication is not simply by voice; it is by gesture, gesticulation, and "body language". Further, it can be measured by frequency, distances, durations, and contents. Because of the unique aspects of the battalion command group and because of the recording techniques to be employed in the CATTS simulation, it was assumed that critical information within the group could be tracked by voice communication (face-to-face or radio/telephone). It is acknowledged that in some significant cases this is not true -- specifically, in reference to the use of maps which are a critically important data base and decision aid and around which the commander and his staff do their work. However, the critical elements on the map are discussed between the group members and, given that those discussions are recorded and analyzed, the voice communication analysis was assumed to be adequate. As part of this approach, a preliminary classification system for voice communications was developed. The classification system of "data transfer" types allowed trained observers to infer the occurrence of higher level decision and other cognitive processes from comparison of input data and the output data (the voice communication).

1.7 THE RESEARCH LABORATORY -- CATTS

A high fidelity, computer-driven, battalion-level simulation coupled with audio/visual recording technologies provided the laboratory for this research project. The Combined Arms Tactical Training Simulator (CATTS) is the most sophisticated device of its kind in the Army. It has the capacity to train mechanized and light infantry and armored battalion commanders and staffs in combined arms operations. The CATTS does this via a computer which contains math models and a digitized terrain data base which can realistically portray the movements of both friendly and enemy units, engagements of these units, weather, and use and input of smoke, as well as a host of other variables which can affect the outcome of the battle. The members of the command group, operating within a realistic mock-up of a Tactical Operations Center (TOC) equipped with a normal complement of communications equipment, interface with their "troops" through professional controllers and role-playing subordinate (company) commanders. The company commander controllers enter the battalion staff's orders into the computer where the battle is simulated. An opposing force controller enters directives for the operation of the enemy units, and the computer provides him, as well as friendly controllers, "feedback" vis-a-vis the status of the battle. The friendly controllers relay appropriate portions of the computer's feedback to the battalion commander and staff, and their reactions are "plugged" back into the battle. Both Mid-East and European terrain data bases are available.

The command group's TOC is equipped with cameras and microphones wired into a video recorder and a multi-channel audio tape recorder. The latter is capable of recording simultaneously all communication transmissions on all simulated radio nets available to the command group. Thus, it is possible to obtain complete audio and visual records of the command group's activities during the conduct of entire exercises. This is currently being done where there is no objection on the part of the participating command group (most do not object). The primary data base available for use in satisfying the first objective will be sets of audio and visual tapes of three entire battalion command group CATTS exercises.

The video and audio records made it possible to visit and revisit both intra- and inter-command group behavior in order to develop insights into what non-procedural individual and multi-individual skills and team behaviors are necessary for more efficient and effective functioning of the command group as a whole.

As part of the project, the initial recording system was evaluated and a series of improvements was made. The improved recording system was installed in September 1981 and included the following improved components:

- 5.5 mm lenses to provide a wider span of vision of the TOC;
- 6-hour video recorders to reduce tape handling and to improve video quality;
- improved noise filtering microphones to enable audible recordings of command group conversations;
- audio feedback controller to filter out background noise in improved audio recordings.

In addition to these hardware improvements, other procedural components were also installed:

- exercise diary recording to record major events as they occurred with references to the time code and tape counters;
- tape library procedures for recording and cataloging all video/audio tapes used for each exercise;
- documentation procedures to collect hard copy documentation on each exercise (sequence of scenarios to be used, participating unit, results of other scoring).

SECTION 2

MYTHODOLOGY DEVELOPMENT

SECTION 2

METHODOLOGY DEVELOPMENT

This section describes the methodological development in logical, not necessarily chronological, order. The sequence of topics follows the sequence indicated in the left column of Figure 1-1.

2.1 THE EXPERT PANEL WORKSHOP (Task 1.1)

Two months after the initiation of the contract (June 9-11, 1981), a workshop was conducted to address the conceptual and methodological issues for the project. The panel included experts in the fields of decision theory, organizational behavior, applied behavior research methodology, and Army command and control modeling. The workshop design followed this scenario: first, background materials on the issues were provided to all participants. The first session of the workshop presented briefings and discussion periods on (a) the methodological issues pertaining to the use of CATTS as the laboratory for the project and (b) review of the conceptual model proposed by SAI in its original proposal. Following the initial briefing, the remainder of the workshop involved a series of sessions of two smaller groups -- one dealing with the model, one with the methods with key resource individuals moving between the groups. The small-group sessions were interspersed with periods for the entire group to give status reports.

The methods group produced an extensive list of potential variables of interest; the list included annotations on ease of collection, method(s) of collection, (focusing on observational techniques) and categorization of each variable vis a vis the individual versus team distinction. Special attention was paid to observational techniques with audio/video recordings. For example, audio/video taping has been used in a variety of research situations. Specific applications with which the panel had personal experience included their use in management development exercises at IBM, teacher "micro teaching" described in detail in the SAI proposal and family therapy sessions conducted at Southern Illinois University. In all cases, the primary feature is to record interactions between individuals in order to provide in-depth post-session analysis and feedback to the participants. Several interaction scaling procedures for such setups were also discussed in the session.

The models group had the more difficult task. However, the group established a general analytical model which categorized variables into ultimate criteria, intermediate criteria, independent predictors and moderators. A primary point was the need to determine observable behaviors and corresponding operational definitions for model constructs.

The discussions generated by the panel helped structure the approach used during the year. The products served, and will serve, for the second and third year of the study, as benchmarks against which to assess conceptual and methodological design.

2.2 PREPARATION OF A DETAILED RESEARCH PLAN (TASK 1.2)

The original plan was submitted in May 1981 as per the SOW. However, it was recognized at the outset that Objective 1 of the project was indeed a highly experimental effort and therefore the plan would most likely have to evolve as experience was gained with CATTS. Further, the usual number of exogeneous variables impacted scheduled events. The plan was to include the outcomes of the expert panel workshop. However, this was delayed for two months for sponsor and contractor travel on objective 3. Further the three sets of video records to be examined at the outset of the project were so poor technically that no judgments regarding observational tasks or strategies could be done until basic enhancements to the recording system were implemented. It was the fifth month of the project before recordings of adequate technical quality were available to assess data collection feasibility. Subsequently, one initial behavior sampling approach was to observe the commander intensively since he: 1) set the tone for the group, 2) would be the maker of the key decisions, and 3) would talk with all the other key players from whom behavioral measurements were also needed. This approach had to be abandoned because the required equipment (remote wireless mike system) could not be located at a reasonable cost.

The incidents cited above are recounted only to indicate the evolving and experimental nature of the first year's activities. Nonetheless, as will be discussed in the sections below, major accomplishments were achieved in expanding the conceptual model, vastly improving the quality of recordings through equipment improvements which facilitated systematic recording procedures, developing a preliminary recording playback laboratory, designing observational tasks which detected higher level cognitive processes, carrying out a range of statistical and analytical procedures on the resulting data, and creating a semi-permanent library of extensive documentation and recordings of each exercise.

2.3 A SYSTEMS VIEW

Before proceeding further with the methodological development it is useful to step back and take a systems view of the research laboratory we are attempting to instrument. Figure 2-1 is a flow chart which portrays the principal components, their basic functions, and the gross information flow in CATTS.

The major components are: the players (the batallion C^2 group), the controllers, and a computer-assisted combat model. These are indicated across the top of the figure. Since the functions of an opposing C^2 side are subsumed into control, CATTS is properly viewed as a controlled one-sided game.

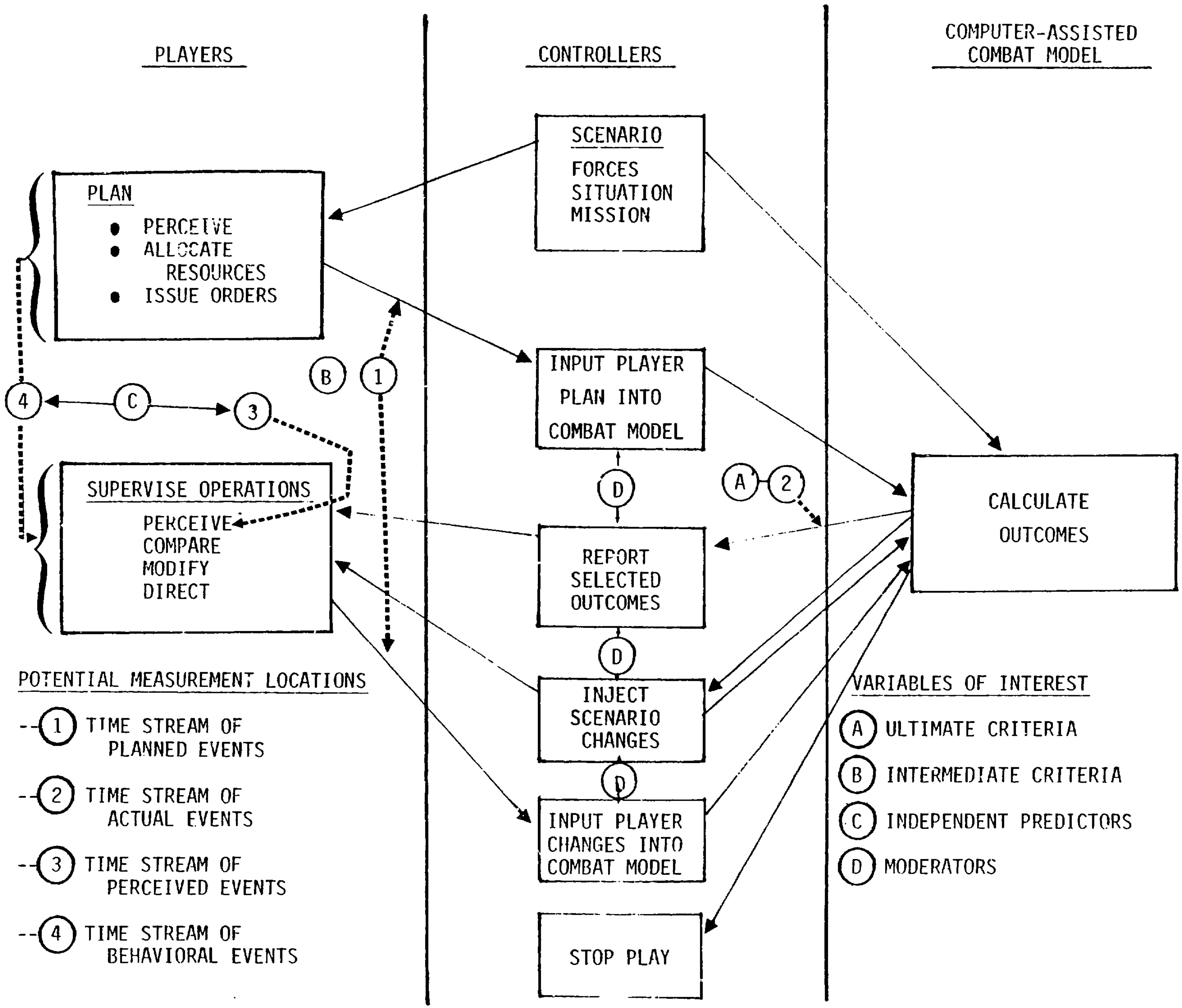


FIGURE 2-1. A SYSTEMS VIEW OF THE CATTS LABORATORY

The players carry out two primary functions. First, based on a scenario provided by the controllers, they prepare a plan for the operation. The scenario provides the basic information needed for planning, i.e., the forces and other resources, the situation to include the environment, and a tactical mission. The planning is accomplished "off-line," i.e., game play is not initiated until the plan has been completed. The plan is, basically, a schedule of desired future events which, if accomplished, would result in carrying out the assigned mission. The second basic player function is fighting the battle which begins after the plan has been entered into the simulation and play has been initiated. Based on combat simulation feedback provided the players through the control element, players build up a perception of the emerging situation, compare this with the desired situation as reflected in their plan, and issue modifications or additions to the plan, usually in the form of frag orders. These are, in essence, modifications to the original desired event schedule.

The controllers perform five basic functions: after providing players with a scenario, they input the player's plan into the combat model, feed back selected combat model outcomes to players, input new player orders into the simulation during the battle, and finally stop the play. It should be noted that the controllers provide a total buffer between the players and the simulation. Players have no direct access to the combat model, neither for inputs nor for outputs.

The computer assisted combat model has only one basic function, that of calculating combat outcomes resulting from the inputs injected by controllers from the initial player plan and subsequent player orders. The computer, of course, also maintains a log tape of all combat events and this tape is available for post-processing.

Clearly, CATTS is a highly dynamic combat model and a number of separate event sequences are being generated. Four of these are of direct interest to this study and are indicated in Figure 2-1. The first of these is the time stream of planned events emanating from both the planning and supervising functions and marked "1." The second is the time stream of actual events produced by the combat model and marked "2." Since both 1 and 2 cross interfaces between major elements of the simulation, they are relatively easy to access by means of suitable instrumentation. The other two time streams of interest exist only inside the player element. One is the time stream of events perceived by the players as a result of the reports of selected events relayed by the controllers. This is labeled "3" in the figure. The fourth stream consists of the entire ensemble of behavioral events generated by the players. This is labeled "4." The reason for distinguishing between 3 and 4 is discussed in the ensuing paragraphs.

The time streams generated within the simulation are also relatable to the variables identified by the expert panel (para. 2.1). The time stream of actual combat events, 2, provides the basis for the ultimate criteria (area exchanged, resources expended, force ratios achieved, and the rates for each) and is labeled A in the figure. The intermediate criteria, labeled (B), are contained in the player inputs into the simulation (1), i.e., the schedule of planned events. It is worth noting that ARTEP standards are, for the most part, such intermediate criteria. The independent predictors, C , are contained within time streams (3) and (4). Finally, the principal source of moderators in this system is provided by the controllers. As indicated in the figure, controller processing of outputs from players as well as inputs to players from the simulation provides the opportunity to moderate the outcome. Such moderation is conceptually measureable by comparing the information stream as it flows into with that flowing out of the control element -- labeled (D).

Based on the four-event time streams identified in Figure 2-1 it is possible to construct four basic classes of metrics of potential application in this study. At this stage the possibility is conceptual; their feasibility must still be estabished. Comparison of the time streams at designated times could potentially yield the following:

- (1) vs. (2): The quality of the plan and subsequent changes (frag orders). Did the scheduled events occur? At the scheduled time? Such a measure would also serve to test the validity of selected intermediate criteria.

- (2) vs. (3): The slack in the total C^2 system, i.e., how much does the perceived situation lag the actual? How incomplete is it? How many errors in it? Is it valid? It must be noted that this is not a measure, <u>per se</u>, of the delays, errors, incompleteness, and spoofs contained in the information provided the players, but rather a measure of their ability to cope with the uncertainty generated by such information defects. In CATTS, these defects are generated primarily by the controllers and are therefore essentially uncontrollable.

- (1) vs. (3): The magnitude of the error signal tolerated by the players. This is the perceived difference between what was planned and what occurred and forms the basis for further changes to the plan. It would be interesting to compare the magnitude of this metric with the magnitude of the "slack" above and with the ultimate criteria derived from time stream 1 .

- (2) vs. (4): This comparison will identify indicators of effective C^2 performance.

Both time streams 3 and 4 are internal to the players element and require instrumenting player activities. In fact, stream 3 results from a subset of stream 4. It has been identified separately only to be able, conceptually, to separate perception from decision.

The effort during year 1 of this study has been concentrated largely on time streams 2 and 4, in fact, almost exclusively on the technical problems involved in collecting time stream 4 data in the laboratory and means for reducing these data from the tapes on which they were collected.

2.4 DEVELOPMENT OF A MODEL OF C^2 GROUP BEHAVIOR

The next step in the development of a methodology for this study was the refinement of a conceptual model of C^2 group behavior. Such a model is critical for establishing a basis for the behavior assessment strategies and the ensuing analysis. In this project a specific team configuration is examined in a specific environment -- the battalion level C^2 group in a simulated combat configuration. Although not specifically focused on battalion, Tiede (1980) examined the mid-level tactical staff operations and proposed a model which describes the functions and information handling processes of a typical decision-making node in the command control system. We will examine that model and extend it to consider team behavior issues raised in the previous section. This extended model provided the basis for the hypotheses and research approach used in this study.

2.4.1 The Decision Node

The SAI team's approach to creating a model of command-control group behavior is to consider the command-control group as a decision node in a tactical information system. Figure 2-2 is a functional representation of the tactical information system in a combined arms force. The physical flow of the service support to the force from outside support sources 1, its redistribution to the other combat functions 2, the application of firepower on the enemy and the environment 3, and the enemy's return fire and other physical actions which can be sensed 4, are all shown as heavy, solid arrows. The flow of information, on the other hand, is shown by narrow arrows, all of which are within the combined arms force box, except for status information 5 and tasking 6, which flow to it from higher and supporting forces. The decision node, i.e., the Tactical Operations Center (TOC), is shown as the three functional boxes at the left. (It should be noted that this is a functional representation. The author is quite aware that the commander is frequently not physically located in the TOC, and may, with elements of the staff, be at a forward command post or with subordinate units.) Sensor 7 and status 8 data flow into the combat management function as do mission 5 and status 6 information from higher headquarters. Preprocessing correlates and collates the available information as to make it reasonably coherent. This provides the basis for situation recognition, which, in turn, provides the basis for status

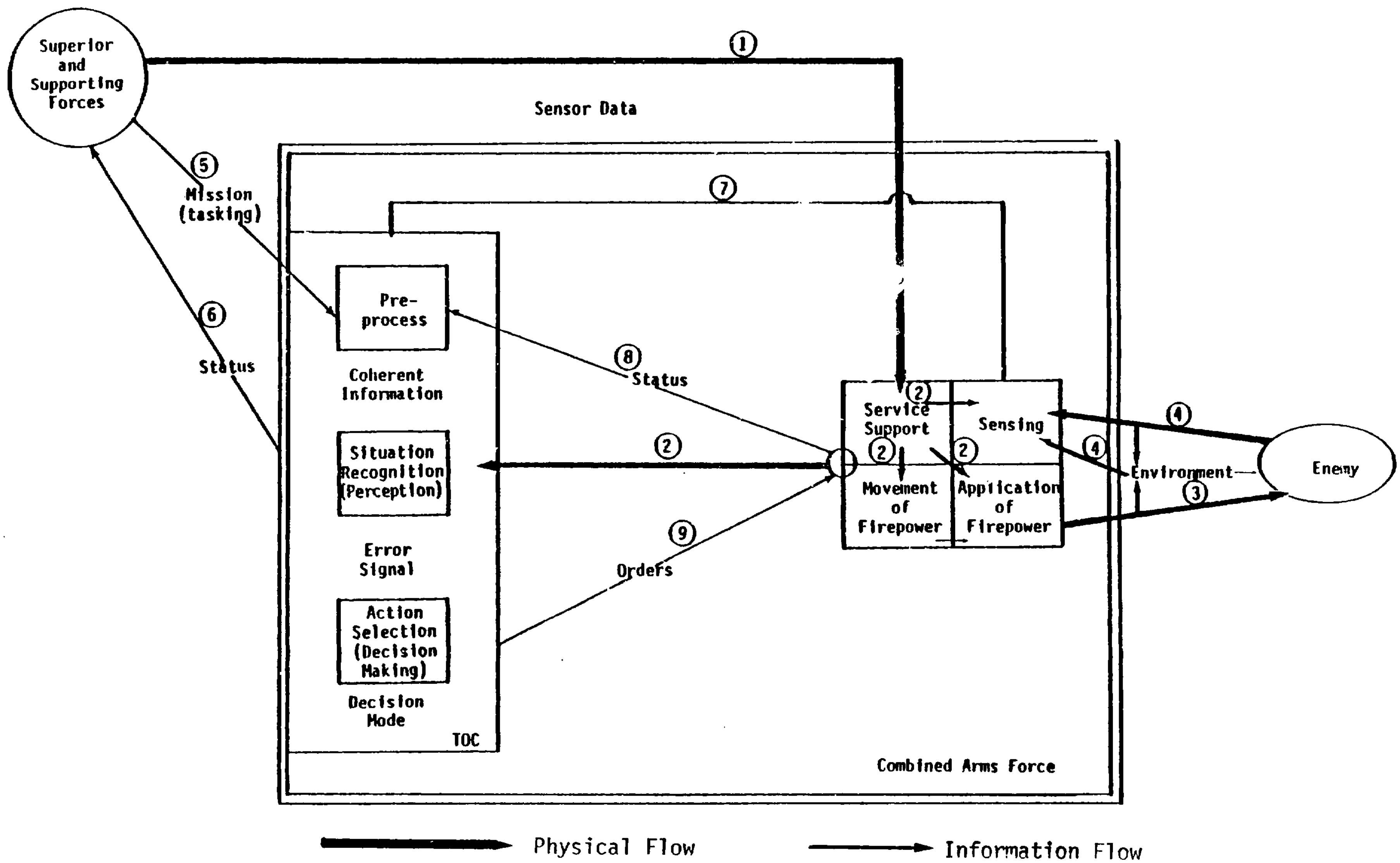


FIGURE 2-2. INFORMATION FLOW IN A COMBINED ARMS FORCE

information fed back to higher headquarters and may generate "error" signals. The latter result from comparison of current status information with planned states and are the basis for triggering the action selection process. The process produces orders 9 that flow back out and cause changes in other combat functions. It should be noted that, even within a single echelon of command, decision making is hierarchical, i.e., minor decisions are made by the staff and major decisions are made by the commander.

Before proceeding to dissect the decision node, it is pertinent to review the role of the commander and staff as described in Army doctrine. The Staff Officer's Field Manual (Department of the Army, 1972) states:

- "Command is the authority that a commander in the Military Service exercises over his subordinates by virtue of his rank or assignment. Command includes the authority and responsibility for effectively using available resources and for planning, organizing, directing, coordinating, and controlling military forces for the accomplishment of assigned missions. The commander alone is responsible for all that his unit does or fails to do . . . He is assisted in performing command functions by deputy or assistant commanders and staff . . ."

- "The staff consists of officers who are specifically ordered or detailed to assist the commander . . . Five functions are common to all staff officers:

  - Providing information
  - Making estimates
  - Making recommendations
  - Preparing plans and orders
  - Supervising the execution of plans and orders."

Clearly, these five functions are cyclic in that supervising execution of plans and orders provides new information which can be the basis for continuing the cycle.

Supervising the Execution of Plans and Orders and Providing Information (input and preprocessing)	Produces	Section Files/Displays
Making Estimates and Recommendations (processing)	Results from	Perception and Decision Making
Preparing Plans and Orders (output processing)	Amounts to	Output Processing

In summary, then, it may be said that the purpose of the military staff at any echelon is to facilitate human decision making by carrying out the supporting input, processing, and output functions.

The most elementary level of the tactical decision node, i.e., the C^2 group of a combined arms force, can be thought of as a black box that receives inputs, stores data, and generates outputs. In other words, it transforms the input data in some way. That this transformation of input data is not simple is demonstrated by the fact that not all data elements that are input via the formal system network emerge as outputs. On the other hand, a substantial number of data elements contained in the outputs apparently never entered the node as inputs -- at least not via the formal information network. The decision node acts as a combination data sink and generator. Neither phenomenon is particularly surprising since the human elements within the decision node are adept at discarding data that do not appear to be useful. The same elements have memories so that the effective data base of the node is partly loaded even before any particular action begins. Furthermore, these human elements are quite capable of adding new hypotheses to the information stream, which amounts to the assignment of probabilities to current and future events based on currently available data. To the extent that these hypotheses are used in decision making or included in outputs, they are tantamount to the creation of new information, i.e., information that did not arrive via the input terminals.

2.4.2 Decision Node Functions

It was originally proposed, and our research plans indicated, that we would use the model developed in the earlier SAI study, "Division Level Battle Simulation" (Tiede, 1980), as the starting point for the current study. The earlier model provided some useful insights and some usefully defined components such as staff actions, triggers, and elementary operations. Among the insights developed were the following:

- Although the actual sequence of elementary operations performed by live staffs is highly variable both by type of staff action and as a function of time (load, mood, etc.), staff behavior in processing staff actions does seem to cluster into at least three phases: input processing, decision making, and output processing. The first and last of these phases are primarily administrative and affect the routing rather than the content of the data stream.

- The notion of elementary operations began by noting observable changes in procedural behavior by members of staff groups, and, thus, were clearly tied to actions by a single individual. This notion was extended in the ARI simulation study to break down the cognitive operations into logically distinct components by an outside observer. They were, however, still thought of as individual behaviors with one or two exceptions. It has become increasingly clear that several of the higher level cognitive operations are frequently performed by small, informal groups rather than by an individual.

These insights led to the following considerations. The individual decision node can be thought of as a black box embedded in a communication net. This black box has as its boundaries easily discernable input and output processes. However, within the black box, some sort of transformation takes place which we can label simply "process" so that the decision node as whole can be described in terms of an input-process-output, or IPO model. The input and output processes are observable and can be specified, but the internal process is not observable nor can it be specified until we take a look inside of the black box. But, we also know that the inside of the decision node is usually populated by a group of individuals and a set of equipment used by the individuals to facilitate the interior processes. Groups of individuals engaged in such information processing, just like groups engaged in any other joint activity, tend to organize themselves into specialties. A division of labor follows which takes advantage of the special skills and experience -- and place in the pecking order -- of each individual. In other words, an organizational structure emerges. There may even be sub-teams of individuals and equipments within the decision node as a whole. Each such sub-team, and finally each individual, can be thought of as another IPO model with observable inputs and outputs. In such a structure, information must be transferred between sub-clusters and between individuals and to data storage devices (files, maps, displays, and terminals). This provides the significant advantage, from the viewpoint of analyzing the processes interior to the decision node, that multiple new interfaces exist. An examination of these interior input and output processes may well provide better insights into the nature of the information process actually being performed. This amounts to breaking the decision node down into a hierarchy of IPO models in which the individual is the lowest level. In this paragraph, we shall develop this notion at the sub-team level, and in the following paragraphs, we shall proceed to the level for the individual as a component of the C^2 group. In this way, we can begin to dissect the interior node "process" into functions performed by sub-clusters and information processes performed by individuals and data storage devices (files, maps, displays, and terminals). Additional functions and individual processes can now be discerned as products flowing between them become observable.

