A RAND NOTE

A COMPUTER AIDED EXERCISE FACILITY FOR TACTICAL AIR COMMAND AND CONTROL EVALUATION: CONCEPTS AND DESIGN OVERVIEW

Monti Callero, Ralph Strauch, Jack Lind

April 1980

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Prepared For

The United States Air Force

Rand
SANTA MONICA, CA. 90406

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PREFACE

This Note describes research efforts carried out under the Project AIR FORCE-sponsored project on Tactical Air Command and Control. A major goal of the project is to develop general methodology for evaluating tactical air command and control. One approach is to combine appropriately computer modeling and military exercises. The Note discusses design considerations for a Computer-Aided Exercise Facility for that purpose.

SUMMARY

The purpose of this Note is to describe a concept and general design for a Computer Aided Exercise Facility (CAEF) for evaluating tactical air command and control. The CAEF would capitalize on and synthesize the strong points of both command and control exercises and computerized conflict modeling.

Computerized combat models are capable of simulating complex combat interactions between opposing military forces, but are unable to deal adequately with the complexities of the human decision processes directing those forces. Command and control exercises, on the other hand, incorporate this human element directly. However, today's manually run training exercises are of necessity pre-scripted and limited in their representation of conflict by calculation and bookkeeping limitations. Hence, the weakness in each technique is the strength in the other, and their appropriate combination should provide a powerful mechanism for the study of the command and control process. Such a facility would also provide far more realistic and challenging training than is possible with current manually supported exercises.

The design suggested here has three major parts--the C2 Components being exercised; an Exercise Driver which simulates the conflict environment and runs the exercise; and an Evaluation Unit responsible for formulating and conducting the evaluation. Each of these would be integrated man/machine units composed of both humans and computer aids.

The C2 Components in any given exercise would consist of the tactical air, and possibly land or sea, command and control elements necessary to support the exercise and evaluation objectives. During an exercise, these components would interface directly and solely with the Exercise Driver, which would represent the entire conflict environment and react to command and control actions taken. The Evaluation Unit would be responsible for preparing an evaluation design prior to the exercise, overseeing the conduct of the exercise and collecting necessary data to assure the evaluation goals are met, and performing the evaluation analyses following the exercise.

The Exercise Driver is the core of the evaluation exercise. It must be able to provide a simulated conflict environment which is sufficiently realistic and challenging to encourage realistic performance, and which is sufficiently responsive to allow that performance to affect the course of the conflict in reasonable ways. The design of the Exercise Driver must differ greatly from the normal research and analysis modeling and simulation designs, in that the processing requirements, manual and computer, are driven primarily by on-line human information needs. In particular, the players must be serviced with information which is in both form and substance like that they would receive in actual practice. Likewise, the staff of the Exercise Driver must have information continually to perform their tasks. For both groups, the information must be available in "live" time rather than an arbitrary "simulation" time driven by processing requirements, and computerized portions of the simulation must be responsive to the man-machine interactions which dominate this mode of operation.

Other design considerations include: (1) the likely need for frequent modification to meet particular evaluation requirements; (2) the importance of systematic, planned evolutionary development of the CAEF at a pace consistent with growing experience as well as with technological advancements; and (3) the availability of funds, facilities, equipment and personnel. These factors favor a highly modular design rather than a design based on a single very large computer model which does everything.

The CAEF would be an ongoing activity in which learning and evaluation take place in an integrated fashion over time, rather than as a disconnected series of conceptually distinct one-time exercises. The most obvious parts of this activity take place during the run of an exercise, but a great deal of important preparatory activity takes place before the exercise, and much of the analysis and synthesis for the final evaluation must be done afterward. The Evaluation Unit, in particular, will have an ongoing responsiblility for organizing and maintaining the cumulative database derived from all exercises run at the CAEF, for performing comparative evaluations using that database, and for evolving the CAEF itself and developing and refining concepts for using it as an evaluative tool. The CAEF must be designed with this whole process in mind, and not focused too heavily on the exercise period per se.