The first major function that now becomes observable is that of a buffer between the input and output processes and the higher level decision processes. This is illustrated in Figure 2-3. The raw data extracted from the information stream by the input function is prepared for the decision makers by sorting it, associating it (placing it in context), aggregating it, and organizing it into a form most easily assimilated for decision making. Similarly, the decision must be prepared for output processing to transform it into information that

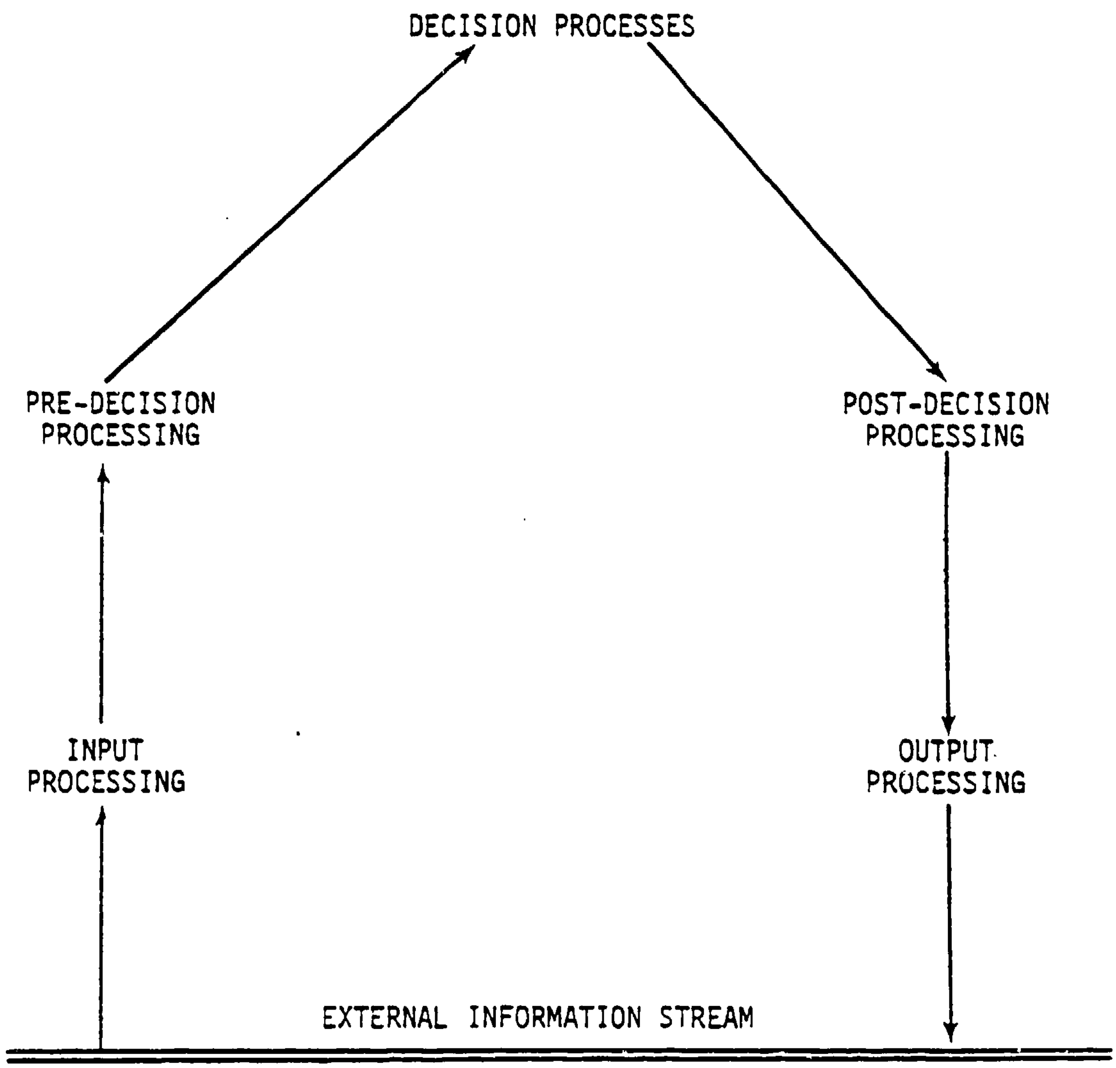


FIGURE 2-3. COMMAND CONTROL GROUP FUNCTIONS

will be useful to the agency(ies) that will implement it. Think for a minute what must be done to the course of action selected by the commander to transform it into an OPLAN.

Lest one fall into the trap that the command control group is an entirely reactive entity, one must immediately recognize that the arrows shown in Figure 2-3 neither imply that this is a continuous process, nor that every input produces an output, nor even that all outputs can be traced to specific inputs. Just as individual human reactions are not necessarily triggered by external stimuli, group outputs can be triggered by internal stimuli which can vary in complexity from periodic reports triggered by an internal clock to actions taken as a result of profound insight or hypotheses generated long after the arrival of the latest segment of raw data that has been considered.

2.4.3 Decision Node Processes

The division of labor does not, however, stop with the functions identified in Figure 2-3. The functions identified there are not always performed by a single individual so that processes comprising each of these functions can also be identified. Figure 2-4 expands the model to show each identifiable process and describes its components, its attributes, and the product on which it operates. This will be done in the sequence indicated in the figure rather than alphabetically. Although an effort will be made to keep the discussion general, i.e., so that it applies both to manual and ADP-assisted groups, the initial discussion will concentrate on the manual mode; changes resulting from automation will be discussed later. The definitions of the model components follow:

> COMMAND CONTROL GROUP: An assemblage of more than one individual and the equipment (communication terminals, files, displays, data processing equipment, etc.) needed to function as a decision node in a tactical command control system. Members of the group are collocated so that non-verbal communications are facilitated. Conversely, members are in some degree shielded from non-verbal communication with non-members of the group. Military staffs of larger units usually function as a number of separate and distinct command control groups (staff sections).
>
> EXTERNAL INFORMATION STREAM: This includes all information received by the command control group from sources outside itself and all transmitted by the group to recipients outside itself. It includes all means of communication (oral, written, electrical, gestures) and includes information to and from other command control groups (staff sections) within the same headquarters -- to include the grim visage of the CG who is still waiting for the chopper he ordered 30 minutes ago. Most of the information flowing in this external stream is in the form of messages.

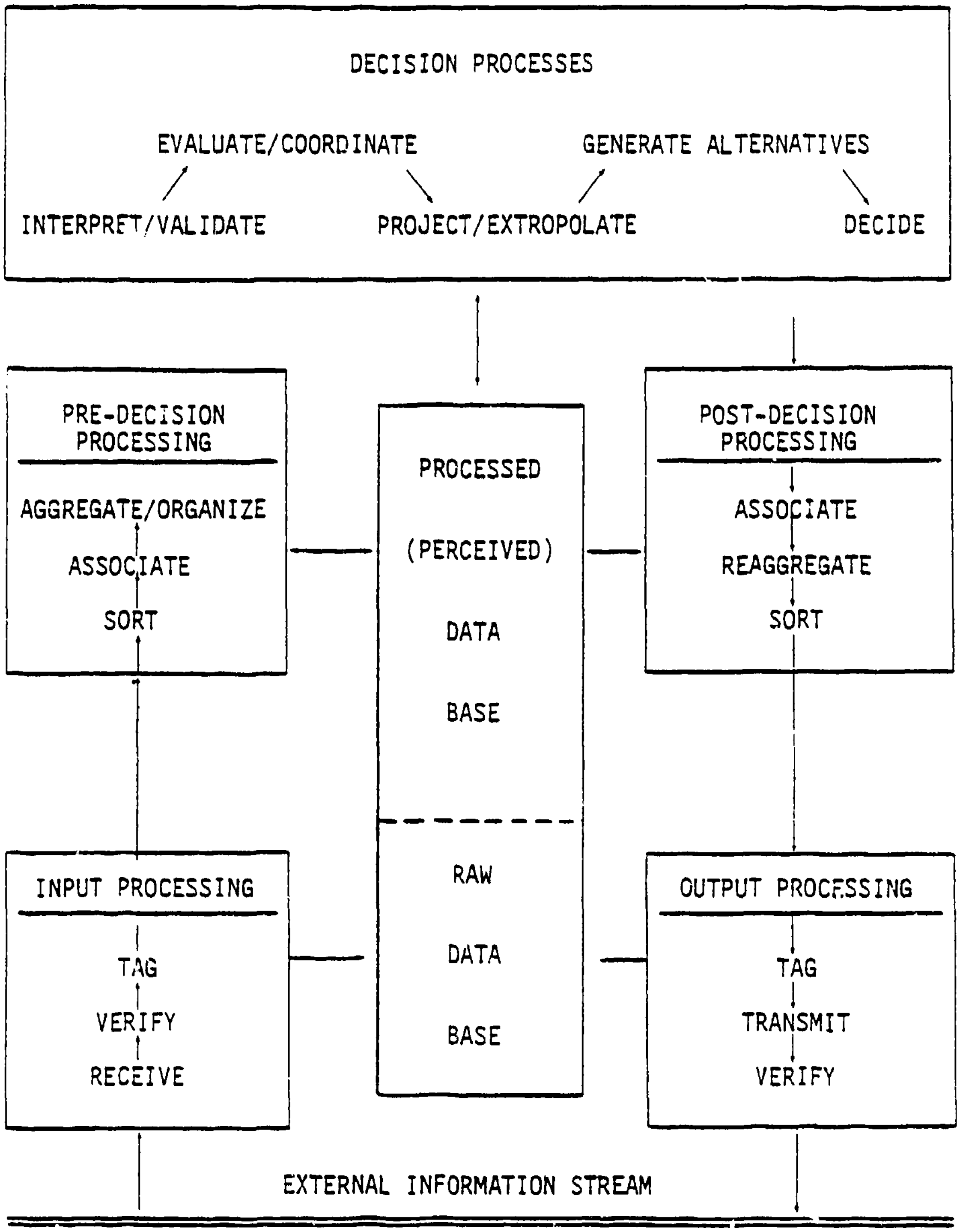


FIGURE 2-4. COMMAND CONTROL GROUP PROCESSING STEPS

MESSAGE: An ordered selection from an agreed set of signs (alphabet) intended to communicate information (Cherry, 1957).

RECEIVE: The process of accepting the string of signs or symbols that constitute a message -- or the process of making a one-for-one transformation of the incoming string, e.g., copying an incoming voice message or repeating aloud an incoming message. This process does not include transforming the string of symbols into information.

VERIFY: The process of ensuring that the accepted string of signs or symbols agrees precisely with the string to be transmitted by the sender. This process may require transmission of procedural signs or even retransmission of the message string by the receiver. It is this process which reduces uncertainty in the sense of Shannon's Communication Theory (Pierce, 1961).

TAG: To affix an identifier (frequently a sequence number) to a message to facilitate retrieval from the raw data base.

RAW DATA BASE: A file containing incoming and outgoing messages processed only through the verification and tagging stages. Example: Staff Journal.

SORT: To arrange entire messages or segments of messages according to a predetermined classification scheme. This is the lowest level process requiring some perception of message content -- at least at the level of the classification scheme. Example: Extracting unit location from a SITREP.

ASSOCIATE: To relate a package of sorted information to other information in the same or allied class. Example: Is the 1st Battalion of the 32nd Tank Regiment part of the 20th Guards Tank Division?

AGGREGATE/ORGANIZE: To combine associated information and array/display it in a manner that facilitates the decision processes. Example: Update the Order of Battle.

PROCESSED (PERCEIVED) DATA BASE: The information used for the decision processes as the best estimate of ground truth.

INTERPRET/VALIDATE: To hypothesize cause-and-effect relationships between ordered sets of information and to assess the probability of their correctly representing ground truth. Since ground truth is usually not accessible, validity must be assessed in terms of consistency with past experience, or against independently derived hypotheses from within or outside the group. This process is significantly different from "reduction of uncertainty" in the Shannon sense (Pierce, 1961). Example: How can the 2/31 Battalion continue to advance at over 5 km/hr against two regiments when it has sustained a reported 60 percent casualties?

EVALUATE/COORDINATE: To determine whether the perceived situation warrants consideration of taking further action or of sharing the perception with another command control group or of both. Example: Does the gap apparently opening up on our right flank warrant issuing a frag order, or notifying the adjacent unit, or both?

PROJECT/EXTRAPOLATE: To estimate probable future situations based on current or predicted trends. Example: Where and when must I lay on the next ammunition resupply operation if present expenditure and movement rates continue?

GENERATE ALTERNATIVES: To postulate alternative courses of action for both friendly/enemy forces which could conceivably lead to mission accomplishment. Enemy missions must usually be inferred or multiple missions within his capability must be considered. The latter process is usually referred to as "determining enemy capabilities."

DECIDE: The process of determining which of the alternatives considered is most likely to yield the greatest success in accomplishing the assigned mission.

ASSOCIATE (POST-DECISION PROCESSING): To relate fully processed information during preparation of output message, and to update impacted data bases. Example: The decision "main effort on the right" might be transformed into "2d Brigade attacks in zone, makes main effort . . . priority of fires to 2d Brigade."

REAGGREGATE: To combine fully processed, relevant, and needed information into preparation of an output message. Example: Revise the Organization for Combat in accordance with the decision.

SORT (POST-DECISION PROCESSING): To arrange segments of an outgoing message in the selected format and to determine distribution.

TAG (OUTPUT PROCESSING): To affix an identifier to an outgoing message.

TRANSMIT: The process of entering into the external information stream the string of signs or symbols that constitute the message.

VERIFY (OUTPUT PROCESSING): Same as for input processing.

Having postulated five functions carried out by C^2 groups and described a series of processes that appear to be performed in each, it would be interesting to compare this with other taxonomies of human performance. It would also be comforting if there appeared to be some degree of correspondence. An effort to correlate the processes identified above with the human ability requirements approach to describing the performance of various tasks proved to be not very fruitful. Unfortunately, the tasks investigated by Theologus and Fleishman (1971) were, for the most part, not tasks involved in the information processing carried out in C^2 groups. However, a comparison of these processes with the taxonomy of tasks identified by J. S. Kidd in Gagne (1962) showed great similarity. Kidd's task descriptions were oriented to radar man-machine systems. It is remarkable that the same task descriptions are applicable to so many of the processes identified in C^2 groups ranging from corps to battalion. Table 2-1 lists the functions and processes identified above, and at the far right the task descriptions proposed by Kidd. The Kidd tasks which most closely correspond to the information processes are indicated.

2.4.4 Process Sequence

The sequence of arrows in Figure 2-3 shows the postulated information flow in carrying out these processes to include data storage and retrieval in the indicated files. The reader may well wonder in comparing Figures 2-3 and 2-4 why there is no arrow leading directly from pre-process to the decision processes. The reason is that the decision processes seem to be triggered far more as a result of scanning the updated perceived data base than by the arrival of a specific message. Even in those cases where the arrival of an important message, e.g., a frag order, inevitably involves the decision processes, the latter are not invoked until after the newly arrived message has been placed in the context of the perceived data base through pre-processing.

The sequence of decision processes indicated in Figure 2-4 cannot be interpreted too rigidly at this time. As indicated earlier, it is only by observing the internal information transfers within the staff group that these processes can be observed separately. The breakdown into processes and their sequence displayed in Figure 2-4 is based on limited observations in this and previous studies (Tiede, 1975 and 1978), and must be treated as a hypothesis still to be tested. Furthermore, this sequence can be observed if and only if an observable information transfer in fact takes place between successive processes. When a series of processes is performed by a single individual there is, of course, no way of ascertaining the sequence in which they are performed or whether they have beeen performed at all. This is made even more difficult by the fact that a single individual performing a series of these processes will depend far more on his memory than on the formal data base for his processed information thus further reducing the observable data transfers.

There is ample opportunity in the command control group for such preemption of the formal decision process sequence by the more senior individuals. The following division of labor is frequently observed: decision processors (senior officers), pre- and post-decision processors (junior officers and NCOs), and input and output processors (telephone and radio operators and journal clerk). If a decision maker

FUNCTION	PROCESS	TASK (Kidd)
INPUT	Receive Verify	Signal Detection
	Tag	Signal Classification
PRE-PROCESS	Sort	Value Weighting Destination Routing Recoding
	Associate	Patern Construction
	Aggregate/ Organize	Accumulating Summarizing
DECISION	Interpret/ Validate	Cause & Effect Attribution
	Evaluate/ Coordinate	Critical Cause Selection
	Project/ Extrapolate	Time-line Analysis & Prediction
	Generate Alternatives	Pattern Construction Time-line Analysis & Prediction
	Apply (Decide)	Effect Evaluation Action Selection
POST-PROCESS	Associate Reaggregate	Synthesis
	Sort	Selection
OUTPUT	Output Tag	Signal Classification
	Transmit Verify	Output Processing

TABLE 2-1. A TAXONOMY OF INFORMATION PROCESSES AND TASKS

answers the telephone, he may give a response which has circumvented the entire set of decision processes, or, more likely, thay have all occurred within his mind using only his memory as a data base. Even more frequently, a decision maker will overhear an incoming message, glance at a display such as the SITMAP, think for a moment, and trigger the post-decision and output processes by dictating a frag order to an NCO.

It is clear from the above examples that the decision processes are the ones most often performed uninterruptedly by a single individual and are therefore the most difficult to discern. In this connection it is interesting to observe the parallelism between the sequence of decision processes postulated in Figure 2-4 and the steps of the decision technique taught in the military service schools. This technique is usually referred to as the Estimate of the Situation. The culmination of this process is the Commander's Estimate. Figure 2-5 shows that the basic sequence is exactly the same and that, indeed, the estimate may provide a basis for further subdivision into even finer processes. This should be investigated in subsequent observations.

As was also indicated earlier there is not a one-for-one relationship between inputs and outputs. Numerous inputs get no further than the first three or four decision processes -- or even the pre-decision processes -- and are used only to update the data bases, to include the waste basket, without triggering an immediate output. This in no way indicates that such updating of the data base is trivial. On the other hand, many outputs appear to be triggered spontaneously and cannot be traced to any specific input. These may be the result of the continuing background processing going on with respect to the data base and represent reactions to associations not made earlier. Others may, however, indicate the generation of initiatives rather than knee-jerk reactions to individual stimuli. Such initiatives are frequently of the kind in which the decision maker seeks to reduce uncertainty by taking an action which restricts his opponent's freedom of action so that the opponent's actions, in effect, become predictable. Such decisions are clearly in the domain of what Streufert (1981) terms "Complexity Theory." A model such as this may provide a basis for searching for behavior, non-procedural as well as procedural, that is associated with such decision making in order to apply the measures proposed by Streufert.

2.4.5 Human Skills

Having defined a set of information processes performed in a command control group, one can examine the skills needed to perform these processes in the manual mode. A proposed listing of required skills is shown at the row headings of Figure 2-6 which relates those skills to the previously defined information processes. These skills were selected and arrayed on a basis of increasing complexity and so that the successively higher level processes invoke all lower level skills. This permits arraying the skills so that the lowest comprise the Level 1 skills required for the input and output processes. The

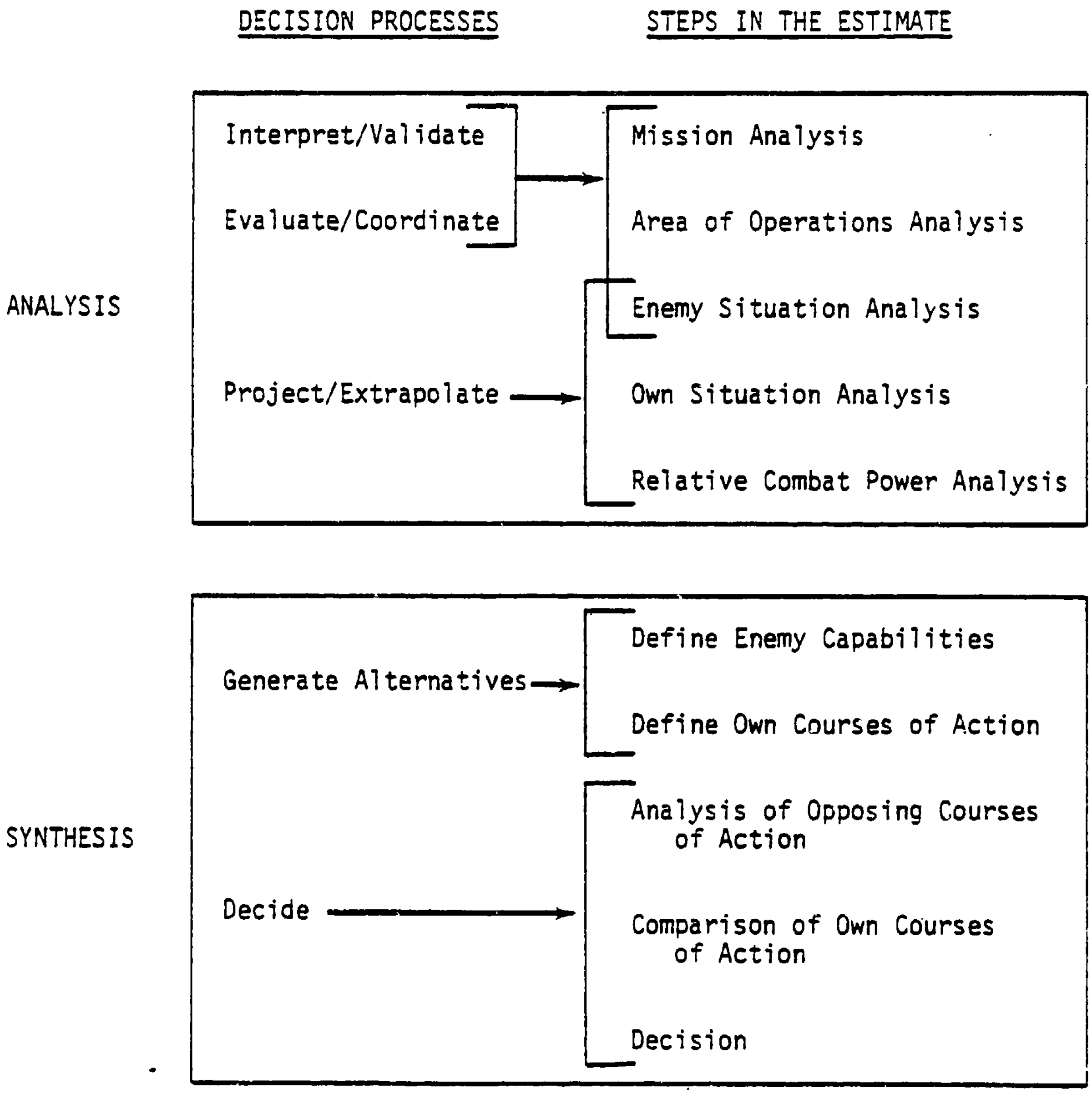


FIGURE 2-5. DECISION PROCESSES IN THE ESTIMATE OF THE SITUATION

REQUIRED SKILLS	COMMAND CONTROL FUNCTIONS AND PROCESSES	INPUT PROCESS			PRE-DEC PROCESS			DECISION PROCESS					POST-DEC PROCESS			OUTPUT PROCESS		
		RECEIVE	VERIFY	TAG	SORT	ASSOCIATE	AGGREGATE/ORGANIZE	INTERPRET/VALIDATE	EVALUATE/COORDINATE	PROJECT/EXTRAPOLATE	GENERATE ALT'S	APPLY (DECIDE)	ASSOCIATE	REAGGREGATE	SORT	OUTPUT TAG	TRANSMIT	VERIFY
LEVEL 3	Weigh Alternatives							✓	✓	✓	✓	✓						
	Construct Alternatives							✓	✓	✓	✓	✓						
	Think							✓	✓	✓	✓	✓						
LEVEL 2	Compose					✓	✓	✓	✓	✓	✓	✓	✓	✓				
	Calculate					✓	✓	✓	✓	✓	✓	✓	✓	✓				
	Retrieve				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
	File/Post/Plot				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
	Perceive				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
LEVEL 1	Write	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Read	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Comprehend Speech	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Speak	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Non-Verbal	Point	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Listen	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	See	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

FIGURE 2-6. HUMAN SKILLS VS COMMAND CONTROL PROCESSES

pre- and post-decision processes require Level 2 skills as well as Level 1 while the decision processes require all three levels. Level 1 begins with such elementary skills as see, listen, and point. These have been included because non-verbal as well as verbal skills must be considered in any study of group behavior. As an example of this consider that a trained military observer, even though he understood not one word of English, could after a short time in one of our command posts tell whether we were winning or losing a battle. The next four skills (speak, comprehend speech, read and write) refer only to the ability to manipulate strings of symbols that compri. a message. They do not refer to the ability to associate meaning with the symbols. Receiving, transmitting, and verifying manually encrypted messages is the perfect example of the skills referred to here. Thus defined, manual encryption and decryption are reading and writing skills. Because of the previous definition of "tag" no skills higher than Level 1 are required as long as tagging means simply the assignment of a unique identifier to a complete message, usually in sequential order.

It is only when we reach Level 2 skills required for the pre-decision processes that perception of message content is necessary. Even here, the perception need to be at no deeper level than that of the sorting or filing scheme to be used. This has profound implications when we consider automation of these processes as is discussed in the next section. The skills of entering (file, post, plot) and retrieving data from data bases round out the sorting process. Associate and aggregate/organize add a requirement for calculating and composing. Since these processes should not add new information to the stream, they are reformulations of data elements already in the data base.

All of the decision processes require all of the Level 3 skills. This may not be immediately apparent until one realizes that any one of the five decision processes can generate an output message. For example, the process of interpret/validate can require the skills needed to answer questions such as, "Who is in a position to know ground truth with reference to this? Who can report ground truth most quickly and with required detail? How shall I send the query? Who needs copies? Similar considerations apply to all the other decision processes. The post-decision and output processes are exact parallels of the pre-decision and input processes insofar as their relation to skills is concerned. The result is the distribution shown in the matrix representative of Figure 2-6 which resembles a truncated Gaussian distribution.

Such a model of command control group behavior and the associated skills may be especially useful in developing the diagnostics needed to associate operational deficiencies with the specific skills requiring training. The author admits that the skill identified as "think" may not provide much diagnostic help until it is better defined. At the very least it requires a much deeper understanding of message content than the Level 2 skill "perceive."

2.4.6 Effect of Automation on Performance

Having structured a model of the command control processes one can use it to determine not only the applicability of automation to those processes but also probable changes in performance. We begin by examining the capabilities of automation in terms of the human skills listed in Figure 2-6.

Skill	Automation
See Listen Point	These three most elementary Level 1 skills were previously defined as the skills required for non-verbal communication. Data processing systems can be programmed to exhibit these skills, at least to a limited degree. They can, for example, "point" to predesignated collections of signs and symbols in a display, "see" a person point with a light pen, and "listen" to pre-programmed voice commands. For the foreseeable future, however, it is probably safe to say that substitution of man-machine communication for inter-person data exchanges and for manual file manipulation will tend to reduce non-verbal interactions within and between command control groups.
Speak Comprehend Speech Read Write	As previously defined these skills refer to accepting, entering, or making one-for-one transformations of the strings of signs or symbols that comprise a message; they do not include extracting information from those symbols. In that context automated systems are at least an order order of magnitude better than human processors because they are faster, make fewer errors, and provide hard copy.
Perceive	This skill requires extracting information from the signs and symbols comprising a message, i.e., association of ideas or concepts with those signs down to the level of resolution of the classification scheme being used. At a higher level, it requires understanding sufficient to evolve a classification scheme. An automated system can neither associate meaning with messages nor evolve new classification schemes. This skill must be provided by a human processor if any of the pre-decision C^2 processes are to be ADP-assisted (usually by adding "keys").

File/Post/Plot Retrieve Calculate	Once the perception has been supplied by a human processor, automated systems are superb at performing tasks requiring these skills. They are infinitely faster and error free compared to human processors.
Compose	This is the reverse of the skill required for "perceive" and involves encoding the ideas comprising a message or message component into a string of signs and symbols. The corollary part of "compose" is "edit" which involves verifying that the string of symbols has no errors. The automated system by itself can neither compose nor edit. However, man and machine together can so improve the edit portion that composition requires far less time and is significantly more error free.
Think	This is the skill needed to understand the processed data in the perceived data base at the level required for decision making. This frequently involves estimating some semblence of ground truth from a confused or even chaotic, dynamic data base. Such skills have not yet been imparted to computers.
Construct Alternatives Weigh Alternatives	These are the basic skills required to cope with the uncertainties inherent in tactical decision making. The attribution of such skills to a computer is equally beyond the state-of-the-art as for "think." However, as in the case "compose" the combination of man and machine significantly alters this verdict. Ready access to automation by the decision maker can also speed and improve both formulation of alternatives and weighing their most likely outcomes that these human skills can be significantly expanded through ADP assistance.

Based on the above determinations we can now estimate the probable effect of automation on each of the C^2 processes. To do this we will redraw the matrix of Figure 2-6 to black out those squares for which each skill is not required. The non-verbal Level 1 skills will be ignored for the determinations. In each of the remaining white squares we will now enter a value that represents the degree to which the C^2

system being evaluated can perform that skill. This is done for an all-manual system in Figure 2-7, as the baseline. We will assume a well trained C^2 group and arbitrarily enter "1" for each skill. Since every skill for which an entry has been made is required to execute the process, we will calculate the geometric mean, i.e., the nth root of the product of the n factors in each column, in order to arrive at a mean value for the performance of each process. For the baseline where every entry is "1," the geometric mean is also "1" as is the ratio of improvement over the baseline (last row at bottom of the figure).

Figure 2-8 examines the capability of a completely automated system to perform the C^2 processes. The assumption is made that for those skills which can be built into the totally automated system it will perform at least one order of magnitude better than will a human operator. Thus we enter a factor of "10." For those skills which cannot be imparted to a totally automated system we enter "0." Calculating the geometric means we now find that the input and output processes are improved by a factor of ten but that none of the rest of the processes can be performed at all because one or more of the required skills is lacking.

Finally, if we examine an interactive system in which a human element provides those skills which cannot be imparted to the automated system, but these are performed in an interactive mode as discussed above, the results are shown in Figure 2-9. All of the C^2 processes, to include the decision processes, can now be performed with significant improvement over the manual mode.

2.4.7 Extending the Model to Individual Behavior

The model described in the previous section focuses on the command control group as a node. It was acknowledged that a single individual may occasionally perform all the functions. In order to fully address the requirements to differentiate team from individual and multi-individual behaviors, let us examine further how the model is applied to account for the fact that all individuals have the capacity to perform all the functions at some level of difficulty or complexity (e.g., the commander DECIDES on tactical alternatives, the RTO may not DECIDE on issues as complex, but he does DECIDE who gets what information and how quickly they get it - and in some cases, the influence of this decision can be as significant as the commander's.)

Figure 2-10 clarifies the categories of behavior which the model needs to address. The ultimate goal is to identify and quantify the behavior in cell 6. However, the requirement also exists to determine how much the cell 6 behaviors account for overall team performance relative to the behaviors in the other cells.

		INPUT PROCESS			PRE-DEC PROCESS			DECISION PROCESS					POST-DEC PROCESS			OUTPUT PROCESS		
REQUIRED SKILLS	COMMAND CONTROL FUNCTIONS AND PROCESSES	RECEIVE	VERIFY	TAG	SORT	ASSOCIATE	AGGREGATE/ORGANIZE	INTERPRET/VALIDATE	EVALUATE/COORDINATE	PROJECT/EXTRAPOLATE	GENERATE ALT'S	APPLY (DECIDE)	ASSOCIATE	REAGGREGATE	SORT	OUTPUT TAG	TRANSMIT	VERIFY
LEVEL 3	Weigh Alternatives							1	1	1	1	1						
	Construct Alternativer							1	1	1	1	1						
	Think							1	1	1	1	1						
LEVEL 2	Compose					1	1	1	1	1	1	1	1	1				
	Calculate					1	1	1	1	1	1	1	1	1				
	Retrieve				1	1	1	1	1	1	1	1	1	1	1			
	File/Post/Plot				1	1	1	1	1	1	1	1	1	1	1			
	Perceive				1	1	1	1	1	1	1	1	1	1	1			
LEVEL 1	Write	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Read	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Comprehend Speech	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Speak	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	N	4	4	4	7	9	9	12	12	12	12	12	9	9	7	4	4	4
	$\sqrt[n]{\pi n}$	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	X MANUAL	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

FIGURE 2-7. CAPABILITIES OF MANUAL SYSTEM TO PERFORM C^2 PROCESSES

REQUIRED SKILLS \ COMMAND CONTROL FUNCTIONS AND PROCESSES		INPUT PROCESS: RECEIVE	INPUT PROCESS: VERIFY	INPUT PROCESS: TAG	PRE-DEC PROCESS: SORT	PRE-DEC PROCESS: ASSOCIATE	PRE-DEC PROCESS: AGGREGATE/ORGANIZE	DECISION PROCESS: INTERPRET/VALIDATE	DECISION PROCESS: EVALUATE/COORDINATE	DECISION PROCESS: PROJECT/EXTRAPOLATE	DECISION PROCESS: GENERATE ALT'S	DECISION PROCESS: APPLY (DECIDE)	POST-DEC PROCESS: ASSOCIATE	POST-DEC PROCESS: REAGGREGATE	POST-DEC PROCESS: SORT	OUTPUT PROCESS: OUTPUT TAG	OUTPUT PROCESS: TRANSMIT	OUTPUT PROCESS: VERIFY
LEVEL 3	Weigh Alternatives							0	0	0	0	0						
LEVEL 3	Construct Alternativer							0	0	0	0	0						
LEVEL 3	Think							0	0	0	0	0						
LEVEL 2	Compose					0	0	0	0	0	0	0	0	0				
LEVEL 2	Calculate					10	10	10	10	10	10	10	10	10				
LEVEL 2	Retrieve				10	10	10	10	10	10	10	10	10	10	10			
LEVEL 2	File/Post/Plot				10	10	10	10	10	10	10	10	10	10	10			
LEVEL 2	Perceive				0	0	0	0	0	0	0	0	0	0	0			
LEVEL 1	Write	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
LEVEL 1	Read	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
LEVEL 1	Comprehend Speech	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
LEVEL 1	Speak	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
	N	4	4	4	7	9	9	12	12	12	12	12	9	9	7	4	4	4
	$\sqrt[n]{\pi n}$	10	10	10	0	0	0	0	0	0	0	0	0	0	0	10	10	10
	X MANUAL	10	10	10	0	0	0	0	0	0	0	0	0	0	0	10	10	10

FIGURE 2-8. CAPABILITY OF AUTOMATION TO PERFORM C^2 PROCESSES

REQUIRED SKILLS	COMMAND CONTROL FUNCTIONS AND PROCESSES	COMMAND CONTROL FUNCTIONS																
		INPUT PROCESS			PRE-DEC PROCESS			DECISION PROCESS					POST-DEC PROCESS			OUTPUT PROCESS		
		RECEIVE	VERIFY	TAG	SORT	ASSOCIATE	AGGREGATE/ORGANIZE	INTERPRET/VALIDATE	EVALUATE/COORDINATE	PROJECT/EXTRAPOLATE	GENERATE ALT'S	APPLY (DECIDE)	ASSOCIATE	REAGGREGATE	SORT	OUTPUT TAG	TRANSMIT	VERIFY
LEVEL 3	Weigh Alternatives							10	10	10	10	10						
	Construct Alternativer							10	10	10	10	10						
	Think							1	1	1	1	1						
LEVEL 2	Compose					10	10	10	10	10	10	10	10	10				
	Calculate					10	10	10	10	10	10	10	10	10				
	Retrieve				10	10	10	10	10	10	10	10	10	10	10			
	File/Post/Plot				10	10	10	10	10	10	10	10	10	10	10			
	Perceive				1	1	1	1	1	1	1	1	1	1	1			
LEVEL 1	Write	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
	Read	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
	Comprehend Speech	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
	Speak	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
	N	4	4	4	7	9	9	12	12	12	12	12	9	9	7	4	4	4
	$\sqrt[n]{\pi n}$	10	10	10	7.2	7.1	7.7	6.8	6.8	6.8	6.8	6.8	7.7	7.7	7.2	10	10	10
	X MANUAL	10	10	10	7.2	7.7	7.7	6.8	6.8	6.8	6.8	6.8	7.7	7.7	7.2	10	10	10

FIGURE 2-9. CAPABILITY OF INTERACTIVE SYSTEM TO PERFORM C^2 PROCESSES

Level of Organizational Aggregation

		Individual	Multi-Individual	Team
Level of Command-Control Behavior	Procedural	1	2	3
	Non-Procedural	4	5	6

Figure 2-10. CATEGORIES OF BEHAVIOR TO BE MEASURED

Having defined the categories, the model had to be applied to measure behaviors in any of the cells. The model is very robust in the sense that it can be applied to individual behaviors relatively easily. Individuals, as well as teams, can be modeled to receive, tag, associate, evaluate, etc., the information they receive. Despite the fact that practically all such processing is opaque to an observer (unless probes of an electronic sort are implanted in an individual's brain), a great deal can be inferred from the individual's subsequent behavior; this is especially true in a situation as highly defined and well instrumented as CATTS.

A graphical representation of the extended model is shown in Figure 2-11. It simply shows smaller replicas of the model shown earlier in Figure 2-4. Here, however, each functional diagram represents an individual on the team. Using this general notion, several specific examples will demonstrate how differences between groups and individuals can be detected and measured.

Example 1. Normal Configuration

In this example, let the following four team members be in the loop: The batallion commander (Component A), a radio telephone operator (Component B), and S3 (Component 3), and the FSO (Component D). Under normal conditions, the division of labor (or specialization of the human components) might look like that in the upper half of Table 2-2. The commander is primarily involved in decision making, the RTO is handling incoming and some of the outgoing message traffic, the S3 is working with the commander but communicates directly with company commanders, the FSO handles fire missions on selected targets.

Example 2. Centralized Configuration

In the lower part of the table is the case where the S3 is "running the war." Not only that, he has eliminated the RTO from the loop and is handling most incoming and outgoing message traffic himself. The commander is simply observing; the FSO is performing his usual function.

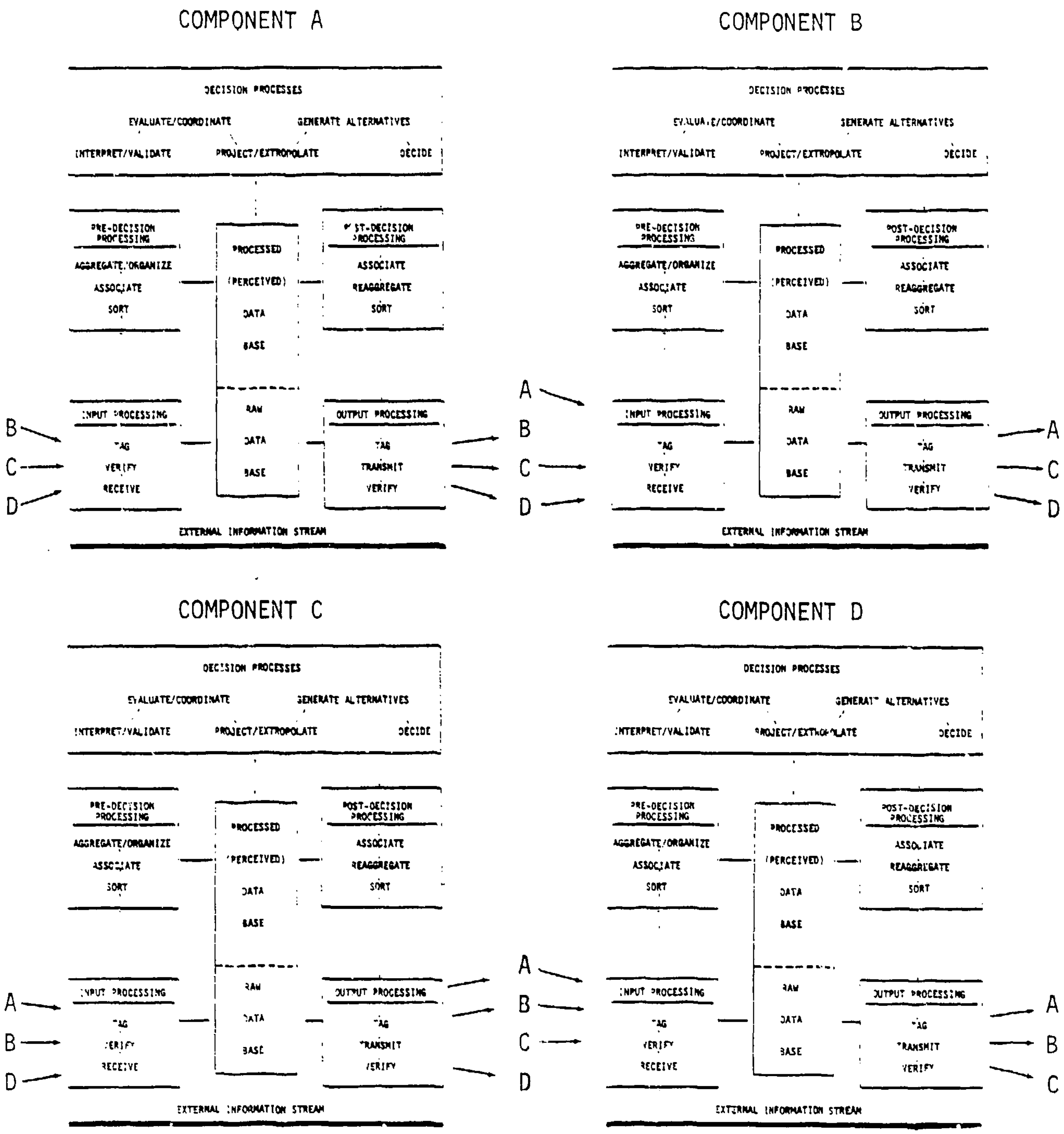


FIGURE 2-11. THE EXTENDED MODEL

TABLE 2-2. COMPONENT SPECIALIZATION IN:

EXAMPLE 1. NORMAL SITUATION

COMPONENT	TEAM ROLE	TEAM I - P - O FUNCTION LEVELS			CONTENT OF INFORMATION HANDLED				COORDINATE BEHAVIOR
		I	P	O	FRIENDLY STATUS	ENEMY STATUS	TARGET LOCATIONS	PLAN	
A	Commander	Lo	Hi	Lo	√	√	√	√	Hi
B	RTO	Hi	Lo	Hi	√	√	√		Lo
C	S3	Med	Hi	Med	√	√	√	√	Hi
D	FSC	Lo	Med	Hi	√		√		Med

EXAMPLE 2. CENTRALIZED CONFIGURATION

A	COMMANDER	Lo	Lo	Lo	√			√	Lo
B	RTO	--	--	--	--	--	--	--	--
C	S3	Hi	Hi	Hi	√	√	√	√	Hi
D	FSC		Med	Hi	√		√		Med

Having defined the model, the next task is to describe how it can be used to explain team behavior and what research questions can be defined to guide data collection and analysis.

2.5 HYPOTHESIS DEVELOPMENT

The purpose of Objective 1 is to determine the dimensions of effective team performance. Having defined a model of the team, described its man and machine components, and discussed the general capabilities required of every component to perform, it is now necessary to clarify several other issues.

2.5.1 Procedural vs. Non-Procedural Behaviors

First, a distinction is made between procedural and non-procedural behaviors. The information flow model provides a means for defining the distinction. Two different kinds of human behavior can be identified with the aid of the model. Type 1 has to do with the performance of the processes identified in the model; Type 2 has to do with the data transfers between processes. Those processes which are understood well enough so that we can write a set of procedures for carrying them out can be described as procedural processes and are, in turn, accomplished with Type 1 procedural behaviors. The remaining processes must then be accomplished with non-procedural Type 1 behaviors. The distinction between them involves considerations very similar to those involved in applying automation as was discussed in para. 2.4.6, above. Processes involved in the input, pre-process, post-process, and output functions are understood well enough so that they can be procedurized. Those involved in the decision processes cannot and must therefore be accomplished with non-procedural Type 1 behaviors. This is illustrated in Figure 2-12.

Similarly, when the data transfer between processes involves a person-to-person interface, both procedural and non-procedural behaviors are involved. The content (prescribed data elements) and format of the message can well be procedurized, but there are also non-procedural elements present in the interpersonal characteristics of the communication. This is illustrated in Figure 2-13.

2.5.2 General Hypotheses

The sponsor's Statement of Work states, "The first objective is to develop and apply a methodology for differentiating the non-procedural individual and multi-individual behaviors from the team or synergistic behaviors in battalion command (control) groups and determining their respective contribution to command (control) group effectiveness." This objective can be restated in the form of two hypotheses:

	COMMAND CONTROL FUNCTIONS				
	INPUT PROCESS	PRE-DEC PROCESS	DECISION PROCESS	POST-DEC PROCESS	OUTPUT PROCESS
BEHAVIOR	Procedural		Non-Procedural	Procedural	

FIGURE 2-12. PROCEDURAL AND NON-PROCEDURAL TYPE 1 BEHAVIORS

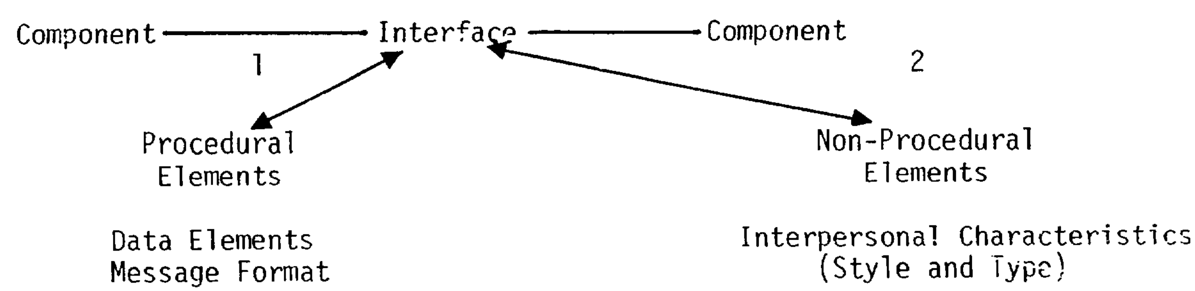


FIGURE 2-13. PROCEDURAL AND NON-PROCEDURAL ASPECTS OF THE HUMAN-TO-HUMAN INTERFACE.

• Hypothesis .: Procedural behaviors contribute to effective C^2 group performance; non-procedural behaviors contribute to effective C^2 group performance.

Discussion: This research is directed at discovering not whether one or the other is important, but to attempt to quantify the relative importance of both. It is clear that a command-control group cannot perform effectively without efficient and effective handling of incoming and outgoing messages (procedural). Similarly, the group cannot complete its mission without good and timely decision making and the effective coordination of the team members (non-procedural).

A specific example occurs in the OPORD briefing conducted prior to the battle. For example, the S2 is to present characteristics of the area (weather, terrain) and characteristics of the enemy. The performance of procedural behaviors is measured by the number of elements presented in the briefing versus the number which are prescribed (as per FM 101-5 p. B-10 or the unit SOP). The non-procedural behaviors associated with the briefing presentation may be measured by the number of comments (which are also "data") which provide tactical relevance or relate the procedural items to each other in a pattern which has relevance. For example, the briefing may include the following discussion prior to a night time Sinai maneuver:

"On weather -- we have winds out of the South at 5 to 8 mph -- no factor at all. Temperature is 105 -- no cloud cover. We have a full moon -- you will be able to see enemy movement and they will be able to see you."

Analysis of this simple example indicates the following points:

- Two "data" points provided insight as to tactical relevance of the weather data. They were "no factor at all" and "you will be able to see enemy movement and they will be able to see you."

- Key weather points were covered -- wind, temperature, and visibility.

There are procedural and non-procedural behaviors associated with this staff activity. The procedural elements are preparation and presentation of the briefing to include the key data elements. The non-procedural behaviors are those that were carried out to satisfy the "evaluation" part of the preparation of the briefing. As FM101-5 states, "The intelligence officer analyzes weather data and provides an evaluation of their effects on military operations" (p. B-15). The G-2 staff section procedures for interpreting or projecting (or other higher level decision processing) those data as part of the evaluation are not specified. It is considered non-procedural. The process itself is, however, generally described by the model just as the larger groups activities are described by the model at a more macro level.

In summary, the hypothesis states that both categories of behavior are important to overall team performance.

- Hypothesis 2: Team behaviors contribute to effective C^2 group performance; individual (multi-individual) behaviors contribute to effective C^2 group performance.

Discussion: Teams have a structure in which the individuals in several grades must coordinate and contribute their specialization to the group effort. However, the individuals in the team can, to some extent, improve team performance through performance of their particular job. As was pointed out in the discussion of Hypothesis 1, it is not an either/or issue; it is a measurement of the relative ability of individuals to improve team perforamnce simply by improving their own performance and to measure the situations under which this is more true than others.

A team, especially a military team such as a command group, has certain properties which differentiate it from an ad hoc group and thereby make it more effective than a group. These properties, as identified in previous research, include (a) pre-defined roles for members, (b) structured paths of communication, (c) awareness of team members of that structure, (d) recognition of a team mission and its importance, and (e) need for coordinated efforts by team members. Other variables which have been found to be related to team performance are ability to adjust and sensing overload of other members, i.e., the ability to effectively adapt as conditions require.

The ability to adjust seems somewhat incongruous with the maintenance of predefined roles and structure. It appears, however, that effective teams have members who know when to stick to their assigned jobs and when either to pitch in to assist other team members or even to take on a new or additional role if the situation warrants. This is another aspect of non-procedural behaviors of the team. That is, although individual members may perform their own sets of procedural tasks, some non-procedural property accounts for changes in the structure. In the command control team, some change is, in fact, procedural (e.g., a commander is killed, the SOP defines who assumes command). Other charge is non-procedural (e.g., the S3 in the battalion begins to handle incoming messages directly with company commanders who are being engaged).

In the context of the model, the first hypothesis can be tested by determining the significance of the correlation between measures of non-procedural and procedural behaviors, on the one hand, and measures of effectiveness on the other. Similarly, the second hypothesis can be tested by determining the significance of the correlation between individual (multi-individual) and team behaviors, on the one hand, and measures of effectiveness on the other. Specific measures are developed in the following section.

2.6 DATA REQUIREMENTS

The next logical step in the development of the methodology is to reduce the general hypotheses to testable statements. These will then define the data requirements. The general hypotheses actually define four categories of behavior measurements (identified previously as "indicators" and labeled 4 in Figure 2-1). Figure 2-14 shows these categories and the types of measures appropriate for each.

2.6.1 Non-Procedural -- Team Behavior Measures

The set of measures chosen as indications of team non-procedural behaviors included:

- Adherence to organizational structure -- Did the team maintain role specialization, that is, did higher level team members stick to higher level processes and did staff sections adhere to their designated functions? What differences did it make? In this first year, only one measure was taken to quantify this factor; this was a "division of labor" measure which indicated the ratio of processes in which higher level team members not only performed the high level cognitive process but also personally handled the transmissions of a message resulting from that process.

- Allocation of team human information processing resources -- A second non-procedural measure is the level of human resources which the team designated to lower level versus higher level processes, i.e., what is the workload level committed to simply receiving and transmitting messages versus the performance of higher level cognitive processes? To measure this factor, a proportion was computed based on the number of messages processed versus the total number of information processing steps carried out.

- Time required to consummate a solution -- As an overall measure of the team's ability to bring to bear an effective response to a presenting problem, the total time from presentation of the problem to evidence of an effective response was measured. As with other variables, there are a number of intervening variables which will affect this time. (A solution to this particular issue is a goal of the second year of the project.) However, the total time was used as a first approximation.

Hypothesis 2

Hypothesis 1	*Individual - Multi-Individual (IMI) Behaviors*	Team (T) Behaviors
Non-Procedural (NP) Behaviors	Interpersonal Style in Communicating	Adherence to Organizational Structure Allocation of Team Human Information Processing Resources Time Required to Effect a Decision Pattern of Intra TOC Communications
Procedural (P) Behaviors	Reaction Time Adherence to Communications Procedures	Turnaround Time Communications Mode

FIGURE 2-14. CATEGORIES OF MEASURES FOR EACH TYPE OF BEHAVIOR

- Pattern of intra-TOC communications -- Another non-procedural team behavior is the number of sections or individuals who actually participate in the decision process and the patterns of interactions between them. This pattern describes several features of a team's operations, e.g., it tells the sections or individuals usually relied on and whose information, insight, or experience is most useful or most valued; it shows differences between teams in terms of the numbers of communications which occur before an effective solution is reached. There were two measures used as indicators of this behavioral variable -- the number of sections included in the decision process and the number of pairs of sections active in the process.

2.6.2 Non-Procedural -- Individual (Multi-Individual) Behavior Measures

- Interpersonal style of communication -- Another non-procedural behavior is the manner in which members of the team interact on an interpersonal basis, i.e., are they supportive and cooperative or negative and non-supportive? Observers were asked to judge this dimension on a three-point scale.

2.6.3 Procedural -- Team Behavior Measures

- Turnaround time -- One aspect of procedural behavior is following the general rule for conciseness and brevity in radio/telephone communications. This is one of many areas where, for the sake of efficiency, the Army has developed highly stylized procedures. As one measure of the team's behavior in performance of these procedures, the average time per communication between individuals was computed.

- Communications mode -- The mode of communication is another procedural behavior of the team. For most products defined by the FMs (e.g., FM101-5, FM 30-5, and the similar documents), there is also a prescribed mode of communication, usually written, by which sections interface with each other. For non-prescribed communication, the mode used is usually the most convenient. Often in battle there may be only one mode available. At battalion, as played at CATTS, practically all communication is either face-to-face or radio, and there is no decision to be made by the player; the mode is determined by the location of the player at the other side of the communication. For example, in this case, the mode between the commander and staff members is determined by the commander's choice to "play" from the JTOC or remain in the TOC.

2.6.4 Procedural -- Individual (Multi-Individual) Behavior Measures

- Reaction time -- There are classes of events which occur which should result in prompt specific reaction. These events are procedural, i.e., events from which individuals in the team are trained and for which the measurement of performance is simply the time required to react to the event. One such event in the command-control group is communications jamming by the enemy. As an indication of performance in this type of behavior, the time required to respond to the jamming was recorded.