The purpose of the CAEF is to conduct exercises as a foundation for the understanding and evaluation of command and control processes and systems. However, the evaluation of the contribution of command and control to the combat effectiveness of military forces is an ill-defined and poorly understood area, in need of considerable conceptual

and intellectual development. Sufficient development of concepts and techniques needs to be completed to provide a basis on which to establish an initial capability, but the CAEF, and in particular the Evaluation Unit, should be thought of in part as a testbed within which further development can take place. Design of the CAEF, then, is not a straightforward task of designing an organizational structure and procedure to perform a well-defined and well-understood task. Rather, it requires the articulation of some initial exercise evaluation concepts and a design permitting, and specifying the responsibility for, self-evolution.

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I. INTRODUCTION

One of the most difficult areas of military analysis concerns understanding the role of command and control and the evaluation of its contribution to the overall combat effectiveness of a military force. It is hard to come to grips with the issue of command and control effectiveness, let alone to address it in a hard quantitative manner as is commonly done in related areas such as weapons systems effectiveness. The purpose of this note is to describe a new tool with which to approach this problem, a Computer Aided Exercise Facility (CAEF) for command and control evaluation. Such a facility, we believe, might capitalize on and synthesize the strong points of both manual exercises and computerized combat modeling, allowing each to compensate for and overcome the weaknesses of the other.

This description is preliminary, intended to serve as a starting point for developing the concept and its applicability.

Computer modeling alone has been used for evaluating a wide variety of systems, ranging from social to mechanical, and has been used extensively by the Air Force to evaluate military systems in a conflict environment. Conflict models focused on engagement outcomes have evolved over the years to a point where they have achieved a measure of face validity within the military community. A similar evolution of command and control modules within these models has not occurred. This is due partly to previous lack of interest, and partly to the complexity of representing the command and control systems themselves. But perhaps the most difficult barrier has been the general lack of understanding (at least in the form necessary to allow

it to be inserted into a computer model) of the command and control decisionmaking process--of how information is translated into decisions. The computer modeling approach does not now adequately represent the basic functions of the command and control process--planning, directing and controlling--and there appears to be no workable way to overcome this deficiency within the current state-of-the-art.

Military exercises are usually conducted for procedural training of personnel and to obtain some nonrigorous insight into the capabilities of the systems and forces involved. These goals can be at least partially accomplished in spite of severe limitations on the dynamics and the realism of the conflict arena within which the exercise supposedly takes place. Live force play is grossly artificial because of cost and safety constraints (a fact which is obvious to all participants, including those involved with command and control), while Command Post Exercises using constructive forces have their own sets of different constraints. Chief among these constraints is the bookkeeping required. So much is necessary to provide the inputs to simulate a large-scale conflict that in current manual exercises most of the play must be pre-scripted well in advance. Actions taken by the players thus generally have little effect on the course of events. This renders futile any attempt to evaluate command and control capabilities with respect to their effect on force employment, and casts doubt on the utility of measures of internal efficiency of the system components and even limits the utility of exercises as vehicles for training command and control personnel.

Thus, computer modeling and manual exercises both have serious limitations when used as a basis for the study and evaluation of command and control processes. The approaches, however, are complementary, in that each possesses the potential for offsetting the deficiencies of the other.

The principle deficiency of the computer modeling approach is that it does not adequately model human processes. An exercise framework overcomes this limitation by incorporating the human process within the exercise. People are actually present making decisions and commanding actions, so there is no need to model or simulate them.

The manual exercise is limited in that the external environment--the "war" which can be presented to the human players--is too flat and unresponsive either to truly challenge their decisionmaking capabilities or to provide a framework within which those capabilities can be tested and measured. Computer modeling can overcome these limitations by providing a richer and more reactive simulation of the external environment than can a control team working in a manual mode. The combination of a human exercise team playing within a computer-driven conflict environment should thus produce a far better vehicle for the study of command and control processes than does either of its components alone.

These ideas are portrayed conceptually in Fig. 1. Real combat is a complex and untidy process, as indicated by the rough and uneven shape in Fig. 1a. Command and control is a complex and untidy part of that process, indicated by its uneven shape within the combat process. Combat modeling deals with representations of both processes in which all the rough edges have been smoothed off, and the whole thing has

been made much more regular and orderly, as depicted in Fig. 1b. For some purposes, such as the study of the effects of changes in weapons system performance parameters, the distortions introduced by this smoothing are acceptable, even desirable. But this is frequently not the case for studying the command and control process. Too much important substance may be removed, limiting the amount that can be learned about the real command and control process from its emasculated counterpart in the combat model.