- Communications formatting -- A second measure of procedural, individual/multi-individual behaviors was whether communications were carried out in prescribed format, complete, and transmitted without error. In the case of battalion, communications are almost always by voice. Therefore, a communication rating was used which required observers to judge whether voice communications were sent and received completely, in standard format, and error free.

2.6.5 Data Transfer

One other extension to the methodology developed thus far needs to be made. In order to collect the data needed for the non-procedural team measures identified above, it is necessary to develop means for associating the cognitive (non-procedural) and the lower level (procedural) processes with the observable data transfers, i.e., the internal and external communications between team members and with the outside world. The model, in fact, provides the basis for such a development.

As was pointed out in paragraph 2.4, above, it is necessary for the members of a decision-making group to exchange information with each other and with data storage files if a division of labor based on specialization is to take place. It was argued that it was these very data transfers which provide the opportunity to identify individual functions and processes into which the labor is divided. Based on limited prior observation and analysis, a series of functions and processes and an approximate sequence was postulated. To close the loop and test the postulate, it is necessary to identify those characteristics of the data transfers which can be uniquely associated with each function and process so that the existence and sequence postulated by the model can be tested through observation. Such a relationship is established in the remainder of this section.

2.6.5.1 Information Flow

Before we attempt to characterize the data transfers associated with each individual process it is helpful to examine the gross information flow between the various functions postulated by the model and the data bases. Figure 2-15 is an expansion of the model depicted in Figure 2-4 and shows the nature of the information flow in a manner consistent with the definitions of the processes contained in each function box. Incoming information from external sources arrives over some form of telecommunication network, including courier, in the form of whole messages. These are processed as whole messages, i.e., they are verified, tagged, filed in the unit journal, and passed on for pre-processing in their entirety. Pre-processing, however, decomposes such messages by sorting the content, associating segments with prior information, and aggregating/organizing the result into forms easily absorbed by decision makers by updating the perceived data base (visible and invisible files). Pre-processing is coupled with the decision-making processes only through the perceived data base; there is no direct coupling of whole messages. Even the case where the text of an incoming message is repeated as an outgoing message to a new addressee requires a decision made in the light of information already in the data base that a new addressee should be added. Data transfers from the decision-making processes are of two kinds. Perceived file updates contain message segments that express new insights, i.e., they contain data elements not contained in any combination of messages from outside sources. Outputs to the post-process function consist of directives which trigger the preparation of an eventual transmittal of whole messages which are processed by the output function as whole messages.

One must, of course, bear in mind that the perceived data base in a manually operating C^2 group is a widely dispersed and amorphous beast. It consists of a combination of simple files (primarily visible) and the collective memories of the individual members of the group. File updates are not, therefore, limited to formal file accessions but will include repartee by which members update and access each other's memories. It is clear then from Figure 2-15 that one can identify the function being exercised by observing the direction and nature of the data transfers between functions and/or the data bases -- provided, of course, data transfers occur.

2.6.5.2 Types of Data Transfers

We can now proceed to determine unique data transfer characteristics which will identify the individual processes comprising the several functions. If we classify the data transfers according to the pattern suggested in Figure 2-15, we find that a hierarchical structure results. This is to be expected since the entire purpose of this structure is diagnostic in nature, i.e., to facilitate identification of the associated processes.

At the highest level, the first distinction that can be noted is between transfers consisting of whole messages (associated with input and output processing) and message segments (associated with the pre- and post-decision and with the decision-making processes). Whole-message transfers are those for which the primary emphasis is on the literal text rather than the meaning of the symbol string. Segment transfer, on the other hand, concentrates on the meaning of the text

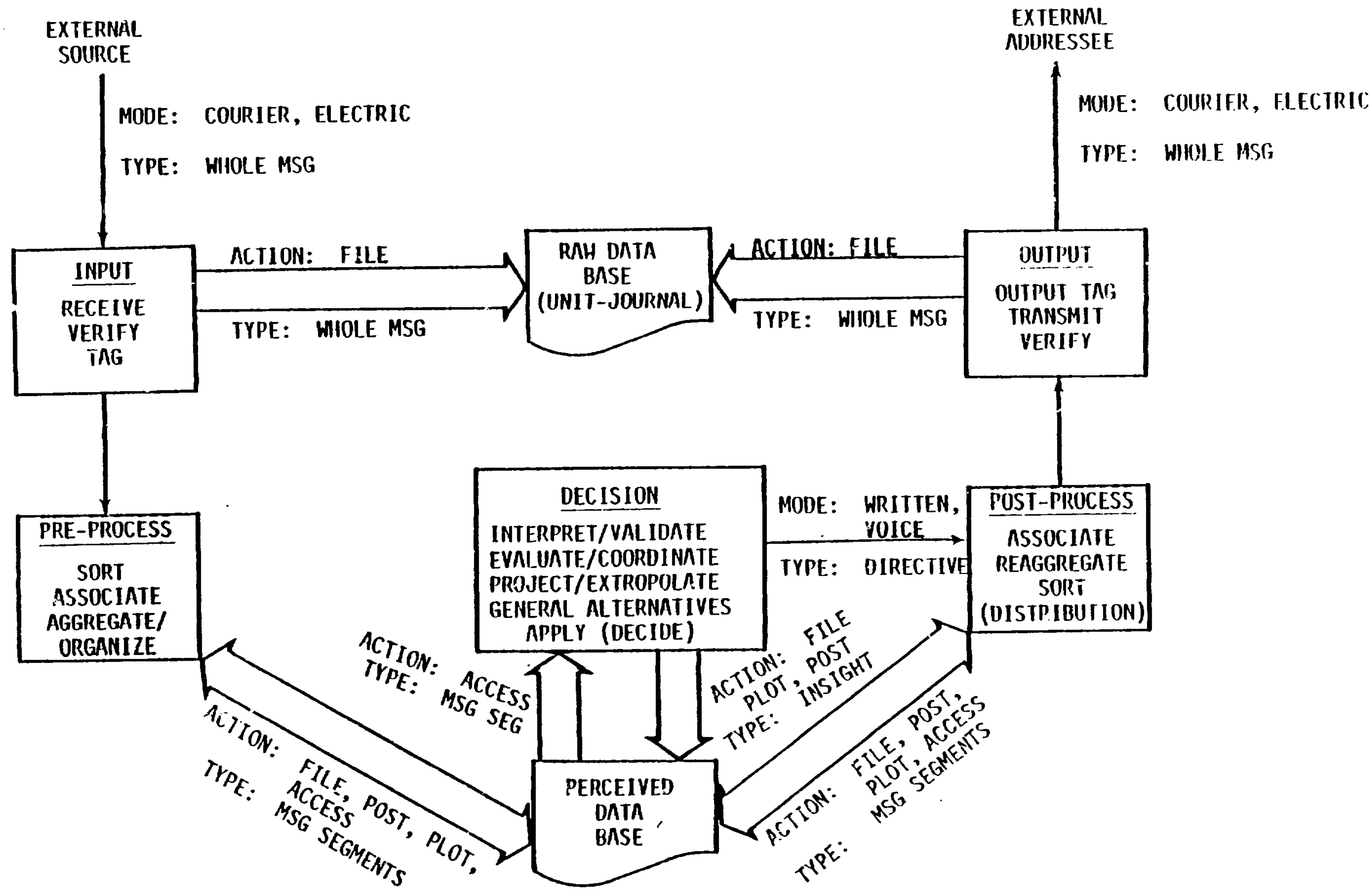


FIGURE 2-15. COMMAND CONTROL GROUP INFORMATION FLOW

rather than on exact repetition of the text. A segment may, in fact, include one or more whole messages in their entirety, although this will be a rare occurrence. This leads us to the hierarchical representation shown at Figure 2-16. At the second level, whole messages can be broken down into incoming and outgoing. Message segments can be broken down into eight sub-classes. At the third level, both <u>insight</u> and <u>directive</u> can be further broken down into two additional sub-classes. The definitions of all these classes and sub-classes are given in Table 2-3.

2.6.5.3 Data Transfer-Process Relationships

Based on the data transfer types defined in Table 2-3 and the dyadic relationship of the transfer, we can now specify the unique combinations of these which uniquely identify the associated process and function. This is done in Table 2-4 which lists as column headings the originator, recipient, and type of data transfer and the associated function and process. The latter two are uniquely determined by the first three -- provided a data transfer takes place. The operator who is actually performing the indicated function and process is indicated by an asterisk. Table 2-4 lists not only the dyads to be expected from the sequence shown in Figure 2-15, but also dyads resulting from cases where the operator performing pre/post-process or decision functions also performs input or output functions. As previously discussed, in the manual mode successive processes are often carried out by the same individual so that no intervening data transfers can be observed. In such cases, Table 2-4 indicates both the highest and lowest function and process that are indicated by the data transfer. Any intervening processes can only be inferred; they have not been demonstrated.

There will also be data transfers in addition to those defined in Table 2-3, but these will not necessarily assist in identifying the processes being performed. For example, there will be queries between the operators as to information processing procedures and discussions resulting therefrom. These would be essentially extraneous to the processing of tactical data and would assist only indirectly in identifying the processes involved.

In the manual mode, one must be careful in identifying file accessions because these are often through an intermediate operator or to another operator's memory. In the manual mode, it is, of course, not possible to observe all file accessions, for example, glancing at the SITMAP or other visible displays.

While the preceding structure has specified the data transfers which are sufficient to identify the associated processes, they are by no means necessary for processing in the manual mode. Nevertheless, they may suffice to begin an analysis of C^2 group behavior, and to begin testing the hypothesis which this model suggests.

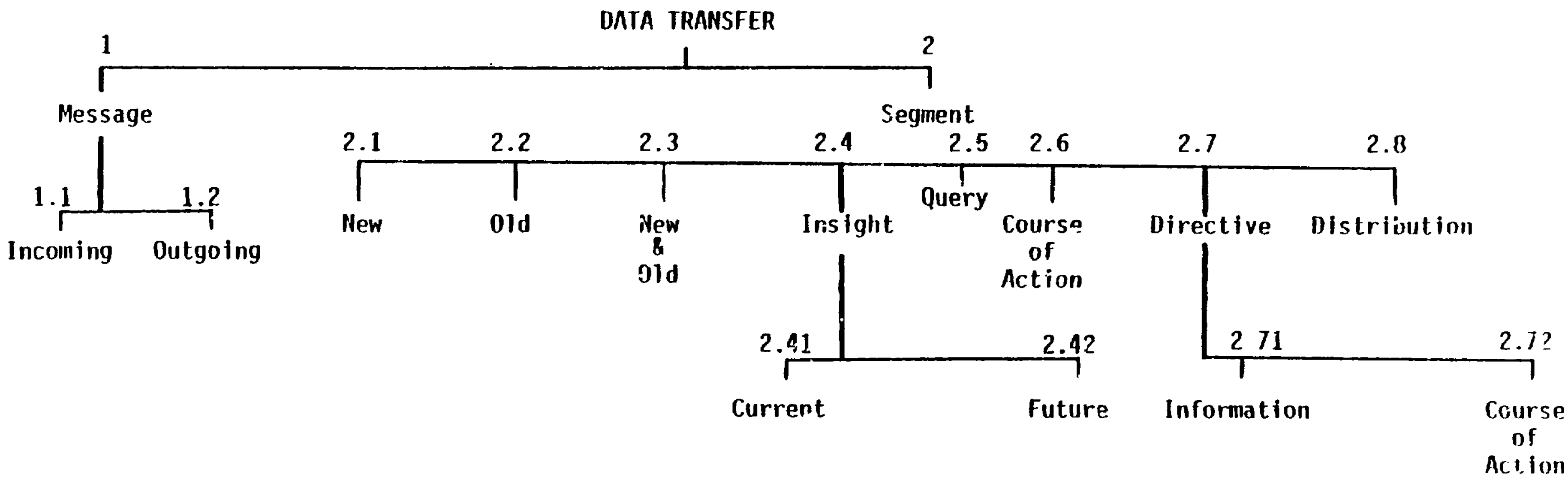


FIGURE 2-16. A HIERARCHICAL CLASSIFICATION OF DATA TRANSFER

TABLE 2-3. DATA TRANSFER DEFINITIONS

1 MESSAGE	Any thought or idea expressed in plain or encrypted language and prepared in a format specified for intended transmission by a telecommunication system. The emphasis in the data transfer is on the literal text rather than on the message content.
1.1 Incoming	A message originating outside the C^2 group.
1.2 Outgoing	A message originating within the C^2 group.
2. SEGMENT	A data transfer in which the emphasis is on message content or meaning rather than on the literal text. When repeating portions of a message it will usually be restricted to segments or paraphrases of the message although occasionally one or more entire message may be repeated.
2.1 New	Any portion of a message currently being processed.
2.2 Old	Any portion of a message previously processed.
2.3 Old + New	A data transfer containing both 2.1 and 2.2.
2.4 Insight	Any thought or idea not contained in the current or previously processed messages.
2.4.1 Current	An insight (2.4) about the current state of the environment.
2.4.2 Future	An insight (2.4) about the future state of the world.
2.5 Query	Any question about the content or meaning of 2.1 through 2.4.
2.6 Course of Action	Any action proposed for execution by friendly forces or deemed sufficiently probable of adoption by the enemy to warrant consideration.
2.7 Directive	An instruction to process an output message.
2.7.1 Information	A directive which does <u>not</u> contain a course of action to be implemented.

TABLE 2-3. DATA TRANSFER DEFINITIONS (CONT.)

2.7.2	Course of Action	A directive which contains a course of action to be implemented.
2.8	Distribution	The list of action and information addresses established for an outgoing message established either _a priori_ or on the spot.

Table 2-4. DATA TRANSFER -- PROCESS RELATIONSHIPS

FROM	TO	TYPE	FUNCTION	PROCESS
Ext	Opr*	1.1	Input	Receive
Opr*	Ext	1.1	Input	Verify
Opr 1*	Opr 2	1.1	Input	Transmit
Opr 2*	Opr 1	1.1	Input	Verify
Opr	Journal	1.1	Input	Tag
Opr*	Ext	1.2	Output	Transmit
Ext	Opr*	1.2	Output	Verify
Opr 1*	Opr 2	1.2	Output	Transmit
Opr 2*	Opr 1	1.2	Output	Verify
Opr*	Journal	1.2	Output	Tag
Opr*	File (SITMAP)	2.1	Pre-Process	Sort
File (SITMAP)	Opr*	2.1 or 2.2	Pre-Process	Associate
Opr 1*	Opr 2	2.1 or 2.2	Pre-Process	Associate
Opr*	Ext	2.1 or 2.2	Pre-Process-0	Associate-Transmit
Opr 1*	Opr 2	2.3	Pre-Process	Aggregate/Organize
Opr*	Ext	2.3	Pre-Process-0	Aggregate/Organize-Transmit
Opr*	File	2.41	Decision	Interpret/Validate
Opr*	Ext	2.41	Decision-0	Interpret/Validate-Transmit
Opr*	File	2.42	Decision	Project/Extrapolate
Opr 1*	Opr 2	2.42	Decision-0	Project/Extrapolate-Transmit

Table 2-4 (Continued)

FROM	TO	TYPE	FUNCTION	PROCESS
Opr 1*	Opr 2	2.5	Decision	Interpret/Validate
Opr*	Ext	2.5	Decision-0	Interpret/Validate-Transmit
Opr 1*	Opr 2	2.6	Decision	Generate Alternatives
Opr*	Ext	2.6	Decision-0	Generate Alternatives-Transmit
Opr 1*	Opr 2	2.71	Decision	Evaluate/Coordinate
Opr*	Ext	2.71	Decision-0	Evaluate/Coordinate-Transmit
Opr 1*	Opr 2	2.72	Decision	Decide
Opr*	Ext	2.72	Decision-0	Decide-Transmit
Opr 1*	Opr 2	2.8	Post-Process	Sort

* Designates operator performing the indicated function and process.

2.7 DATA COLLECTION TECHNIQUES

The next step was the development of the instrumentation and the procedures needed to extract the data for the measures that have been identified. The general methodology had been established by the designation of CATTS as the laboratory facility. The CATTS exercises and recording system described in para. 1.7 provide a massive number of possible observational data points. Instrumentation and a selected data collection system to facilitate extraction of the needed data from the voluminous mass of recorded data were developed.

2.7.1 Instrumentation

The instrumentation consists of the following:

- 6-hour video recorders with full control key pad to provide easy manipulation of the video recordings for search, play, and replay of behavioral sequences to be rated
- Microcomputer-based behavior rating recording system to facilitate recording and analysis of observers' ratings of individual, multi-individual, and team behaviors
- Digital time code/character generator equipment to display the game time on the video screen and on the digital display for the audio recorder (this allows synchronization to the second of audio and video recordings)
- A portable 8-track audio recorder with audio and digital recording capability to permit the high use audio sources and the digital game time to be recorded and transported to an observer laboratory.

In addition to this hardware, the following software and procedural components have been developed:

- Observer ratings software to prompt the observer to enter the data needed for each observation for each observation task
- Microcomputer-to-mainframe interface software to allow edited observer ratings to be passed directly to the larger computer
- Library procedures for recording and cross-referencing audio reels, video cassettes, data disks, and hard copy documentation for each exercise

- Data editing/merging routines for editing and merging the observer ratings, data collected from other sources, and the game status statistics.

2.7.2 Data Measurement Procedures

The measurement problem appeared to be twofold. It appeared that procedures were needed to: 1) elicit behavior from the group, and 2) record measureable differences in behavior between groups and over time for the same group.

After reviewing the first several months' exercises, it was determined that there was little requirement for special procedures to elicit behavior. The natural flow of the game presented numerous challenges to the group which could be sampled to measure behavior. There also appeared to be a natural ebb and flow of the simulated battle which provided a natural change in the decision-making environment in terms of the intensity of battle or information processing demand on the group. Since the first year comprised a pilot effort to demonstrate the feasibility of gathering meaningful data on C^2 group behaviors by means of the CATTS facility, it was decided that, in view of the time and resources available, this initial data collection effort would be limited to two sequences:

1) A sequence of procedural behavior induced by an "active" (artificially introduced) probe during mid-intensity combat.

2) A sequence of procedural and non-procedural behavior induced by a "passive" (naturally occurring) probe during high intensity combat.

2.7.2.1 The Jamming Probe

The active probe selected was jamming the communications. During the exercises included for analysis in this report, jamming was introduced approximately 20 minutes after the start of the battle. This probe was introduced at what was considered to be a moderate level of battle intensity, i.e., contact had been made but heavy engagement had not begun. The response to this jamming, that is, the team's ability to re-establish communications, was measured. These activities were a sample of the rote completion of previously well defined procedures.

The data collection form for the jamming probe (M) is simple and straightforward (Figure 2-17). The heading provides the information required for identification of the data sample and a brief of the probe activity. Item 1 records the three pertinent times which are further illustrated in the probe schematic (Figure 2-18). Item 2 records the level of communication jamming actually introduced; this was at two different levels because of a parallel experiment being run simultaneously by ARI personnel. Item 3 records the relative success of the team in countering jamming.

Unit: ______________________________

Day: ______ Date: ___ / ___ / ___

Probe #: ______ Probe Section: ________

Scenario: Fulda ___ Attack: ____

Sinai ___ Covering ____

Irwin ___

Observation Task: Command Group Information Processing

Probe Brief: ____

____

____

1. Game times for the following:

   (a) ___ / ___ / ___ Start of jamming.

   (b) ___ / ___ / ___ Decision to evade jamming.

   (c) ___ / ___ / ___ Communications reestablished (if within 15 minutes)

2. Planned level of communications interference for the exercise (circle one):

   (a) bad

   (b) good

3. Degree of difficulty with interference at the end of 15 minutes of jamming (circle one):

   (1) Team has less difficulty than most.

   (2) Team has as much difficulty as the majority of teams.

   (3) Team has more difficulth than most.

FIGURE 2-17. JAMMING PROBE (M) DATA COLLECTION FORM

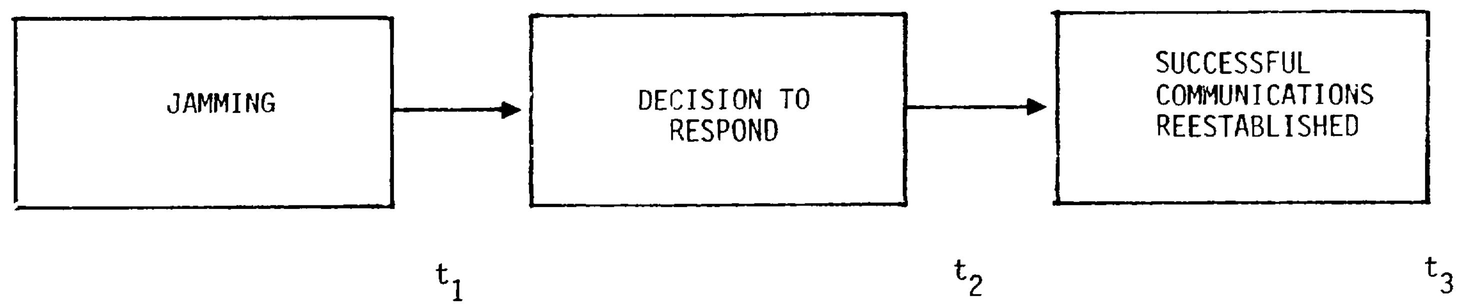


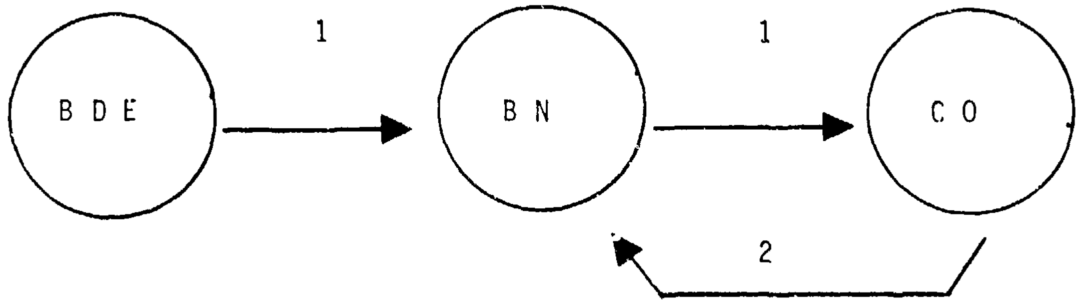
FIGURE 2-18. PROBE "M" SCHEMATIC.

2.7.2.2 The Counterattack Probe

The passive probe selected was the initial sighting of an enemy counterattacking force after successful seizure of the assigned objective by the battalion. All attack scenarios included such a counterattack which was always heralded by the sudden appearance of a company of T-62 tanks. This sequence (H) started with the report of the initial sighting and ended with the first kill of one of the T-62 tanks. This segment represented high intensity combat for the C^2 group. The sampled behaviors included the initial input of the challenge (tank sighting), pre-decision processes (association and aggregation of that message with other data on enemy and friendly dispositions and activity), decision processes (interpretation of the fact that an enemy counterattack was underway and selection of a response), post-decision processing (formulation of orders to appropriate action agents), and output processing (transmission of messages to upper and lower echelons). A schematic of the sequence of major actions is shown in Figure 2-19.

The data collection form for the counterattack probe is shown in Figure 2-20. Since this form is designed to capture non-procedural as well as procedural behavior, it is somewhat more complex than for the jamming probe. The heading contains similar identifying information, but from that point on the form tracks the flow of every data transfer resulting from or pertaining to the initial data (probe) input. In each instance, where the message, a portion of the message, or a message segment which incorporates a portion of that message is relayed or acted upon, an entry is made on the form. In each of these instances, the entry includes the game time at which the instance started, the end time, a set of data regarding the sender and the receiver, the mode of communication used, and the data transfer category for that activity. In regard to both the sender and the receiver, ratings will be generated providing information on the overall effectiveness with which the information is sent or received, the interpersonal manner in which it was conveyed, and identifying codes for the staff positions of the sender and receiver.

T e coding schemes for each of the observer ratings are presented in Table 2-5. The communication effectiveness rating is rated on a scale of 1 to 5, and is intended tc easure the extent to which information is both accurate and complete in transmission. For example, a sender who is reporting the sighting of light enemy vehicles and provides this information and the coordinates but fails to provide the number or direction, would receive a rating of 5. If that same sender, when he is sending the message, conveys the description, size, number, direction, and coordinates of the sighting, and, in addition, makes reference to a previous message reporting other activity in that area, he would receive a rating of 1. A listener receiving that message who accurately listens to the message but fails to verify its contents would receive a rating of 3. If that listener, in verifying the contents of the message, makes an error in repeating the message (when it is apparent to the observer that the message was accurately, completely,



1 - T62s SIGHTED

2 - T62(s) KILLED

FIGURE 2-19. COUNTER ATTACK (H) PROBE SCHEMATIC

UNIT: ____

Day: ______________ Date: ____/____/____

Probe #: ______________ Probe Section: ______

Scenario: Fulda __________ Attack __________

Sinai __________ Covering __________

Irwin __________

Observation Task: Command Control Group Information Processing

Probe Brief: ____

____

____

			Sender					Receiver		
Start Time	End Time	Com Mode	ID	Rating	Style		Type	ID	Rating	Style

FIGURE 2-20. COUNTER ATTACK PROBE DATA COLLECTION FORM

Table 2-5. CODES FOR OBSERVATIONAL TASKS

Position Codes:

01		10	S1
02		20	S2
03	Brigade 3	30	S3
04		40	S4
05		50	XO
06		60	Entire Group
07		70	Commander (71-"A" Co, 72-"B" Co, 73-"C" Co, 74-CSC)
08	FDC	80	FSO
09	Friendly Air	90	ALO

Note: Additional codes for subordinates in each section can be assigned for each exercise unit. For example, "31" could be Asst S3, "32" could be the Operations NCO, "21" could be an enlisted man assigned to the S2 section.

Mode of Communication:

1 or F - Face-to-face

2 or T - Telephone

3 or R - Radio

4 or N - Note (handwritten)

5 or C - RATT Communication

6 or H - Face-to-face with reference to hard copy data base

7 or L - Radio with loudspeaker on

Table 2-5 (Continued)

Information Flow Ratings:

1. All information passed/received in standard format with additional relevant information.
2. All required information passed/received with additional relevant information or in standard format.
3. All required information passed/received.
4. Most required information was passed/received but follow-up communications required.
5. Only part of the required information was passed or received or serious errors were made in sending or receiving.
6. No response or acknowledgement given to input.
7. Sender is asked to wait by receiver.

Style Codes:

1 or A - Angry, hostile, or defensive reaction

2 or O - Objective or neutral reaction

3 or S - Supportive reaction

Data Transfer Type:

1.1 Any verbatim transfer (heading and body) of a message (any thought or idea expressed in plain or encrypted language and prepared in a format for intended transmission by a telecommunication system) that originated outside the C2 group and where the emphasis in the data transfer is on the literal text rather than the message content.

1.2 As above, except message originated within the C2 group. Note: Repeating the same message content to another addressee, e.g., notifying brigade of initial contact reported by a company, is classed as 1.2 because someone had to read the original incoming message for content and decide to add a new addressee (change message heading) even though the body of the message may be identical to the incoming message.

Table 2-5 (Continued)

2.1	Any portion of the probe being currently processed and where the emphasis is on content rather than on literal text.
2.2	As for 2.1, except data transfer concerns any portion of a message(s) arriving prior to probe being processed.
2.3	Any combination of 2.1 and 2.2.
2.4.1	Any transfer that contains a thought or idea not contained in the current probe or previously processed message and which concerns the current state of the environment. Note that it may also contain 2.1 through 2.3.
2.4.2	As for 2.4.1, except new thought is about future state of the world.
2.5	Any question about the content or meaning of 2.1 through 2.4.
2.6	Any action proposed for execution by friendly forces or deemed sufficiently probable of adoption by the enemy to warrant consideration. Note this is a special case of 2.4.2.
2.7.1	An instruction to process an output message which does NOT contain a course of action to be implemented.
2.7.2	An instruction to process an output message which does contain a course of action to be implemented.
2.7.3	The list of action and information addresses established for an outgoing message either a priori or on the spot.

and clearly provided), then that listener might receive a 4. If the listener, after receiving the message, identifies the fact that there is a missing piece of information from the sender, then the listener might receive a rating of 1.

The data transfer code is one that has been derived from the model described earlier (para. 2.6.5). This paradigm is intended to categorize each information processing activity into its place in the overall processing of that information by the command group as a whole. In addition, it allows for the determination of points at which pre-decision, decision, and post-decision processes are occurring.

The style code is a measure of the interpersonal interactive quality of the communication of the information. It is intended to be a measure of the degree to which individual human components on the team are able to cope with their workload and handle the tasks which they have been assigned.

Mode of communication is simply a categorization of whether the communication occurred over radio, telephone, face-to-face, or face-to-face with reference to a hard copy data base, i.e., a map or note pad.

The observers providing the ratings were project personnel. The procedure involved the play (and frequently, repeated replays) of the video and audio records and the development of consensus ratings on the items in the probe data collection sheet. After three days of developing consensus ratings, it was decided that there was sufficient "cross training" among the observers to permit tasks to be carried out by single observers. When any observer had a question in regard to a rating, other observers were consulted.

2.7.3 The Criterion Measures

One of the advantages of the CATTS facility is that a wealth of simulated battle information is available to be used to track the success or failure of the command control group to achieve its objectives. The computer used to calculate combat outcomes keeps track of equipment and personnel status and location for each platoon-level unit. Losses inflicted by weapons system, location, and time and replacements by type and time are all recorded. In addition to the computer-generated data, the game controllers, who are permanent-duty staff for CATTS, also provide a series of ratings on the performance of the teams.

For the preliminary analysis in this first year, five computations based on the computer-generated data were used as criteria along with the average controller's ratings of overall team performance. The computer-generated indices were: measures of relative losses between friendly and enemy forces, changes in overall combat ratio at the beginning and at the end of the training exercise and computational variations on these data.

2.7.4 Additional Data Sources

In addition to the exercise data described above, a great deal of additiional data were collected on the exercise and from CATTS players and controllers. Although these data were not analyzed the first year, they may represent a valuable data source in the future, therefore they are listed in Table 2-6.

Data	Source	Subject	Number of Measures	Responsible Organization
Simulation Outcomes	CATTS Computer	E	Continuous	ARI
Simulation Outcomes	CATTS Computer	E	Final	ARI
Alerts & Messages	CATTS Computer	E	Continuous	ARI
Demographics, Training, & Experience	Questionnaire	I	Pre-Exercise	TRASANA
Knowledge	Questionnaire	I	Pre - Post	TRASANA
Player Ratings of -				
(a) own job performance	Questionnaire	I	Pre - Post	TRASANA
(b) least preferred coworker	Questionnaire	I	Pre	TRASANA
(c) organizational climate index	Questionnaire	I	Pre	TRASANA
(d) attitudes toward group	Questionnaire	I	Pre	TRASANA
(e) task criticality, frequency, and self-performance	Questionnaire	I	Pre - Post	TRASANA
(f) own job knowledge	Questionnaire	I	Pre - Post	TRASANA
Information Flow in Planning	Questionnaire	I	Post-Planning	ARI
Exercise Data	Varied	E	Per Exercise	ARI
Planning Measures	Trained Observers	E	Per Exercise	SAI
Model Functioning Measures	Trained Observers	P	Per Probe	SAI/XL

Legend - Subjects - E - Exercise
I - Individual
P - Probe (a selected time sequence within an exercise)

TABLE 2-6. SOURCES AND CATEGORIES OF DATA BEING COLLECTED

SECTION 3

LABORATORY INSTRUMENTATION AND DATA COLLECTION/REDUCTION

SECTION 3

LABORATORY INSTRUMENTATION AND DATA COLLECTION/REDUCTION

This section reports on Task 1.3 (Review and Analyze Existing Tapes), the development of recommendations for both short- and long-range improvements, and the implementation of the short-range improvements for both data collection and reduction which constituted Task 1.5.

3.1 REVIEW AND ANALYZE VIDEO/AUDIO TAPE SETS

The purpose of this task was to:

- Assess the quality of the recording system extant at CATTS
- Assess the capabilities of the extant system in relation to the requirements of the methodology proposed in the project
- Define proposed modifications to the system

The activities carried out as part of this task were:

Subtask 1.3.1 -- Define what the system would be required to do to satisfy the methodology which was proposed.

Subtask 1.3.2 -- Observe and assess the quality of the recordings of three exercises provided by the sponsor.

Subtask 1.3.3 -- Propose alternative equipment changes or additions which may be required to meet the methodology's requirements.

3.2 SUBTASK 1.3.1

A first step was to define the general methodology to be used in the project. Based on the methodology, a general set of requirements was developed for the CATTS recording system. As described earlier, the approach taken in the project was to view the TOC as a node in an information system. Though a node in and of itself, the TOC has INTERNAL NODES (or components, the systems engineering term, or subteams -- the organizational/psychological term, staff sections -- the military term) whose individual and collective behavior must be analyzed. The approach also presumed that any given message to the TOC could enter at any internal node, activate any other internal nodes, and, subsequently, new messages would exit from any internal node. (The stimulus is usually transformed in the process.) It was necessary, therefore, insofar as possible, to trace a message from its introduction into the TOC through its various transformations and to trace the genesis and dissemination of a message coming out of the TOC.

Using this general approach placed heavy demands on the recording system. The recording system would be required to:

- Record (audio) all conversations of all key players which occur from introduction of the stimulus through completion of the processing

- Record (video) all actions which occur between key players which occur from introduction of the stimulus through completion of processing

Key players include, at least, the commander, the S1, S2, S3, S4, the ALO, the FSO, and engineer and commo officers, if present. The measures of group behavior and group effectiveness all depended on the ability of the recording systems to account accurately for input, propagation, transformation, and output of information. The specific stimuli to be used were not defined until later in the year. Therefore, to the extent possible, the recording system had to record the entire exercise. This provided the capability to define, post-hoc, the stimuli and resulting exercise segments to be used as samples of a team's behavior.

<u>Summary</u>:

The methodology made it necessary for all key players to be recorded for essentially the entire exercise to ensure accurate tracking of input, propagation, transformation, and output of information on which the behavioral metrics are based.

3.3 SUBTASK 1.3.2

The second step was to review a set of tapes taken from three exercises to assess the quality of the extant audio/video recording system and determine its adequacy for providing the data needed for the methodology to be used. The recordings were observed by the project team and a set of deficiencies was prepared. The deficiencies were organized into two functional areas:

1) recording system deficiencies and

2) playback system deficiencies.

The first dealt with problems in the technical quality of the recordings; the second dealt with problems which the team confronted when considering how the recordings would be used in analyzing team and individual behavior.

The recording system deficiencies were as follows:

- Very little of the audio recordings was intelligible; high background noise level was the primary difficulty.
- There was no documentation on call signs, channels or modes of communication to be used by each player.
- There were no means for audibly identifying each player.
- The video cameras covered only about 70% of the TOC.
- Lighting was very low level which made it difficult to distinguish between individuals and made it impossible to read maps to which key players referred.
- There were no means for easily recognizing the players in each role.
- Video recording required hourly reloading of tapes and loss of data during reloading.

The playback system had the following deficiencies in audio and video operations:

- There was no capability to play back any of the audio recordings off-site from CATTS except for the audio track on the video tape.
- There was no capability to synchronize the audio recordings with the video recordings except through very laborious searches of the tapes.
- Locating a specific stimulus and subsequent actions by the group was an extremely time-consuming process since no scenario or game time was available.
- There was no capability on the video playback equipment to search for specific frames where an action was initiated or message received.

<u>Summary</u>:

Major improvements in equipment and procedures were needed for both recording and playback systems before ANY methodology could be applied to behavioral analysis of CATTS exercises.

3.4 SUBTASK 1.3.3

The third step in this task was to identify both (a) short-term (and within budget) improvements that could be made to the system, and (b) long-term (and/or not within budget) improvements which are necessary to overcome the deficiencies.

The set of short-term improvements to the recording system included the following:

- Installation of an audio-feedback controller to filter out background noise.
- Installation of high quality, noise filtering microphones.
- Installation of wider angle (5.5 mm) lenses to capture 90% of TOC area.
- Installation of 1/2", 6-hour, video recorders to eliminate the requirement to handle tapes (and loose data) during the exercise.
- Repositioning of microphones to provide better coverage of conversations of key players.
- Development and implementation of procedures for set-up, adjustment and monitoring of equipment during exercises.
- Development and implementation of procedures for collection and archiving documentation on each exercise (scenario, overlays, exercise diary).

The long-term improvements recommended for the recording system were the following:

- Installation of wireless microphones on all key players.
- Installation of a audio-feedback controller for all audio recording channels.
- Installation of a recorder to capture the game controllers' display throughout the exercise.

The playback system improvements for both audio and video, short-term and long-term, were also extensive and, as with the recording system, the improvements were needed in both hardware and operational procedures. Some requirements were based on the necessity to replay and analyze the recordings at a laboratory which could not be co-located at CATTS.

The short-term improvements to the playback system were:

- Installation of video recorders with full remote control (pause with still frame, search with picture being displayed, slow speed, forward and reverse with picture being displayed). This would enable observers to locate specific times at which information transfers occurred or other actions were taken.

- Installation of an audio playback machine to permit replay of the most active channels of communication between the TOC and uppper and lower echelons.

- Insta..ation of a timing device on the audio system which would enable observers to quickly locate specific events noted in the exercises diary.

- Installation of amplifiers, headphones, speakers, and channel selection devices needed for observers to replay and anlayze the recordings.

- Installation of procedures for documenting channel use and assignments during the exercise.

- Installation of video monitors and video playback equipment neded for video replay and analysis.

- Installation of devices needed to record and display the time on the video picture. This capability was needed to (a) enable observers to quickly locate specific events, and (b) enable observers to synchronize audio and video recordings.

- Installation of a micro-computer to permit direct entry of the observers' ratings and categorizations of team and individual behavior.

The long-term improvements to the playback system were recommended with two complementing goals in mind: 1) the project requirements for behavior analysis had to be satisfied, and 2) after the project teams' familiarization with CATTS, it was recommended that the training effectiveness of CATTS could be enhanced with greater use of audio/video feedback to the players. Since the equipment needed for the first goal would support the second, the following list of improvements was recommended:

o Installation of additional video recorders to fully record the conversations and actions of all key players during the exerise.

- Installation of a 20-channel audio playback device to enable observers to playback any of the 20 channels recorded at CATTS.

- Installation of a video recording editor to enable researchers to prepare excerpts of the exercise for analysis. (This device would also allow for preparation of excerpts for players as part of the feedback.)

- Installation of a remote control, color, zoom, pan, video camera to enable the recording of tactical maps when players are pointing or referring to them.

During the first six months of the project, all of the short-term recommendations were implemented. The final configuration for the first year was made of equipment already at CATTS, equipment made available by this project's sponsor (ARI), and contractor supplied or procured equipment. The resulting system used for the first year had the capability to record 7 channels of audio, 2 channels of video (1 was actually used). Both audio and video had time recording based on the same time generation equipment. The data collected during the first year was, therefore, limited by this capability. Table 3-1 lists the equipment used during the first year in the recording systems and Table 3-2 lists the observation system equipment. Figures 3-1 and 3-2 illustrate the layout of the video and audio recording systems respectively. Figure 3-3 illustrates both video and audio systems for playback.

3.5 LONG-TERM IMPROVEMENTS

The long-term recommendations for improving the system will complete the CATTS hardware instrumentation needed to implement the methodology as it was originally designed. A major step toward the complete system was initiated during the first year of the project by proposing purchase of an additional set of equipment which will satisfy most of the long-range functional requirements. With the acquisition of this set of equipment, the recording system will have additional capabilities for recording during the second year.

The recording system will be able to follow two key players at all times and all audio recording will be noise filtered. The playback system enhancements will enable observers to: a) relay all audio recordings, b) replay activity in all three "locations" played at CATTS (TOC, JTOC, and Trains), and c) produce selected excerpts for analysis or feedback.

Table 3-1. EQUIPMENT USED IN RECORDING SYSTEM

2	Panasonic 1/2" Video Tape Recorders (SAI purchase)
1	Sony 3/4" Video Tape Recorder (CATTS)
1	Magnasync 20-Track Audio Tape Recorder (CATTS)
1	Vetter 8-Track Audio Recorder (ARI)
1	Panasonic Special Effects Generator (CATTS)
1	Audio Mixer (CATTS)
1	Audio Feedback Controller (SAI purchase)
1	Time Code Generator (ARI)
1	Video Character Generator (SAI purchase)
7	Monitors (CATTS)
4	Low Level Sount Reducing Mikes (SAI purchase)
3	Mikes (CATTS)
1	Panasonic Video Camera (CATTS)
1	Wide Angle TV Camera Lens, 5.5 mm (SAI purchase)

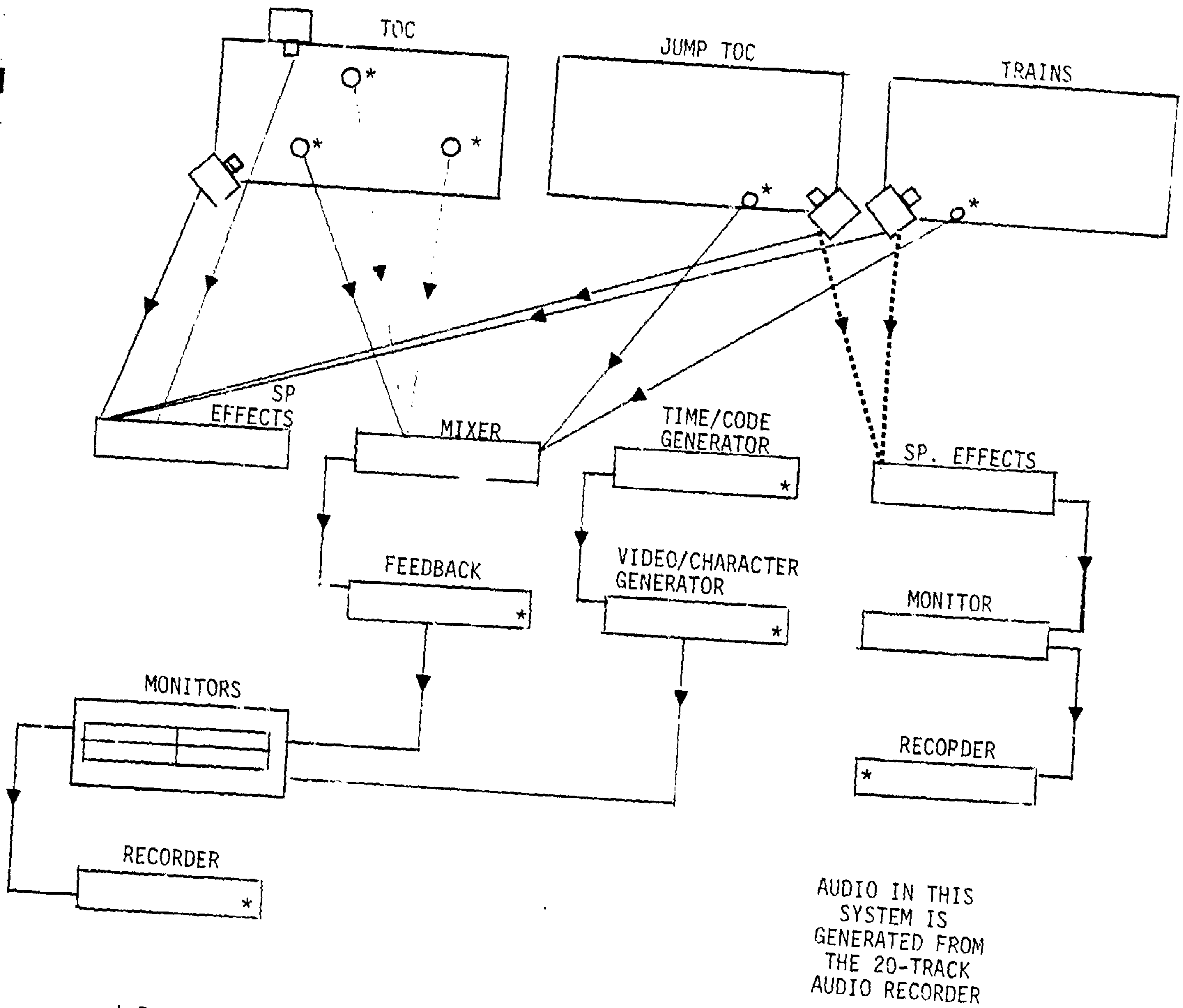
Table 3-2. EQUIPMENT USED IN OBSERVATION SYSTEM

2	Panasonic 1/2" Video Tape Recorders (SAI purchase)*
2	Monitors (ARI)
1	8-Track Audio Recorder (ARI)*
1	Channel Selector, 8-Track (SAI purchase)
1	AMP/Speaker (SAI purchase)
1	Time Code Generator (ARI)*

<u>Supplemental Equipment</u>

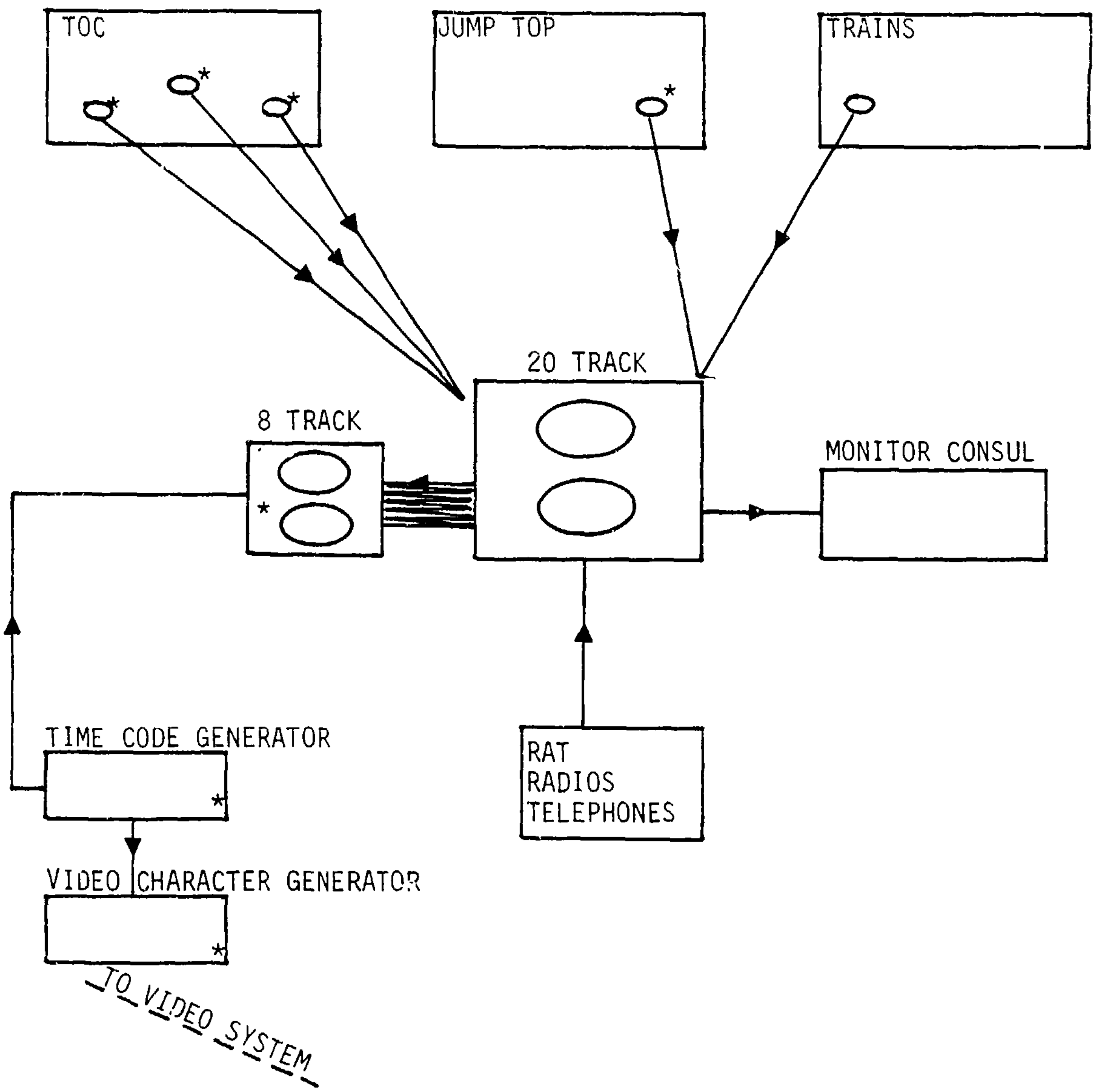
1	Sony Video Camera (ARI)
1	Special Effects Generator (ARI)

* Also used for recording.



* Equipment purchased or borrowed from ARI.

FIGURE 3-1. RECORDING VIDEO SYSTEM.



* Equipment purchased or borrowed from ARI

FIGURE 3-2. RECORDING AUDIO SYSTEM

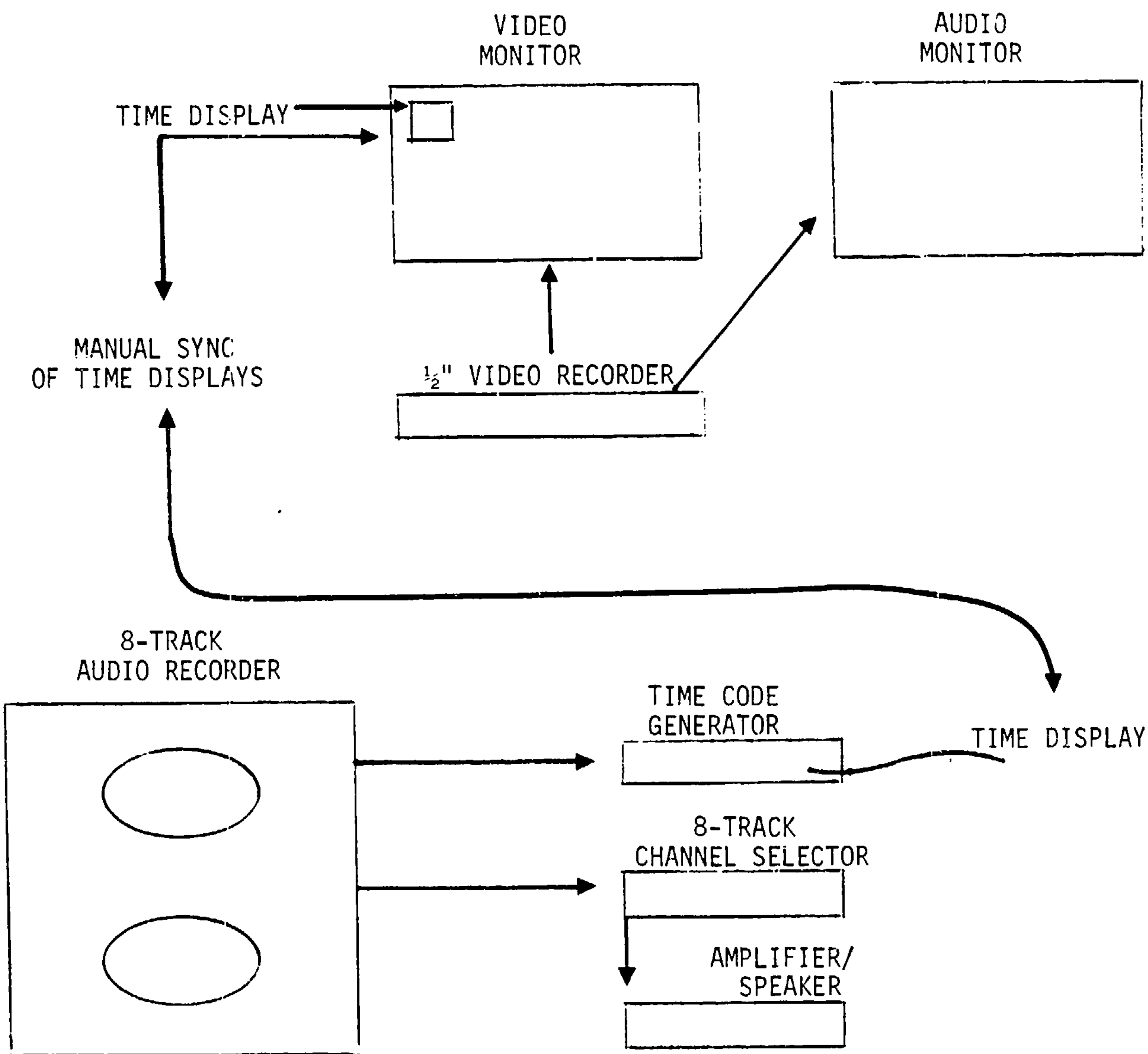


FIGURE 3-3. OBSERVATION VIDEO AND AUDIO SYSTEMS.

The primary capability which has as yet not been developed (due to funding limitatons) is the capability to record and synchronously replay the tactical situation. This capability would involve recording two sets of data:

- The record of the controller's (and game computer's) view of the battle. This can be accomplished by recording the video display of the brigade controller's CRT.

- The record of the tactical map(s) used by the players. This would permit detailed analysis of the battle as perceived by the command group. The original long-range recommendation was for this data base to be captured by use of a remotely controlled high resolution color video camera. Another alternative is the use of a map digitizer such as those being used in the Army SOTAS system and now available for use in conjunction with a variety of microcomputers. This approach would generate a real time computer analyzable data base of the team's perception of the battlefield.

This capability has not been addressed by the additional equipment purchase proposed during the first year but is a capability which should be developed for CATTS (or other similar training systems) in the future.