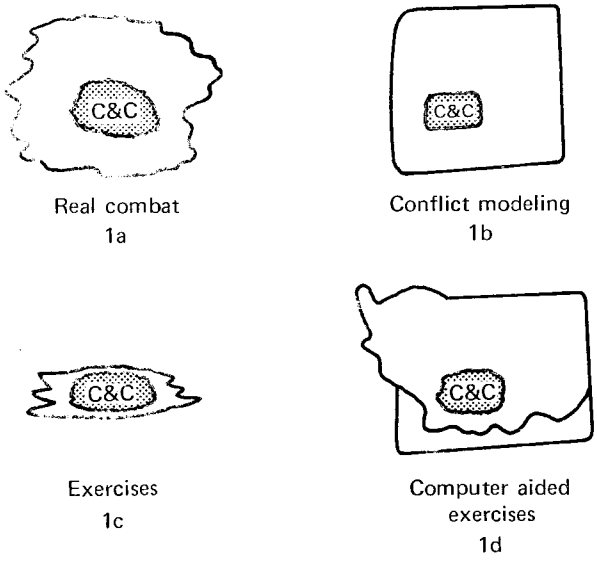

Fig. 1 — Command and control in real and artificial conflict

Moving in the other direction, exercise command and control processes retain much of the richness and complexity of the real process, because the same types of people performing the same types of activities are involved in both. The simulated environment within which most exercises are conducted, however, is too flat and one-dimensional to realistically stress command and control and provide measurable feedback about how it performs (Fig. 1c). But it should be possible to develop a computer-aided exercise methodology in which the real command and control process, with all its complexities and rough edges, is embedded in and interacts with a man/machine simulation of an external combat environment of sufficient complexity and responsiveness to provide a reasonable basis for evaluation of command and control performance and effectiveness (Fig. 1d).

We are concerned with the conceptual design of a CAEF which would integrate a human command and control process with a computer-aided simulation of one conflict environment. The CAEF would provide an environment within which appropriate portions of the existing command and control system (or alternatives or proposed improvements thereto) could be exercised against a computer-aided combat simulation providing a degree of realism, challenge and responsiveness to actions taken not otherwise attainable apart from actual combat. For evaluative purposes, the CAEF might be better than actual combat. The actions taken and the effects of various actions can be monitored and analyzed to a degree impossible in actual combat, and replications and systematic variations would be possible as well.

While we are concerned here with the CAEF as an evaluation tool, it should be noted that it provides important training capabilities as

well. The same flatness and unresponsiveness which limits the evaluative value of manual exercises also limits their training value, and may sometimes encourage trainees to learn the wrong lessons. The kind of responsive environment needed for evaluation should provide players with a much more realistic and challenging training experience if operated in a training mode, and we would expect the CAEF to be used for both purposes.

The CAEF should not be thought of as a conceptually distinct series of one-shot exercises, but as an ongoing activity in the business of conducting computer-aided command and control exercises and evaluating and learning from the results. The ongoing nature of the activity is important because it allows learning and evaluation to take place in an integrated fashion over time, and the evaluation function must be performed in a way which takes advantage of this. This has significant implications for the design and operation of the CAEF.

It is our intent to explore design and operating concepts and develop a feasible preliminary design for such a facility. But it is not our intent to prescribe structure and operations in detail. We feel that must evolve over time. Our preliminary design will provide a starting point to be fleshed out as the facility itself is implemented incrementally. To accomplish our task, we give some attention to issues beyond those of designing and running computer-aided exercises, including the evaluation process itself, the operation of an ongoing facility and the organization supporting it.

II. THE COMPUTER-AIDED EVALUATION EXERCISE

The principal activity of the CAEF is to conduct computer-aided evaluation exercises, i.e., computer-aided exercises for the purpose of evaluating command and control systems and processes. The most obvious part of this activity takes place during the run of an exercise--while the players are at the facility engaged in fighting an imaginary "war" and the whole place has an active combat air to it. But this is only a part of the activity which goes into the conduct of such exercises and the evaluations based on them. A great deal of important preparatory activity takes place before the exercise, and much of the analysis and synthesis for the final evaluation must be done afterwards. The CAEF must be designed with this whole cycle in mind, and not focused too heavily on the exercise period per se.