<u>Summary</u>:

Substantial improvements were made to both recording and playback systems during the first year. An additional set of equipment has been proposed for purchase which will provide most of the capabilities required. The remaining capability will be to: 1) track all key players with wireless microphones, and 2) record and play back complete data bases of perceived and actual tactical displays.

SECTION 4

DATA REDUCTION AND ANALYSIS

SECTION 4

DATA REDUCTION AND ANALYSIS

The data reduction and analysis which were undertaken during this first-year pilot effort were much more in the nature of a feasibility test and demonstration of what kinds of analysis might be undertaken with the data being collected than an effort to "prove" the hypotheses or to derive hard experimental evidence. Although some tentative findings have been developed, it must be remembered that they are based on a tiny segment of the total behavior that led to the combat outcomes and controller ratings of group performance. Furthermore, as discussed in Section 5, there are grave reservations concerning the validity of the criterion measures used for the analysis.

The data considered for the analysis were: 1) the data collected by observers reviewing the probes, and 2) combat outcome data (and controllers' ratings) being generated by the CATTS computer. The ostensible purpose of this first-year analysis was to determine the extent to which selected dimensions of team behaviors are related to team performance. The focus of attention was on command and control dimensions (as opposed to either purely tactical or purely interpersonal dimensions). These dimensions, as discussed earlier, are derived from a model (para. 2.4) of the command and control team which emphasizes the information handling dimensions of the group's behavior, i.e., how effectively and efficiently information is: 1) gathered (Input), 2) used in decision making (Process), and 3) disseminated both within the group and to the echelons above and below (Output). The predictors of effectiveness and efficiency in this first-year analysis included the speed with which communications are carried out, the number of primary nodes (brigade, staff sections, the battalion commander, the company commanders) and node pairs (or dyads), the nature and frequency of the information passed, the relative frequency of decisions made versus other information processes. This is, of course, only a small subset of the individual and group behaviors extractable from the CATTS recordings. The above measures were applied for this initial effort solely because they appeared easiest to extract and apply.

One other notion which pervades the analysis is that few of the relationships between behavior and performance are simple; for example: 1) the value of a dimension is always viewed in the context within which it is performed, and 2) there is a level of performance which is appropriate -- either too much or too little of something usually results in degraded performance.

4.1 THE PREDICTORS

Although a much broader set of data was recorded (and will be analyzed during the next two years of the project), only the above subset of those measures was examined in this first-year analysis. Since the number of observations from the first year were limited and since the primary focus is on the viability of recording/observational techniques, the attention in the first year was on the latter.

As discussed earlier, the basic model of the command group is that of an information flow system. There are two categories of measures which can be used to predict performance of that system: 1) the information handling properties of the system and its major components (staff sections) within the system, and 2) the functional analysis of the performance of each staff section in carrying out its unique function within the system. The latter category overlaps the ARTEP criteria; that is, the function of each staff section is defined by the ARTEP (and other doctrinal literature).

The information handling characteristics of this man-machine system were measured by collecting data using the observational techniques described earlier. The observer data captured on the data collection sheet (refer to Figure 2-20) provided this series of measures. These are listed in Table 4-1. Each of these measures will be computed for the counterattack probe. A brief explanation of each is as follows:

- Frequency and Rate of Nodal Activity

  The number of times for the duration of the probe that each node is active as sender and as receiver and the number of times per minute.

- Frequency and Rate of Dyadic Activity*

  The number of times any two nodes connect (one sender and the receiver or one of the receivers) and the number of connections per minute.

- Number of Active Nodes per Probe

  The number of nodes which were either senders or receivers of information during the duration of the probe.

- Number of Active Dyads per Probe*

  The number of dyads which were connected one or more times during the duration of the probe.

---

* It should be noted that in C^2 groups such as those in CATTS, where most intra-group communication is by voice and where much radio traffic is on loudspeakers, it is difficult to identify all receivers for any given transmission; hence, the dyad count will err on the low side.

Table 4-1. MEASURES COMPUTED FROM COUNTERATTACK PROBE DATA COLLECTION FORMS

- Frequency of Nodal Activity
  - per probe
  - per time period per probe
- Frequency of Dyadic Activity
  - per probe
  - per time period per probe
- Number of Active Nodes per Probe
- Number of Active Dyads per Probe
- Proportion of Active Dyads to Total Possible Dyads
- Response Time per Probe
- Turnaround Time per Internodal Event per Probe (dyadic duration time)
- Communication Mode Frequency
- Quality of Dyadic Activity
- Style of Communication (interpersonal dimension)
- Frequency of Type of Data Transfer

- Response Time

  The total number of minutes from receipt of the information starting the probe until the probe is ended through appropriate response or overcoming events.

- Turnaround Time

  The average duration of each dyadic connection.

- Communication Mode Frequency

  The relative frequency of each of the modes of communication.

- Quality of Dyadic Activity

  Consensus ratings of trained observers of whether communications were sent or received in a neutral/objective, positive/supportive, or negative/uncooperative manner.

- Type of Data Transfer

  A categorization of data handling activities which distinguishes between I, P, O processes, between whole, parts, and combinations of messages, and simple transmittal vs. decision activities.

Four additional predictor measures were obtained from the probe. These measures were derived from the data items on the probe data collection form (Figure 2-17). These measures are:

- Time required to determine the need to switch channels during jamming
- Time required to successfully re-establish communications
- Jamming-induced communication difficulty of the exercise
- Degree of effectiveness in successfully re-establishing communications.

4.2 THE CRITERIA

The criterion issue was discussed in the "best and final" proposal. The key points of that discussion were:

1) The ultimate criterion is mission success.

2) Lacking actual combat, the actions which increase the probability of success serve as intermediate criteria (labeled B in Figure 2-1). These actions are those found in the ARTEPs.

3) The criterion measures proposed were (a) a task-per-event ratio and (b) a task-per-period by category ratio.

Several things have occurred during the course of the project which have modified the applicability of the proposed criteria:

1) The CATTS system is now maintaining a record of simulated tactical status variables (e.g., number of personnel, number of weapons, sub-unit locations over time, level of engagement). A computerized data base has been developed by SAI to enable SAI and ARI researchers to manipulate those data to create composite criterion measures. Several preliminary resource utilization criterion have already been developed by ARI researchers. The result is that although actual combat criteria are not available, simulation outcomes are available which are the best approximation of actual results (given all the assumptions and parameters in the CATTS model).

2) The ARTEPs have not been translated into a level of detail adequate to provide a basis for per position performance as determined by observers. Thus, no analysis of the "ARTEP" performance has been included in the first-year analysis.

The final set of criteria used in this first-year analysis was the controller ratings of overall performance and five measures of manpower outcomes generated by the CATTS computer. The CATTS controller ratings of overall performance on each exercise day (see Barber et al., 1982) uses a rating instrument involving a magnitude estimation technique (Stevens, 1957). The manpower outcomes included:

> . . . loss exchange ratio (LER), relative exchange ratio (RER), surviving maneuver force ratio differential (SMFRD) (which have all been used in previous research and/or battle simulations). The LER is simply computed by dividing OPFOR loss by friendly losses; RER is a ratio of the percentage of OPFOR losses to the percentage of friendly losses; and SMFRD is the percent of friendly forces surviving minus the percent of OPFOR forces surviving battle. Also included are

two measures of battle performance that were generated to bear a relationship to overall controller ratings. The change in combat ratio (CR) was calculated by subtracting the end of battle combat ratio from the beginning of battle combat ratio and dividing the difference by the initial combat ratio. The other potential battle performance measure* (1/2% Blue Surviving + % Red Losses) was calculated by adding the percentage of OPFOR losses to one-half the percentage of friendly forces surviving. The purpose of formulating these post-hoc measures was to find overall measures of battle performance in CATTS that had a higher degree of generalizability across mission and unit type than those measures found in the literature (Thomas, 1982).

All the simulated battle outcomes are significantly intercorrelated. However, these outcomes are not correlated with controller ratings (see Table 4-2). Hence, as would be expected, the variables in the predictor set which relate to each criterion (outcome) differ. These results will be presented in the section below. However, one variable accentuates the problem. ATIM (average time to communicate) is significantly correlated with both controller ratings (RATG) and LER (the loss exchange ratio). It is negatively correlated with ratings and positively correlated with LER. The plots of these data appear in Figures 4-1 and 4-2. The implications of this are discussed after the presentation of the other findings in Section 5.

Table 4-2. CORRELATIONS BETWEEN MANPOWER BATTLE OUTCOMES AND CONTROLLER RATING

	LER	RER	SMFRD	CR	CILL
LER(1)	1.00	0.75	0.78	0.64	0.89
RER(1)			0.79	0.67	0.83
SMFRD[1]				0.96	0.92
CR[1]					0.79
Controller Rating[2]	-0.16	-0.14	-0.04	-0.03	-0.14

1. All correlations significant (p = 0.00) for manpower measures.
2. No correlations are insignificant.

* This measure is the "weighted force measure" referred to in this report as CILL.

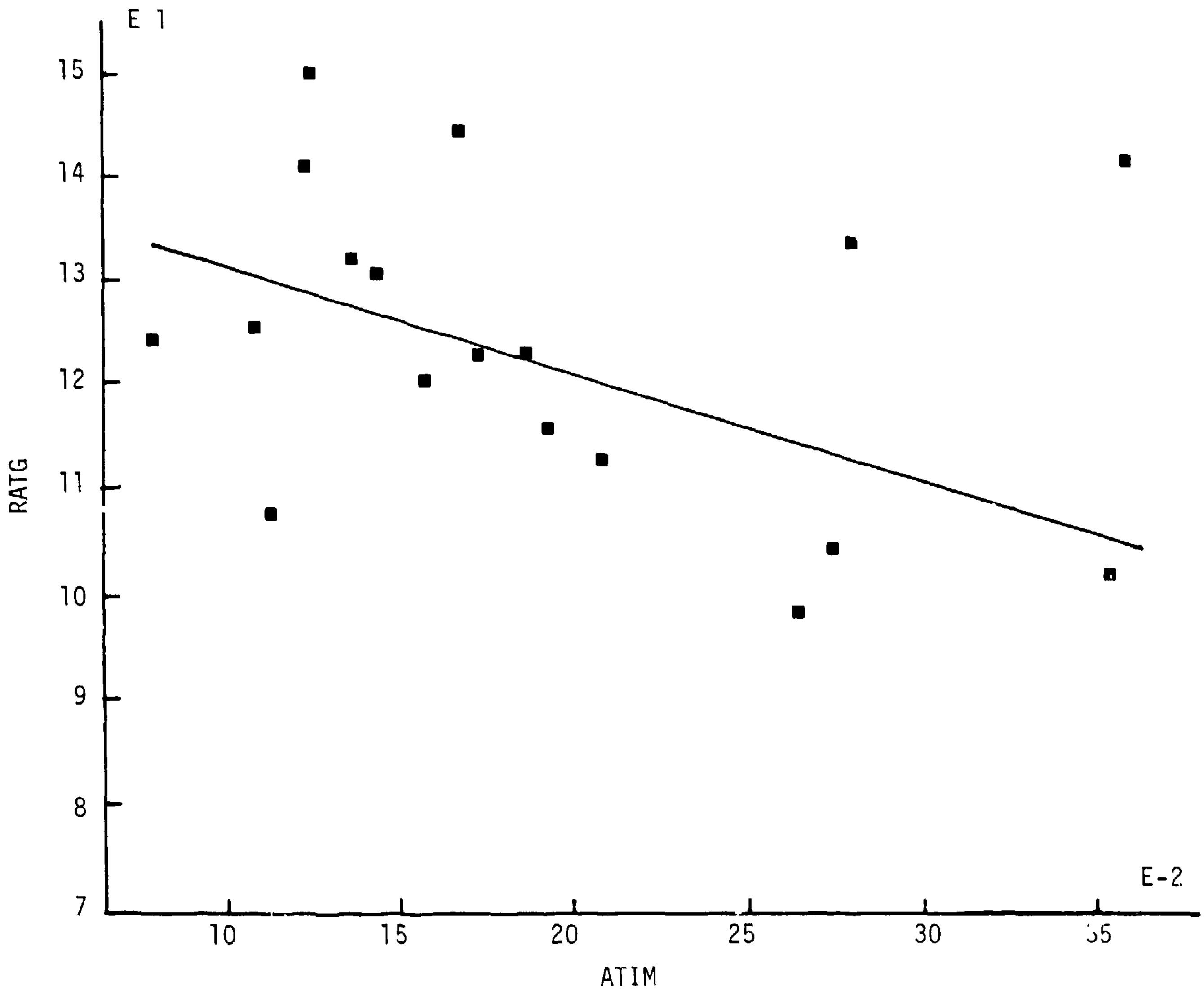


FIGURE 4-1. CONTROLLER RATINGS OF OVERALL PERFORMANCE (RATG) AS A FUNCTION OF THE AVERAGE TIME TO COMMUNICATE (ATIM)

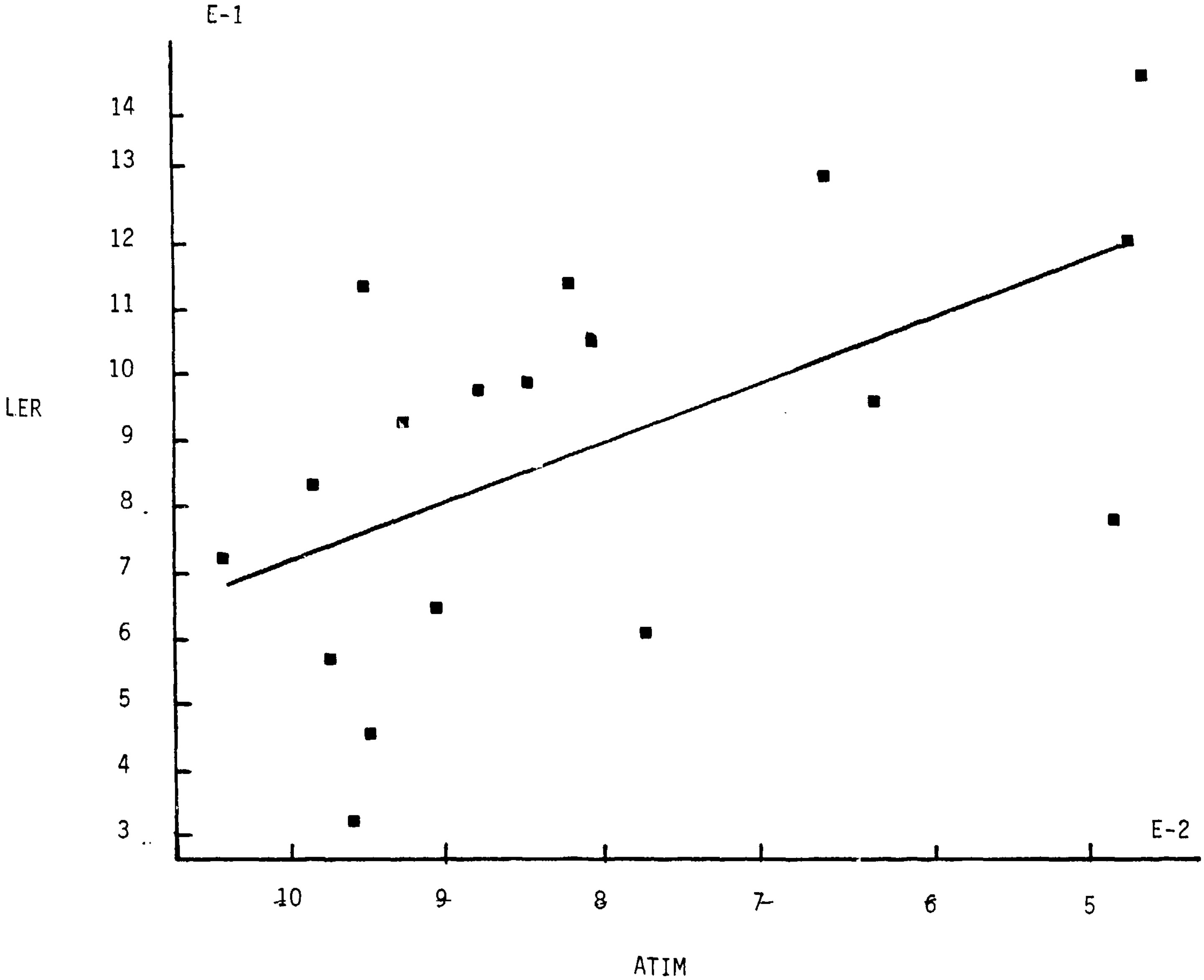


FIGURE 4-2. FINAL LOSS EXCHANGE RATIO (LER) AS A FUNCTION OF THE AVERAGE TIME TO COMMUNICATE (ATIM).

4.3 THE VARIABLES

Table 4-3 is a listing of all of the variables discussed above and is the totality of the variables included in this analysis. The first six of these are the criterion measures, the next four are the predictors obtained from the jamming probe, and the remainder are predictors from the counterattack probe.

Table 4-3. VARIABLES TO BE INCLUDED IN THE PRELIMINARY ANALYSIS IN THE FIRST YEAR

Name		Description
1.	RATG	Controller ratings of team overall performance (higher ratings = better performance)
2.	LER	Loss exchange ratio (higher scores = better blue performance)
3.	RER	Relative exchange ratio
4.	SMFRD	Surviving maneuver force ratio differential
5.	CR	Change in combat ratio
6.	CILL	Weighted force measure
7.	RTIME	The time required to determine the need to switch channels during jamming
8.	CTIME	The time required to successfully re-establish communications
9.	JAMP	The jamming-induced communication difficulty of the exercise (1 = bad, 2 = good)
10.	JAMS	The degree of success the team had in successfully re-establishing communications in response to enemy jamming (1 = "experienced less difficulty than most" to 3 = "experienced more difficulty than most")
11.	RNOD	Number of nodes which received probe-related transmissions (7 major nodes)
12.	SNOD	Number of nodes which sent probe-related transmissions
13.	DYAD	Number of pairs of nodes which communicated probe-related transmissions (26 possible pairs)
14.	DYDR	Ratio of above (13) to total possible

Table 4-3. VARIABLES TO BE INCLUDED IN THE PRELIMINARY ANALYSIS IN THE FIRST YEAR (Cont'd)

15.	TIME	Total time in minutes for probe to be completed
16.	ATIME	Average length of each probe-related transmission
17.	CFTF	Proportion of each mode of communication used for probe-related transmissions (CFTF -- face-to-face, CRTO -- ratio/telephone, CRTL -- radio/telephone with speaker)
18.	CRTO	
19.	CRTL	
20.	SQUA	Average quality of sender communications (1 = "good" to 6 = "poor")
21.	RQUA	Average quality of receiver communications
22.-33.	Dxxx	Ratio of each type of data transfer related to the probe
34.	SSTL	Average style rating (sender and receiver) for probe-related transmissions (1 = "hostile" to 3 = "supported")
35.	RSTL	

4.4 STATISTICAL PROCEDURES

The analysis consisted of computing Pearson product-moment correlations between the variables. This matrix was inspected and the data for suspect correlations were plotted; then, stepwise regressions were performed and, in some cases, a curve-fitting program was used to establish the best curvilinear formulation of the relationship between predictor and criterion. Of the 28 one-day exercises considered as the set for analysis, one exercise was not conducted and several had little data. The correlations were computed on a pair-wise (rather than observation-wise) deletion basis since few exercises (i.e., observations) had all data available. The correlations were, therefore, based on n's which ranged from the middle to upper teens.

Inspection of the predictor x criterion correlation matrix provided the following significant results:

- Controller ratings were found to be significantly correlated with
  - day of training ($r = 0.66$, $p = 0.00$)
  - the average transmission time ($r = -0.49$, $p = 0.01$) (the shorter the average time, the higher the rating)
  - the quality of sender transmissions ($r = 0.37$, $p = 0.05$)

- Some simulated battle outcomes were significantly correlated with the proportions of various data transfer types (Table 4-4).

- The loss exchange ratio (LER) was significantly correlated witn ATIM (average transmission time -- 4 = 0.56, p = 0.007 (this relationship is discussed in Chapter 5).

- The criteria variables, LER and RATG (controller ratings) were negatively correlated (r = 0.49, p = 0.015).

- Average length of time of probe-related transmissions (ATIM) was positively correlated with LER (r = 0.56, p = 0.01) but negatively correlated with controller ratings (r = -0.49, p = 0.03).

Table 4-4. CORRELATIONS BETWEEN THE PROPORTION OF VARIOUS DATA TRANSFER TYPES AND THE SIMULATED BATTLE OUTCOMES

Data Transfer Type	Simulated Battle Outcome Measure				
	LER	RER	SMFRD	CCR	CILL
1.1	0.58	-	-	-	-
2.1					
2.2					
2.3					
2.41					
2.42		0.60	0.60	0.57	
2.5					
2.6					0.63
2.71					
2.72			-0.51	-0.55	
2.9	-0.58				

As an exploratory procedure, a stepwise regression analysis was carried out using the 11 observations for which complete data were available. This statistical procedure determines which variables, from a set of independent variables, are the best predictors of the criterion, or dependent variable. The procedure, then, determines which pair of independent variables together are the best predictors; then, which group of three variables are the best predictors, and so on. At each step, the statistical significance is tested (F-test) and the correlation (or multiple correlation) is computed. The multiple correlation (R) is a measure of the extent to which the behavior(s) is associated with the effectiveness of the group as measured by the simulated battle outcomes. A summary of the results is provided in Table 4-5.

Table 4-5. SUMMARY OF STEPWISE REGRESSION DISPLAYING FOUR MOST CONTRIBUTING VARIABLES

Criterion	R-Square	Variables	Coefficients
LER	0.9367	(Intercept)	-0.5929
		RNOD	0.1088
		ATIM	0.8799
		D11	1.3574
		D26	5.6784
RER	0.9593	(Intercept)	0.8581
		RQUA	-0.2110
		D242	6.5422
		D25	1.3607
		D26	9.7118
SMFRD	0.9283	(Intercept)	0.0572
		RNOD	0.0457
		RQUA	-0.1244
		D22	-3.3735
		D27	-0.1900
CCR	0.9766	(Intercept)	0.0812
		RNOD	0.0798
		RQUA	-0.2007
		D22	-5.0572
		D27	-0.2982
CILL	0.9097	(Intercept)	0.6390
		ATIM	0.2349
		RQUA	-0.0826
		D25	0.3781
		D26	3.0296

For LER, the predictor variables included the number of active receiving nodes (RNOD), the average length of time of transmissions (ATIM), and two of the data transfer type proportions -- the proportion of whole messages handled (D11) and the proportion of communications which proposed courses of action (D26).

For RER, the predicting variables are the rated quality of the receiver's reception (RQUA) followed by three of the data transfer type proportions -- the proportion of communications which conveys a thought or idea not in a previous message and pertains to a predicted future condition (D242), the proportion of communications querying or verifying previously processed data (D25), and a special case of D242 described in the preceding paragraph (D26).

For SMFRD and CCR (the two are correlated at 0.96), the predicting variables are RNOD, RQUA, and two data transfer type variables -- the proportion of communications dealing with a portion of the content of a previously received message (D22) and the proportion of communications directing that a message be sent (D27).

For CILL, the predicting variables are ATIM and RQUA followed by D25 and D26, all of which are described above.

These preliminary data suggest that simulated battle performance is related to four factors:

1) Ability to accurately receive incoming information

2) Degree of information dissemination within group

3) Degree of information dissemination to adjacent echelons

4) Average duration of communications.

Furthermore, there appears to be a relationship between battle outcomes and the relative emphasis placed on various information collection, processing and dissemination functions of nodes.

In addition to these correlational analyses, an in-depth inspection of the data transfer type data was made to determine the extent of the division of labor in an information flow sense. The data forms used for recording the data collected from the audiovisual tapes of CATTS exercises (Figure 2-20) included sender, receiver, communications mode, and type of data transfer. These data, combined with the data transfer process relationships listed in Table 2-4, permitted identification of the function and process required for every observed data transfer as well as determination of which member (node) performed the process. Figures 4-3 and 4-4 are typical of such data reduction forms.

The above data were then summarized in matrix form as shown in Figures 4-5 through 4-7. These show the number of times each group member performed each process. The functions (input-output, pre- and post-processing) are also indicated. The processes, beginning with "associate," are shown as double entries. The upper heading is used for recording those transfers for which the subject transferred data to another member face-to-face, i.e., without also having to use communication procedures to transfer data. The lower heading denotes that he performed the process "on the horn" so that he performed not only the higher level process but that he also transmitted the data over telephone or radio links. The data entry is also double in this case -- the upper indicating the number of times the higher level process was performed and the lower indicating the associated transmissions. As indicated earlier, such a double entry indicates the highest and lowest

OBSERVATION NR 19

SENDER	RECEIVER	COM MODE	TYPE	NODE	FUNCTION	PROCESS
Bde-3(Ext)	S2	T	1.1	20	Input	RCV
S2	Ast S3	F	1.1	20	Input	TR
Ast S2	S2RTO	H	2.71	21	DEC	Eval/Coord
S2RTO	Ast S3	H	2.1	23	Pre Proc	Assoc
Ast S3	S2RTO	F	2.5	31	Decision	Int/Val
S2RTO	Ast S3	F	2.1	23	Pre Proc	Assoc
Ast S3	S3 (EXT)	R	1.2	31	Output	TR
S2	Ast S3	F	2.1	20	Pre Proc	Assoc
S2	Ast S3	F	2.71	20	Decision	Eval/Coord
S2	FSO	F	2.72	20	Decision	Decide
S2	FSO	F	2.5	20	Decision	Int/Val
FSO	S2	H	2.3	80	Pre Proc	Aggreg/Org
S2	S2RTO	H	2.1	20	Pre Proc	Assoc
S2RTO	SIT MAP	H	2.1	23	Pre Proc	Sort
S2	FSO	F	2.5	20	Decision	Int/Val
FSO	S2	F	2.2	80	Pre Proc	Assoc
S2	FSO	F	2.41	20	Decision	Int/Val
S2	FSO	F	2.5	20	Decision	Int/Val
FSO	S2	F	2.1	80	Pre Proc	Assoc
S2	FSO	H	2.72	20	Decision	Decide
FSO	FDC(EXT)	T	1.2	80	Output	TR
S2	Ast S2	F	2.71	20	Decision	Eval/Coord
S2RTO	Bde3(EXT)	T	1.2	23	Output	TR
S2RTO	S2	F	1.1	23	Input	TR

FIGURE 4-3. DATA REDUCTION FORM FOR DATA TRANSFER ANALYSIS

OBSERVATION NR 19 Continued.

SENDER	RECEIVER	COM MODE	TYPE	NODE	FUNCTION	PROCESS
S2	SITMAP	H	2.1	20	Pre Proc	Sort
Ast S3	S2	F	2.5	31	Decision	Int/Val
S2	Ast S3	H	2.1	20	Pre Proc	Assoc
S3RTO	(EXT)	T	2.1	33	Pre Proc-Out	Assoc-TR
S2	Ast S3	F	2.71	20	Decide	Eval/Coord
Ast S3	CO"A"(EXT)	R	1.2	31	Output	TR
CO"A"(EXT)	Ast S3	R	1.2	31	Output	Verify
CO"B"(EXT)	Ast S3	R	1.1	31	Input	RCV
S2	FSO	F	2.5	20	Decision	Int/Val
CO"B"(EXT)	Ast S3	R	1.1	31	Input	RCV

FIGURE 4-3. DATA REDUCTION FORM FOR DATA TRANSFER ANALYSIS (CONTINUED).

OBSERVATION NR 27

SENDER	RECEIVER	COM MODE	TYPE	NODE	FUNCTION	PROCESS
Bde-1(EXT)	Ast S2	L	1.1	21	Input	RCV
S2	Bde-2(EXT)	L	2.5	20	DEC-Out	Int/Val-TR
Bde-2(EXT)	Ast S2	L	1.1	21	Input	RCV
S2	Bde-2(EXT)	L	2.5	20	DEC-Out	Int/Val-TR
Bde-2(EXT)	Ast S2	L	1.1	21	Input	RCV
CO	Ast S2	F	2.5	70	DEC	Int/Val
S3	CO"C"(EXT)	L	2.71	30	DEC-Out	Eval/Coord-TR
S3	CO"B" & "CSC"(EXT)	L	2.71	30	DEC-Out	Eval/Coord-TR
CO"B"(EXT)	S3	L	7.2	30	Output	Verify
S3	CO"B"(EXT)	L	1.2	30	Output	TR
CO	ALO	F	2.72	70	DEC	Decide
ALO	CO	F	2.1	90	Pre Proc	Assoc
TAF(EXT)	ALO	L	1.1	90	Input	RCV
ALO	S3	F	2.5	90	DEC	Int/Val
CO	S3	F	2.71	70	DEC	Eval/Coord
S3	CO"B"(EXT)	L	2.5	30	DEC-Out	Int/Val-TR
CO"B"(EXT)	S3	L	1.2	30	Output	Verify
S3	CO"B"(EXT)	L	1.2	30	Output	TR
CO"B"(EXT)	S3	L	1.1	30	Input	RCV
S3	CO"B"(EXT)	L	2.71	30	DEC-Out	Eval/Coord-TR
S3	ALO	F	2.72	30	DEC	Decide
CO"B"(EXT)	S3	L	1.1	30	Input	RCV
S3	ALO	F	2.72	30	DEC	Decide
S3	CO"B"72(EXT	L	2.5	30	DEC-Out	Eval/Coord-TR

FIGURE 4-4. DATA REDUCTION FORM FOR DATA TRANSFER ANALYSIS

OBSERVATION NR 27 Continued.

SENDER	RECEIVER	COM MODE	TYPE	NODE	FUNCTION	PROCESS
CO"B"(EXT)	S3	L	1.1	30	Input	RCV
S3NCO	ALO	F	2.1	32	Pre Proc	Assoc
S3	CO"B"72(EXT)	L	2.71	30	DEC-Out	Eval/Coord-TR
CO"A"(EXT)	S3	L	1.1	30	Input	RCV
CO"B"(EXT)	S3	L	1.1	30	Input	RCV
	SITMAP	H	2.1	30	Pre Proc	Sort

FIGURE 4-4. DATA REDUCTION FORM FOR DATA TRANSFER ANALYSIS (CONTINUED)

	PROCESS	S2	AST S2	NCO S2	RTO S2	S3	AST S3	NCO S3	RTO S3	CO	FSO	ALO	TOTAL	ADJ. TOTAL
INPUT-OUTPUT	Receive		3	1		42				1			47	47
	Transmit		1	2		1							4	42
	Verify					3							3	3
	Tag													
PRE & POST PROCESS	Sort	1				2							3	3
	Associate		1	1		1				1			4	7
	Associate-Transmit					3/3							3/3	
	Aggregate/Organize											1	1	1
	Aggregate/Organize-Transmit													
COGNITIVE	Interpret/Validate	1	1			1				1			4	19
	Interpret/Validate-Transmit		2/2			12/12				1/1			15/15	
	Evaluate/Coordinate													6
	Evaluate/Coordinate-Transmit					6/6							6/6	
	Project/Extrapolate					3	1						4	7
	Project/Extrapolate-Transmit					3/3							3/3	
	Generate Alternatives													
	Generate Alternatives-Transmit													
	Decide					2					1		3	14
	Decide - Transmit					9/9				2/2			11/11	
	TOTAL	2	10	4		121	1			9	1	1	149	149

Total Cognitive + Transmit: 35
Total Cognitive: 46
%: 76%

FIGURE 4-5. INFORMATION PROCESS MATRIX
OBSERVATION NO. 7

	PROCESS	S2	AST S2	NCO S2	RTO S2	S3	AST S3	NCO S3	RTO S3	CO	FSO	ALO	TOTAL	ADJ. TOTAL
INPUT-OUTPUT	Receive	1					2						3	3
	Transmit	1			2		2				1		6	7
	Verify						1						1	1
	Tag													
PRE & POST PROCESS	Sort	1			1								2	2
	Associate	3			2						2		7	8
	Associate-Transmit								$\frac{1}{1}$				$\frac{1}{1}$	
	Aggregate/Organize										1		1	1
	Aggregate/Organize-Transmit													
COGNITIVE	Interpret/Validate	5					2						7	7
	Interpret/Validate-Transmit													
	Evaluate/Coordinate	3	1										4	4
	Evaluate/Coordinate-Transmit													
	Project/Extrapolate													
	Project/Extrapolate-Transmit													
	Generate Alternatives													
	Generate Alternatives-Transmit													
	Decide	2											2	2
	Decide - Transmit													
	TOTAL	16	1		5		7		2		4		35	35

Total Cognitive + Transmit: 0
Total Cognitive: 13
%: 0%

FIGURE 4-6. INFORMATION PROCESS MATRIX
OBSERVATION NO. 19

	PROCESS	S2	AST S2	NCO S2	RTO S2	S3	AST S3	NCO S3	RTO S3	CO	FSO	ALO	TOTAL	ADJ. TOTAL
INPUT-OUTPUT	Receive		3			5						1	9	9
	Transmit					2							2	11
	Verify					2							2	2
	Tag													
PRE & POST PROCESS	Sort					1							1	1
	Associate							1				1	2	2
	Associate-Transmit													
	Aggregate/Organize													
	Aggregate/Organize-Transmit													
COGNITIVE	Interpret/Validate											1	1	5
	Interpret/Validate-Transmit	2/2				1/1				1/1			4/4	
	Evaluate/Coordinate									1			1	6
	Evaluate/Coordinate-Transmit					5/5							5/5	
	Project/Extrapolate													
	Project/Extrapolate-Transmit													
	Generate Alternatives													
	Generate Alternatives-Transmit													
	Decide					2				1			3	3
	Decide - Transmit													
	TOTAL	4	3			24		1		4		3	39	39

Total Cognitive + Transmit: 9
Total Cognitive: 13
%: 69%

FIGURE 4-7. INFORMATION PROCESS MATRIX
OBSERVATION NO. 27

processes that have been performed. Intermediate processes may also have been performed by the operator but there is no tangible evidence from the observable data transfer. Each such double entry then represents at least two processes. More may have been performed but are hidden in the mind of the operator. The adjusted total column on the extreme right spreads these double entries out across the basic processes.

These matrices highlight some interesting aspects of C^2 group behavior with respect to information processing. For example, Figure 4-5 shows virtually no division of labor. Nr. 30 (Bn S3) is running the whole show by himself; the other members of the staff might as well not be there. The S3 performed more than 80 percent of all processing, handled personally more than 89 percent of all incoming messages, and transmitted 81 percent of outgoing messages. Also, the preponderance of cognitive processes were performed "on the horn" so that the operator was not only performing the higher level cognitive process but had to shift gears to recall call signs, authentications, and all the other distracting minutiae of the communication process. In short, there was little division of labor either on a basis of subject matter or on a basis of information function.

Figure 4-6 shows a far different situation. In this case, the S2 (20) is the dominant figure. There are no entries at all for the S3 or the Bn CO (30 and 70, respectively) because both have been declared out of action when the jump TOC was destroyed. Even so, the S2, who has assumed command, performs less than 50 percent of the processing personally, and it will be noted that no cognitive processes have been performed in conjunction with communication. Thus, this is a good example of significant division of labor. Figure 4-7 again shows an active S3, although not as hyperactive as in Figure 4-5, and extensive combined cognition with communication processing.

Not apparent from these data sheets, but quite apparent to the data collectors, was the fact that all of the verification processing and well over half of the interpret/validate processing concerned erroneous coordinates. Coordinates and CEOI (communication) data were subject to the greatest number of errors in human data transfer.

Despite the limited data reduction effort and small sample size of the data, it is interesting to note that every process postulated by the model was, in fact, observed. Table 4-6 shows the number of times each process was observed across 11 data sets (observations). It is not surprising that the process "generate alternatives" was observed only once because only one of the probes (counterattack) really required the consideration of alternative courses of action. Even these were rather simple at battalion level, being limited to the employment of artillery, air assets, or one or more maneuver units to destroy the counterattacking force of 12 T-62 tanks. Table 4-6 does show that all of the postulated processes were performed and all are observable.

Table 4-6. NUMBER OF PROCESS OBSERVATIONS

Information Process	Number of Times Observed
Receive	101
Transmit	96
Verify	7
Tag	3
Sort	11
Associate	26
Aggregate/Organize	3
Interpret/Validate	51
Evaluate/Coordinate	29
Project/Extrapolate	7
Generate Alternatives	1
Decide	25

Table 4-7 shows a measure of the division of labor observed for the 11 observations that were analyzed. This measure was the ratio of pure cognition (i.e., not combined with electrical communication) processes to the total number of cognition processes performed. It was felt that this DOL (division of labor) measure was reasonably representative of the division of labor with respect to information processing.

Table 4-7. OBSERVED DIVISION OF LABOR

Observation Number	% Cognitive Processes Not Combined with "Transmit"
2	0
4	33
5	24
7	25
12	0
16	0
19	100
22	80
23	50
25	50
27	31

This DOL measure was then plotted against two different measures of combat outcome -- the controller rating and the weighted force measure (Thomas, 1982). These plots are shown in Figures 4-8 and 4-9 (statistics in Table 4-8). The relationship between the division of labor measure and the two outcome measures seems to be strongly curvilinear. As can be seen from the fitted polynomial regression curves in both Figure 4-8 and 4-9, an increase in the DOL (division of labor) seems to have an initial positive effect on both the weighted force measures and the controller ratings. However, as the DOL measure increases, both outcome scores evidence a systematic drop off in performance. In both comparisons, there is a definite peak at near 30 percent DOL. It must be remembered, however, that a single battle outcome score is the result of several hours of information processing and that a single probe represents but a tiny fraction of that processing. Hence, no definite conclusions should be drawn from the data analyzed thus far.

These preliminary results must be heavily caveated. There are several such caveats:

1) The biggest single problem is the time between the probe measures and the simulated battle manpower outcome measures. The first-year analysis correlates brief samples of C^2 behavior with final simulation outcomes which were obtained up to several hours later. In the interim, other significant events occurred, such as additional unplanned resources might be made available by the brigade controller, or luck may influence the final outcome. An approach to greatly improve on the sensitivity of the data and its analysis is presented in the next chapter.

2) Performance is heavily dependent on communication difficulty. The difficulty was intentionally varied from exercise to exercise as part of the experimental design. The importance of communication is borne out by the correlations between level of communication difficulty (JAMP) and several other measures -- SNOD (the number of sending nodes, $r = 0.38$, $p = 0.048$), the proportion of active dyads ($r = 0.37$, $p = 0.055$), the proportion of face-to-face communications ($r = 0.52$, $p = 0.01$), and the quality of sender transmissions ($r = 0.56$, $p = 0.004$).

3) The observation data collected was highly dependent on the choice of which video camera was selected as input. If the JTOC camera was on, no face-to-face communications in the TOC could be observed or rated and vice versa. It is, therefore, critical that additional equipment be installed for complete recording of both TOC and JTOC activities to improve validity and completeness of the observation statistics.

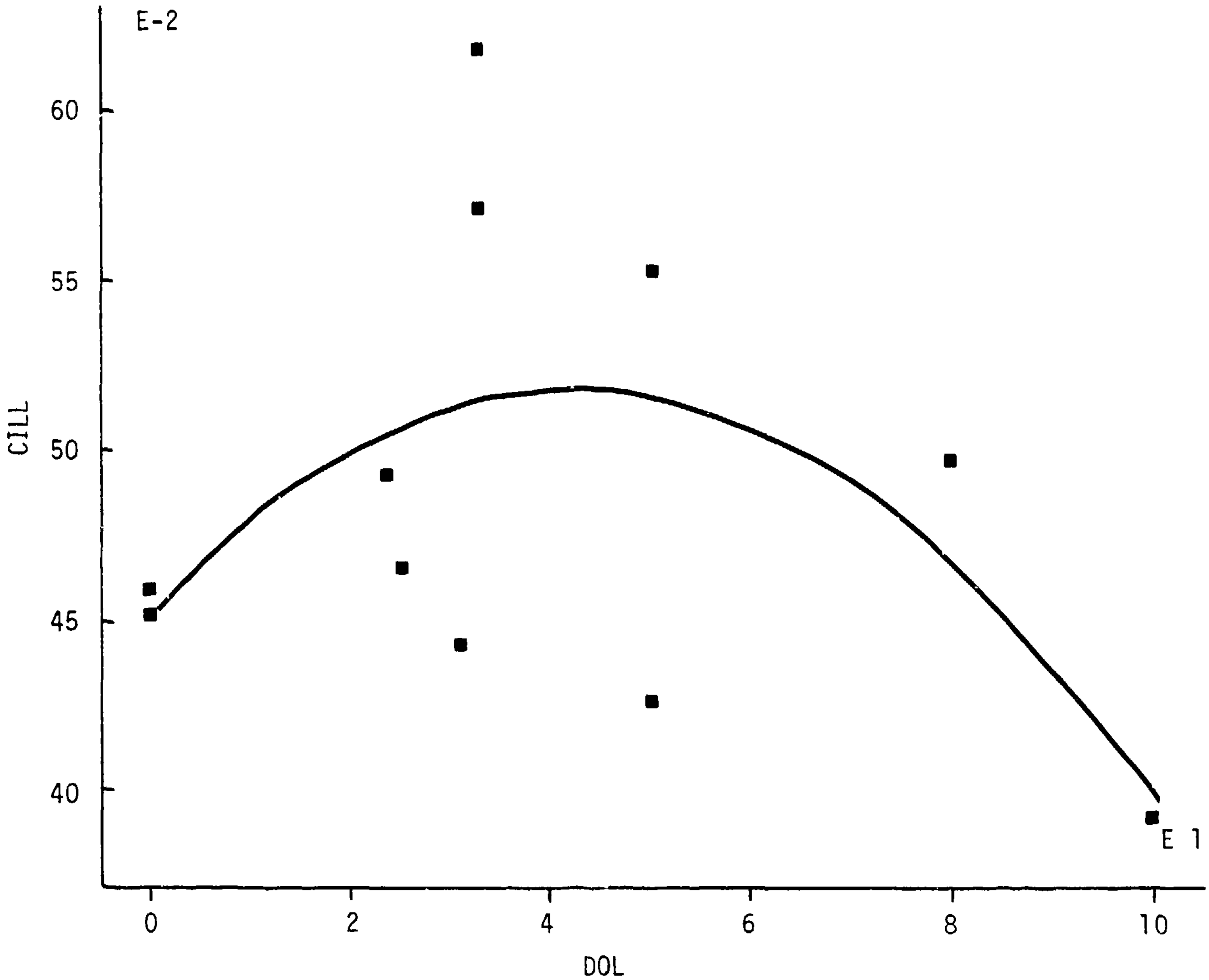


FIGURE 4-8. DIVISION OF LABOR (DOL) VS THE WEIGHTED FORCE MEASURE (CILL)

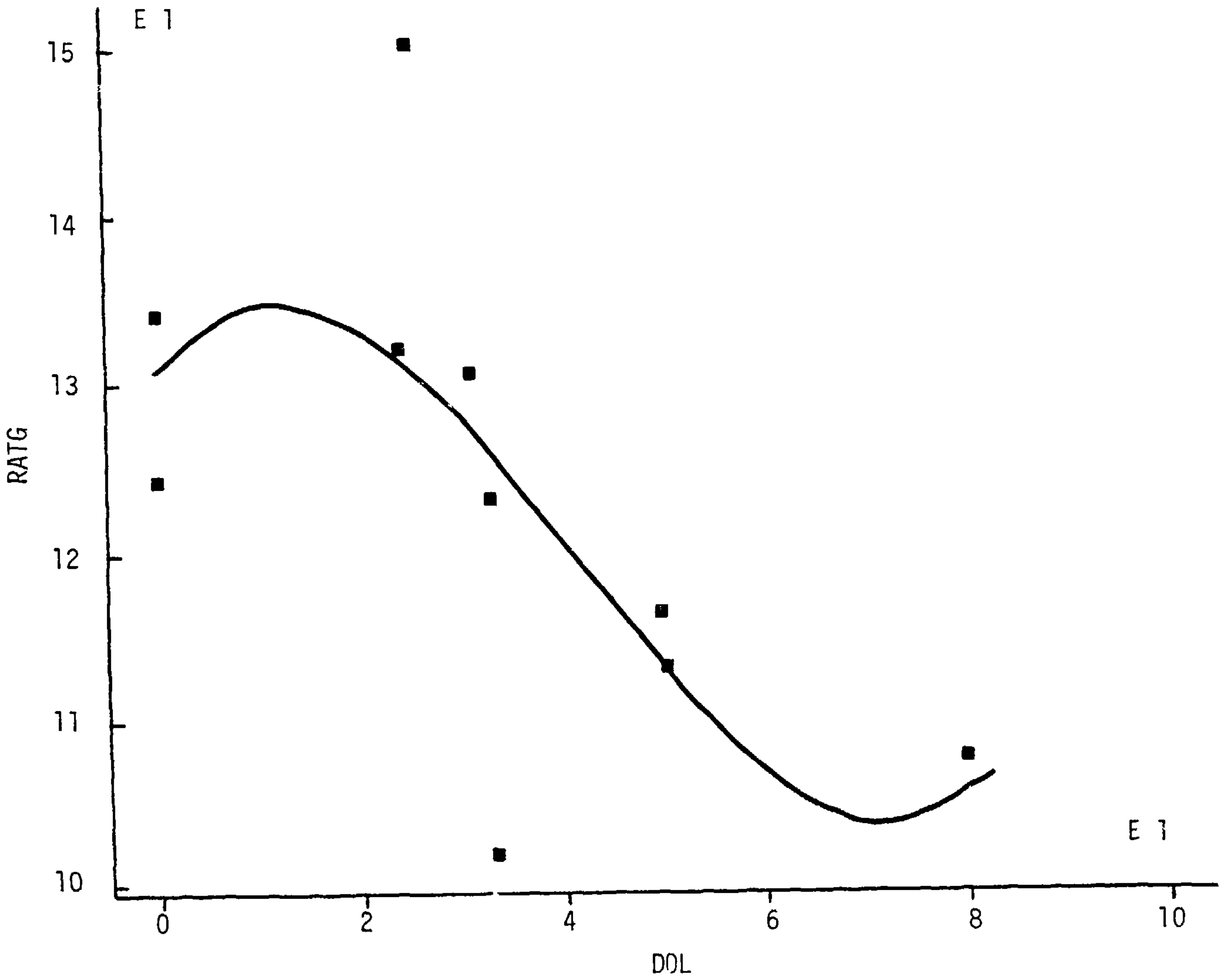


FIGURE 4-9. DIVISION OF LABOR (DOL) VS. CONTROLLERS' RATING OF OVERALL PERFORMANCE (RATG).

4) The results are only preliminary: (a) the computed measures have not been thoroughly examined, and (b) additional measures (both from additional observation tasks and from reduction of already collected but unanalyzed data) need to be analyzed.

Table 4-8. CURVE FITTING STATISTICS

	Coefficient of Determination	Correlation Coefficient	Standard Error
Division of Labor x RATG			
Linear	0.105	0.3241	0.136
Polynomial (2)	0.1879	0.4335	0.137
(3)*	0.4475	0.6689	0.121
Division of Labor x CILL			
Linear	0.0361	0.1899	0.0722
Exponential	0.0506	0.2249	0.1443
Polynomial (2)*	0.1330	0.5829	0.0632
(3)	0.3463	0.5885	0.0674
(4)	0.3515	0.5928	0.0725

* Plotted relationship

4.5 TENTATIVE FINDINGS

4.5.1 Procedural vs. Non-procedural Behaviors

The distinction between procedural and non-procedural behaviors was drawn along two lines: 1) within the context of the model, I and O tasks are generally considered procedural; P tasks are generally non-procedural; and 2) certain aspects of the interface between human components.

Regarding the P-related tasks, it is apparent that there are wide differences between groups in the distribution of the decision-making activities. This was clear from the descriptive analysis of the three units for which the ratio of "cognitive" to "cognitive-transmit" ratio was presented. Further, three of the cognitive (or at least "P") data transfer types were related to at least one of the simulated battle outcome measures (Insight regarding a future state -- 2.42, statement of a proposed course of action -- 2.6, and statement of an output message to be processed -- 2.72).

While some of the "P" level data transfer types were significantly correlated, so too were the frequencies of both whole message input processing -- 1.1 and output message distribution -- 2.8.

Both non-procedural and procedural dimensions of the group's behavior as measured by I-P-O functions appear initially to relate to overall group performance measures.

The second operational distinction between procedural and non-procedural behaviors related to the interface between components. The procedural aspects of the interface were efficiency in communication procedures (ATIM) and the method of communication (mode). The non-procedural aspect was what was here referred to as style.

The mode of communication was not correlated with any of the outcome measures. However, this may have been simply due to the fact that the vast majority were made via radio or telephone with loud-speaker. The quality of video recordings does not permit very accurate assessment of non-verbal face-to-face communication. On the other hand, the average transmission time was correlated with the controller's ratings of performance and one of the simulated battle outcome measures.

The procedural aspects of the interface were at least in part measured by the quality ratings of senders and receivers. Sender transmission quality was correlated with controller ratings of overall group performance.

<u>Summary</u>:

- There are preliminary indications that both procedural and non-procedural behaviors as measured by aspects of the interface are related to measures of overall group performance.

4.5.2 Individual, Multi-Individual, and Team Behavior

Section 2 presented the argument that the same generic model could be applied to individual and multi-individual behaviors as well as team behavior. The data which were collected included both individual measures and collective team measures. These data were used to provide individual, aggregated individual and team behavior indicators. However, the focus of the analysis was on team behaviors.

One uniquely team measure was the division of labor measure based on relative distribution of cognitive processes. The previous section pointed out that the division of labor measure appeared to be a very sensitive measure of differences between teams. The preliminary finding is that perhaps during execution of the battle, higher division of labor may not be as effective, but the caveats stated in para. 4.4 apply.

Another team measure was the time taken to react effectively to a situation. One indication of this was the time to react to jamming. This measure did not correlate with simulated battle outcomes or overall team performance ratings. However, this preliminary analysis did not control for important extraneous variables (e.g., level of communications difficulty) which were systematically varied from game to game.

The analysis also included measures which are aggregated individual measures and, as such, are dimensions of team behavior. The average time to transmit (or communicate) is one such measure. The average transit time was significantly correlated with the controller's ratings of overall performance and with one of the simulated battle outcome measures. A second aggregated individual measure was the quality of sender transmissions. This measure correlated with the controller ratings of overall performance.

Several team measures were sensitive to differences between team operations or were related to criteria measures. These included one measure which can be considered a measure of the degree of synergistic sharing of tasks.

4.5.3 Conclusions on the Methodology

The essence of the approach is the ability to detect and classify higher level cognitive processes reliably. Their occurrence must be inferred from a comparison of the outputs from a component with the inputs provided to that component. Successful performance of this task requires: 1) the capability to track, in detail, the information traffic (including face-to-face conversations) through the staff; (2) observers familiar with the specific environment, who know the vocabulary and who can recognize from the output-input comparison what higher level processes have occurred; 3) a useable taxonomy of output-input comparisons from which reliable inference can be drawn.

The first two of these requirements are satisfied respectively by the upgraded recording and playback systems and using experienced trained observers. To satisfy the third requirement, the data transfer type taxonomy (DTT) was developed. The taxonomy was at least in part successful. It was, at the very least, sufficiently sensitive to measure differences between unit information/decision activities.

However, there needs to be further operational and conceptual clarification of the categories to develop thorough, logical, and, if possible, theoretically based links between the DTT categories, the cognitive processes, and dimensions of team behavior.

SECTION 5

DISCUSSION

SECTION 5

DISCUSSION

5.1 METHODOLOGY

The methodology for evaluating group behaviors (information processing activities, styles, decision processes) is still in need of refinement and further testing. One problem is the criterion issue.

Controller ratings are highly correlated ($r = 0.66$, $p = 0.00$) with the day of training. A large part of this is likely to be the effect of the training. However, the scores appear to be influenced by what might be called the "verbal skills" of the players. For example, the ratings (variable RATG) appear to be highly negatively correlated with ATIM (average transmission time); i.e., the longer they talk, the lower their ratings. RATG is also significantly correlated with SQUA (the rating of quality of the sender transmissions); i.e., the better the team's performance in transmitting information, the better the controller ratings. Both of these make intuitive sense. However, ATIM was also significantly correlated with the loss exchange ratio (LER).

The correlations in Table 4-4 indicate that the data transmission typology may be one useful paradigm of information process activities and argues for the logical incorporation of I-P-O concept within the general model. There is still a great deal of decision activity which either has not been measured or, if measured, has not been analyzed. The data transmission typology does not adequately address the non-observable decision processes. Measures are needed which differentiate between team and individual capacities or predispositions for using information in decision making; then, it is necessary to tie these measures to performance. Complexity Theory (Streufert, 1981) may provide a needed extension.

A related issue is the ARTEPS. To translate the results of Objective 1 into pragmatic training requirements, the specific tasks required to complete a staff function need to be translated into a set of information processing activities which can, in turn, be measured. This is being addressed in the Objective 2 effort.

A more general concern is the need for greater precision and breadth in the data collection analysis. Much of the data collected during the first year have not yet been analyzed. Additional observational tasks need to be carried out on the exercises already collected as well as those to be recorded. One obvious requirement is a comprehensive data base of criteria, observations, questionnnaire data, and ratings to be constructed covering continual snapshots of each exercise.

In summary, the following issues are priority concerns for the subsequent years of the research:

- Develop a better analytical procedure for reducing the uncontrolled variation due to time between probe and simulation outcome measure. One approach is to develop the capability to tie, temporally, group behaviors to unit status measures.

- Develop an approach to assess decision processes. The approach should integrate an improved data transmission typology and other decision analysis strategies (e.g., Streufert).

- Develop an expanded research data base to incorporate ratings, observation measures, and simulated status data.

- Further develop the behavioral model. Emphasis should be on relating the information flow model to 1) ARTEPS, 2) group behavior constructs found in the literature, and 3) performance outcomes.

5.2 OTHER OBSERVATIONS

5.2.1 Measuring the Effect of C^2

The observational tasks stimulated some adjustments in the rating procedures and a number of discussions regarding the ultimate purpose of Objective 1. It could be said that one of the purposes of Objective 1 is to quantify and objectify "command and control" (at battalion-level) and to "prove" that C^2 is a significant determinant of the outcomes of battle (at least so far as simulated in CATTS). This may appear obvious, but the importance of this purpose and the importance of declaring it as a purpose (at least within the project) was brought out by a player's comment overheard at CATTS that "command and control didn't make any difference anyway" (the implication being that it was all tactics and trigger-pulling).

The question is: If C^2 is important, how is it important; what things does it affect on the battlefield; how do you assess it; how do you train it; and how do you improve it? The methodology for Objective 1 is being developed to provide some answers to these questions. It has been of interest to note that in a number of cases which were observed during the audio/video review, some command groups which did not perform particularly well came out of situations "smelling like a rose." Several instances come to mind:

Case 1: A battalion essentially lost track of one company in a sister battalion's sector. Upon gaining control again, after almost losing the company to friendly artillery fire, it was discovered that that company and another had an advancing red tank unit flanked. The red unit was eliminated in minutes.

Case 2: A battalion receives a SLAR report that enemy tanks have been sighted but fails to pass the information to the companies which soon thereafter encounter the T62s. The unit manages to come out of the fight in good shape.

Case 3: An assistant S3 is put in charge of running the war while the JTOC moves. The particular individual is an especially religious person who spends more time discussing his persuasion than dealing with the war. The company commanders essentially take over the war until the JTOC is back up. (In this instance, essentially no training was going on since the company commanders are player/controllers working with computer displays. No one in the TOC paid much attention to the war.) The application of fire power allowed the unit to survive.

All of these instances have implications for the purpose of Objective 1, i.e., the demonstration of the connection between C^2 and success on the battlefield. In the instances provided above, poor C^2 yielded superior results. However, luck is not a trainable or controllable factor in combat success. Despite these instances, it is the objective of training to develop the skills and knowledge needed to improve chances of success. In C^2, chances of success are improved: a) when accurate, timely information is disseminated and used, and b) when timely decisions are made which, when implemented, have a high chance of success because of their use of the best information available. The focus of the second year is on improving the data collection and analysis methodologies for demonstrating the connection between C^2 and success on the battlefield.

A second but related issue deals with how the purpose can be achieved, i.e., how the methodology being employed can be used to determine the extent to which C^2 has a direct, measurable impact on the outcome of battle. Further, Objective 2 must determine how the methodology of Objective 1 can be used to better train staffs in the "how to" of C^2 and fully impress staffs with the significance of efficient, accurate information collection, decision making, and order and information dissemination. To this end, an analytical model has been conceptualized which is discussed in para. 5.3. This model (or some version thereof) will most likely be that which guides the second year's analytical efforts.

5.2.2 The Laboratory

There are a number of observations regarding the recording and playback/observations systems. These are summarized as follows.

5.2.2.1 Recording System

- Although cooperation and coordination with CATTS personnel has been excellent, there have been some occasions where equipment has been adjusted for the convenience of the controllers and where such adjustments have impacted on the quality or completeness of the recordings. This situation is being resolved through informal "education" of the staff.

- The recording system itself is a collage of audio/video equipment placed on top of 7-foot equipment racks, behind consoles, and stacked on improvised shelving. This has undoubtedly contributed to the periodic unreliability of the system. Regardless, it is a full-time job during the exercise to monitor equipment and keep the necessary records of exercise and recording system operational events. This problem can only be solved when the planned facilities changes have been completed and recording control room and workstations are available.

- There are not adequate devices to ensure complete recording of the exercise. Additional recorders, lapel mikes, and possibly even color cameras are needed to improve the recordings. The solution is, in part, the additional equipment which CATTS contemplates purchasing.

- Neither the current system nor the enhanced system now being contemplated will allow adequate tracking of at least one significant set of data -- references to wall maps. Maps represent the most important single hard copy data base in the tactical operations center. It serves as a principal mechanism for communication between individuals and is probably the most often "queried" data base. However, the video recordings now being made do not enable the observers to clearly distinguish what, on a map, a staff or group is referring to. A solution to this probably involves the purchase of remote controlled, zoom, turret cameras. No funds for such equipment are currently available.

5.2.2.2 The Playback/Observation System

- The final observation tasks underscored the limits to the playback equipments, both the number and quality thereof. Information cannot be completely tracked through a staff when only one video camera recording is made of the three different physical locations. The probes conducted for the first year had the major limitation of being biased by the selection of the camera location. That is, the probe data for some exercises is based on video data of two or three people (e.g., the commander, the S3, the FSO) in the JTOC; for other exercises, the same probe data is based on the entire command group in the TOC with a view of the S2 map; still others are of the TOC with a view of the S3 map. This being the case, the counts of references to hard copy data bases (one of the probe frequency data) are entirely dependent on the view of the camera during the probe sequence.

The solution to this is largely based on the currently proposed equipment purchase. This will ensure at least two video records (JTOC and TOC) at all times and, given the status of equipment at any given time, should permit recording and assessment of the S1/S4 activity also.

- Assessment of any information flow sequence is most valuable when performed in the context of the tactical situation. The data for the first year are limited by the fact that there is no capacity for the rater/observer to "see the battlefield" while rating. This capacity is needed to judge the perceived urgency of the actions of the command group (e.g., targets 10 km away are not as critical as targets 1.5 km away).

  One step that has been taken is to retrieve the tissue overlays used in planning which specifies the tactical objectives laid out in the plan. Second, the maps for the locations of the battles will be placed in the observation laboratory. Proposed steps are:

  1) The purchase of a remote control, zoom camera which will allow recording of tactical maps and the placement of tactical information on those maps.

  2) Equipping the CATTS with digitizers on which the tactical maps are placed. This would allow observers to electronically record and command group's "perception" of the battlefield. This would directly and significantly improve the detail of information which can be fed back to players in the past exercise training. It would also significantly improve the data available for research purposes, specifically, the data necessary for the analytical model proposed in the attached working paper.

- The observer's task is greatly encumbered by the manipulation of multiple recording devices in order to attempt to identify the threads of information regarding a probe topic. (The original concept proposed at the beginning of the first year was the capability for a single control switch operation.) The additional equipment being purchased will not solve this problem -- all equipment will be driven by the same time code generator; however, there will be more equipment to keep synchronized. (Note: In one of the discussions in a recent visit, it was agreed that SAI should take a preliminary look at the size of the engineering task needed to solve the problem.)

5.2.2.3 The Probe Data

- As the analysis of the first year's data is progressing, a number of other questions and probes for gathering data on those questions have been identified:

- One of the most repeated and error-prone communication activities in the command group is the reporting and dissemination of coordinates. The problem presumably comes from the fact that: 1) six digits span is about all that can be remembered by a typical person (granted trained military personnel are more accustomed to the use of 6-digit numbers); 2) a raft of coordinates are being used at the same time, all of which may have a number of similar digits (e.g., a company in a quadrant 804794 may have a platoon in 805793 and may have the enemy at 802799); 3) the coordinates for any given unit can change every couple of minutes, depending on the rate of advance. All of these factors present significant mental workload on the staffs. The observable dimension of the workload is the frequent occasions observed during review of the video tapes in which a single set of coordinates is repeated again and again, even within the confines of a 6 to 8 man group within the TOC. This is one obvious place where a simple, automated filing and retrieval system would greatly cut down the inefficiency and error rates of the group.

In order to get a better understanding of this, the probe system for the second year will include a data collection exercise which will track coordinates through the staff and identify the frequency of their collection, dissemination and use, and the number and type of errors which occur during their processing.

- The second modification in probe methodology will be to select a series of comparable events in the observed exercises; then, to rate the success of the events and, then, to work backwards in time to identify the C^2 activities which contributed to the adequacy of the performance of the event. This methodology is in line with the fault analysis discussed in the original proposal for the project.

5.2.2.4 Improving the comparability and Training Significance of Simulated Tactical Outcomes

- There are a number of alternative procedures which can be employed at CATTS to improve: 1) the comparability of the tactical simulation outcomes data and, thereby, 2) the specificity of the feedback which CATTS can provide to the participating groups. These are:

  - The single most "uncontrollable" game variable (next to controller behavior) is the existence and use of the tactical CRT monitor in the JTOC. The existence of the monitor is usually discovered by the second day of a team's training. Often, once the CRT's existence is discovered, the commander spends time learning how to interpret this "tactical decision aid" rather than exercising his C^2 and tactical skills in the manner for which CATTS was designed. This process also completely confounds the results of the impact of training over the several days of a group's training.

  - Frequently, events occur which significantly reduce the realism of the game. For example:

Case 1. In one exercise, the JTOC is killed and an assistant S3 takes over the war. After several minutes of attempting to update the status of friendly and enemy forces, the individual walks out of the TOC, across the hallway, and into the room which houses the JTOC and the tactical display. He takes a quick look at "the battlefield," walks back to the TOC, and begins ordering a series of maneuvers which his company commander resists until he is told the new commander has seen the computer display.

Case 2. The commander goes into the JTOC to "see the battlefield." As part of the procedure, he pulls the company commanders out of the control room to get a briefing from each. All this was satisfactory. However, he then summarizes all the computer display information and "sends it" to the TOC to update the S3 and S2 maps.

Case 3. The TOC is informed by the JTOC that the JTOC is moving. However, a significant piece of information comes over the radio during the simulated move. The switch operator denies the request for contact with the JTOC by the TOC but the switch controller is told that JTOC "really isn't moving YET." After some discussion with other controllers, the call goes through.

Case 4. The JTOC is moving. The game requires 15 to 20 minutes before communications are normally resumed. In several cases, the JTOC assumed a new location and resumed communication almost immediately.

CATTS is one of the most sophisticated instrumented training simulations in the Armed Services. This capacity could be taken advantage of by modest changes to the administration of the exercises. The changes include:

1) Adherence to realistic JTOC move times and communications

2) Removal of the CRT in the JTOC (at least until a more realistic and appropriate display can be developed (even then the JTOC players will tend to train on the CRT, not fight the battle with current capability)

3) Enforcement of rules regarding the physical movement of players into the various rooms in the CATTS facility until all training is completed.

5.3 A REVISED ANALYTICAL MODEL

A team is a coping organism. Like other organisms, it assesses its environment and determines how it can best accomplish its mission and survive. One of the principal means by which the command group assesses its chances for survival in combat is by tracking the extent to which the battle is going according to its plan. Surviving requires that the group:

1) Sense quickly any deviations from the plan or events unanticipated by the plan

2) Communicate this information to the decision component and other components potentially affected by the information

3) Identify and assess alternatives

4) Choose an alternative in a timely manner

5) Disseminate that decision to action elements.

All these steps are taken to make the battle turn out as planned (i.e., mission is accomplished and the unit survives).

The first year's analysis was oriented toward simply testing out the technology and methodology for obtaining useful records of command group behavior and toward testing the preliminary methodology for identifying and quantifying behaviors. The second year will focus more closely on behaviors which tend to allow the group to survive. An adequate familiarity with procedures has been gained which will allow the project to gather data to measure these behaviors.

This section discusses a possible approach to quantifying some of the team concepts which the C^2 Group Behavior project is addressing. It describes a means for: 1) measuring a team's sensing of the emerging situation (i.e., not simply change, but deviation from the expectations as expressed in the planned course of action), 2) differentiating between teams based on their tolerance for deviation from the planned course, and 3) measuring the thresholds at which different teams will attempt to take corrective action.

To illustrate the proposed approach, the following example is used: A battalion plans an attack. As part of the plan, two objectives -- green and blue -- and two intermediate phase lines, PL1 and PL2, are defined along with the times they are to reach these points. This is pictured in Figure 5-1. The vertical axis is the number of kilometers of advance. The horizontal axis is time, and is marked with the points in time at which the phase lines and objectives are to be reached. (PL1 is 2 km and is to be reached within 30 minutes.) Three items are plotted on the graph for each time -- the planned value (P), the actual value achieved (A), and the known or perceived value (K -- the value based on the best information the command group has at the time). Note that the perceived value is slightly displaced from the time of the other two values. This represents the fact that the data received in the command group is always somewhat delayed. Sometimes this is a matter of seconds; sometimes it is a matter of hours.

If these three sets of data are known (they are retrievable in CATTS, see para. 2.3 above), then a number of computations are possible:

- (P-K) The difference between the planned and the known values is the degree to which the battle is emerging in unanticipated ways. The bigger the difference, the more likely it would be expected that the group will be discussing alternatives and making decisions on how to correct the situation.

- (A-K) The difference between the actual situation and the perceived situation is the difference between "ground truth" and the group's perception of that truth. It is a measure of the group's information gathering and data base maintenance skills.

- (A-P) The difference between the actual state of affairs and the planned state is a measure of the quality of the plan (assuming that the battle has been conducted according to the plan).

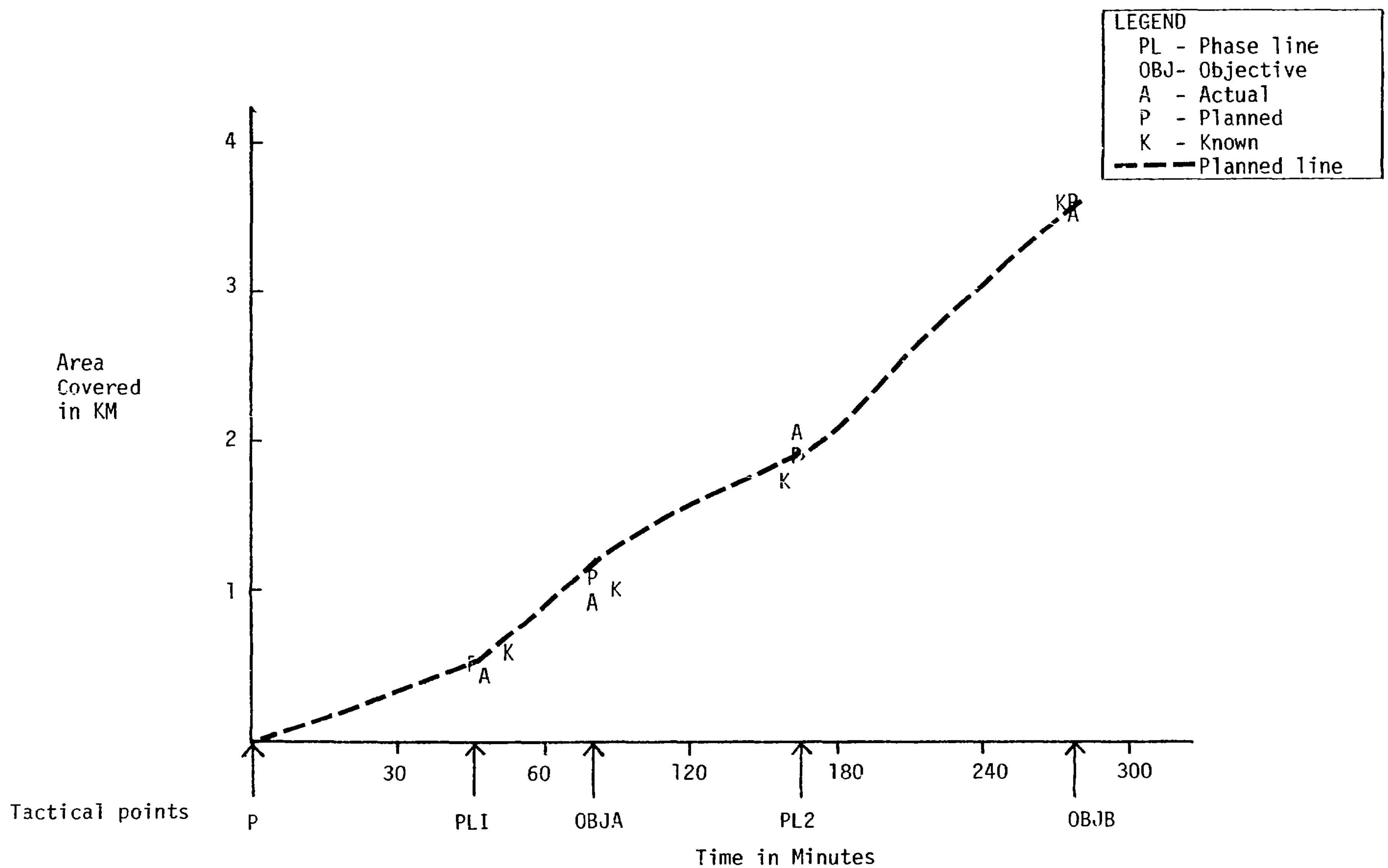


FIGURE 5-1. PROPOSED ANALYTICAL STRATEGY

One of the predictors of team performance is the degree to which the team successfully senses the deviation from the plan. A measure of this sensing behavior is the average (or the maximum) value of (P-K) during an exercise. The hypothesis is that teams with lower values are better sensors and, therefore, other things being equal, will perform better by more quickly responding to (i.e., adapting to) the environment.

Another predictor of performance, especially in combat, is planning skills. A measure of this is the average of maximum value of (A-P). The hypothesis is that the lower the difference, the better the plan since the plan was, in fact, a better predictor of a future state of affairs.

A third predictor which follows from the model used in the CGB project is (A-K). The hypothesis is that groups which are better in information processing skills and data base maintenance will be better performers since the data on which they will base their decisions is more valid. (A-K) is a measure of the validity, vis-a-vis the actual state of affairs, of the data base.

As indicated above, the data needed to test this model and resulting hypotheses are readily available from CATTS. The planned data are retrievable from the OPORD briefing, augmented through retrieval of the tactical overlays and review of the audio/video tapes. The actual data are retrievable from the game status tapes which provide snapshots of the exercises at 10-minute intervals. The perceived data can be taken from the review of the audio/visual tapes.

The advance and rate of advance are not the only variables which determine decision-making behavior or the content of the decisions. A large set of other variables is taken into account both in the planning process and in the decisions made during the execution of the battle. Most of these have to do with the level of, rate of expenditure of, and rates of resupply of resources. Planned, actual, and known (perceived) rates for these variables are also available as part of the CATTS exercises and can be included in the algorithms for the measurement and prediction of sensing and decision-making activities.

Having defined the general procedure for measuring planned, actual, and known (perceived) events, the next issue is how to relate these measures to the behavior of the command and control team. It is the measurement behavior of the teams in response to P-K that should distinguish between effective and non-effective teams. For example, it would be expected that the better teams would more quickly sense deviations of K from P; they would be expected more quickly to generate alternative solutions to rectify the situation; they would be expected to disseminate the chosen alternative more thoroughly, more quickly, and more accurately.

SECTION 6

RECOMMENDATIONS

SECTION 6

RECOMMENDATIONS

Based on the first-year effort in methodology development, instrumentation of CATTS, data extraction and analysis, and the preliminary findings and discussion, it is recommended that the following steps be taken to improve the viability of CATTS as a C^2 group behavior laboratory and to facilitate its use in reaching Objective 1:

- Carry out as many (preferably all) of the long-term improvements proposed in para. 3.5 above to provide the following capabilities:
  - Follow two key players at all times with voice-activated mikes and filter all audio recordings
  - Record and replay video in all three locations played in CATTS (TOC, JTOC, and TRAINS)
  - Produce selected excerpts for analysis and feedback to players
  - Provide the capability to record and synchronously replay the tactical situation, both player and controller.
- Tighten up the administration of CATTS by:
  - Adhering to realistic JTOC move times and communication restrictions
  - Removing the CRT display from the JTOC
  - Strict enforcement of rules restricting player access to unauthorized CATTS facilities until completion of training.
- Extend the data extraction methodology to collect the data needed to calculate Streufert's "Complexity Measures" and to implement the analysis proposed in para. 5.3 above (measures of team performance with respect to slack in the team's perception of the situation, magnitude of the tolerated difference between plan and perception, and difference between plan and execution).
- Extend the model inherent in the first-year methodology to show the conceptual interrelation among combat outcomes, team performance measures, complexity measures, and the behavioral, information processing measures.

- Implement and exercise the analytic methodology proposed in para. 5.3 to demonstrate the correlation among: combat outcomes, the proposed team performance measures, complexity measures, and behavioral measures.

APPENDIX A

REFERENCES

APPENDIX A

REFERENCES

Alexander, L. T., and A. S. Cooperband, System training and research in team behavior, Technical Memorandum 2581, System Development Corporation, August 1975.

Barber, H. F., I. T. Kaplan, and G. S. Thomas, Preliminary results of the CATTS system and scenario characteristics investigation, Working paper FLvFU 82-1, U. S. Army Research Institute, May 1982.

Bloom, J. N., and A. M. Farber, Art and requirements of command, Technical Report 1-191, The Franklinn Institute Research Laboratories, April 1967.

Boguslaw, R., and E. H. Porter, Team functions in training, R. M. Gagne (Ed.) in Psychological Principles in System Development, Holt, Rinehart, and Winston, New York, 1962.

Briggs, G. E., and W. A. Johnston, Team training, Final report, February 1966-February 1967, NAVTRADEVCEN 1327-4, Naval Training Device Center, Orlando, Florida, 1967.

Burns, T., The directions of activity and communication in a departmental executive group, Human Relations, 7, 1954.

Cherry, Colin, On Human Communication, John Wiley & Sons, Inc., New York, 1957.

Defense Science Board, Report of the task force on training technology, Chapter 8: Crew/Group/Unit Training, Office of the Director of Defense Research and Engineering, Department of Defense, Washington, D. C., May 1975.

Denson, Roland W., Team training: literature review and annotated bibliography, Final report AFHRL-TR-80-40, Air Force Human Resources Library, May 1981.

Department of the Army Field Manual 101-5, Staff Officer's Field Manual: Staff Organization and Procedures, 19 July 1972.

Department of the Army Field Manual 100-15, Larger Unit Operations, 15 March 1974 (Test).

Department of the Army, Army Training and Evaluation Program (ARTEP) 71-2 for Mechanized Infantry/Tank Task Force, 17 June 1977.

Department of the Army ARTEP 100-1, for Maneuver Brigade Command Groups and Staff, 22 May 1978.

Department of the Army ARTEP 100-2, for Division Command Group and Staff, March 1978.

Federman, P., and A. I. Siegal, Communications, as a measurable index of team behavior, Technical Report NAVTRADEVCEN 1537-1), Naval Training Device Center, Orlando, Florida, October 1965.

Gagne, Robert H. (Ed.), Psychological Principles in System Development, Holt, Rinehart, and Winston, 1962.

Hall, E. R., and W. A. Rizzo, An assessment of U. S. Navy tactical team training: focus on the training man, TAEG, Report No. 18, Training Analysis and Evaluation Group, March 1975.

Harper, W. K., Executive time: a corporation's most valuable, scarce and irrecoverable resource, DBA Thesis, Graduate School of Business Administration, Harvard University, 1968.

Horn, J. H., and T. Lupton, The work activities of "middle" managers -- an exploratory study, Journal of Management Studies, 2, 1965.

Horrocks, J., R. E. Krug, and E. Hearman, Team training II: individual learning and team performance, Technical Report NAVTRADEVCEN 198-2, Port Washington, New York: U. S. Naval Training Device Center, August 1960.

Johnston, W. A., Transfer of team skills as a function of type of training, Journal of Applied Psychology, Vol. 2, No. 2, 1968, 89-94.

Kanarick, A. F., D. G. Alden, and R. W. Daniels, Decision making and team training in complex tactical training systems of the future, 25th Anniversary Commemorative Technical Journal, Naval Training Device Center, 1971.

Klaus, D. J., and R. Glaser, Increasing team proficiency through training, 5: Team learning as a function of member learning characteristics and practice conditions, AIR-E1-4/65-TR, Pittsburgh, Pennsylvania, American Institutes for Research, Team Training Laboratory, 1965.

Klaus, D. J., and R. Glaser, Increasing team proficiency through training, 8: Final summary report, AIR-El-6/68-FR, Pittsburgh, Pennsylvania, American Institutes for Research, 1968.

Mintzburg, H., An emerging strategy of "direct" research, Administrative Science Quarterly, Vol. 24, No. 4, December 1979.

Olmstead, J. A., M. J. Baravick, and L. B. Elder, The Skills of leadership, Professional Paper 15-6/, The George Washington University: Human Resources Research Office, April 1967.

Pierce, John R., Introduction to Information Theory, Dover Publications, Inc., New York, 1961.

Simon, A., and E. G. Boyer (Eds.), Mirrors for behavior II: an anthology of observation instruments, Vol. A and B, Philadelphia, Pennsylvania, Classroom Interaction Newsletter, C/P Research for Better Schools, Inc., 1970.

Stevens, S. S., Psychophysics, John Wiley and Sons, New York, 1975.

Streufert, Siegfried and Susan, Decision Making in Complex Tasks, Technical Report #3, Pennsylvania State University, College of Medicine, Hershey, Pennsylvania, May 1981.

Theologus, G. C., and E. A. Fleishman, Development of a Taxonomy of Human Performance, American Institute for Research, Technical Report 10, Washington, D. C., April 1971.

Tiede, R. V., et al., Some Guidelines for Effective Task Design in Command and Control Simulations, U. S. Army Research Institute for the Behavioral Sciences, Research Note 80-40, November 1980.

Tiede, R. V., et al., The Integrated Battlefield Control System (ICS) Third Refinement Study, Final Report, Science Applications, Inc. (SAI), McLean, Virginia, March 1975.

U. S. Army Training and Doctrine Command (TRADOC) Pamphlet 350-30, Inter-service procedures for Instructional Systems Development: Executive Summary, Phase I, II, III, IV, and V, 1 August 1975.

U. S. Department of Army Training and Evaluation Program, Division Command Group and Staff, ARTEP 100-2, June 1978.

U. S. Department of Army Training and Evaluation Program, Maneuver Brigade Command Group and Staff, ARTEP 100-1, May 1978.

U. S. Department of Army Training and Evaluation Program, Battalion/Task Force (Command Group and Staff), ARTEP 71-2 (Draft).

U. S. Department of Army, Staff Organization and Procedure, FM 101-5, Washington, July 1972.

U. S. Department of Army, Corps Operations, FM 100-15 (Coordinating Draft).

Van Maanen, J., Reclaiming qualitative methods for organizational research: A preface, Administrative Science Quarterly, Vol. 24, No. 4, December 1979.

Vreuls, D., and L. Wooldridge, Aircrew performance measurement, Westlake Village, California, Canyon Research Group, Inc., 1977.

Wagner, H., et al., Team training and evaluation strategies: state-of-the-art, Technical Report TR 77-1, Human Resources Research Organization, February 1977.