Because of the ongoing nature of the CAEF and the size of the permanent party staff likely to be assigned, it seems reasonable to assume that it would be exercised on a regular and routine basis. That is to say that the scheduling of exercises would not be driven solely by evaluation questions but would also be influenced by considerations of facility utilization. The sequence of events associated with a particular exercise would probably be similar to that shown in the exercise cycle in Fig. 2.

The cycle begins several months before the exercise, as the evaluation objectives are formalized. These exercise objectives would probably be negotiated between various interested parties both internal to and external to the facility. The various aspects of command and control systems and processes which might be evaluated in

a particular exercise could include, for example, organizational or procedural alternatives, new or modified sensor or communications systems, automated aids under consideration, or doctrinal alternatives.

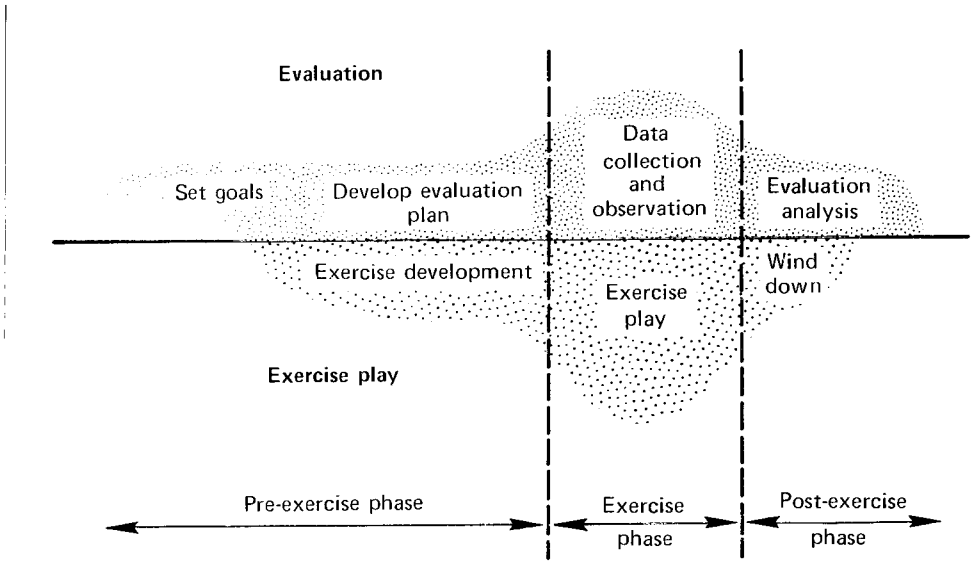

Fig. 2 — The exercise cycle

Development of the exercise plan would then begin. Depending on the nature of the evaluation objectives, a scenario would be chosen to set the stage for the exercise. Since the exercise is conducted in a free play mode, there is no detailed scenario to be followed as the exercise progresses; however, the overall objectives and operations plans for both friendly and enemy forces must be established to provide a baseline for conducting the conflict consistent with the

evaluation requirements. This might be a new scenario or an update of a stock scenario already available.

Modifications would be made to accommodate whatever variations in equipment, organization or procedure might be required for the current exercise. New systems should not be evaluated using old environments and procedures. Players must learn how to use new things in the best way before they can be fairly evaluated, and this experience should be acquired during this pre-exercise phase so the evaluation can be done on a smooth, efficient operation of a modified system. Existing procedures, subsystems and supporting systems should be adapted to best accommodate test system configurations.

Development of an evaluation and documentation plan would take place concurrently with the exercise development. Evaluation objectives would guide the definition of data to be collected and observations to be made. Some of this data could be picked off automatically by the computer during the course of the exercise, while some would require the presence of knowledgeable human observers. Provisions would be made for more complete documentation than that required by the exercise objectives, in order to support the historical database.

Close coordination should occur between exercise planners and evaluation planners throughout the development cycle. Exercise planners would probably be almost entirely facility personnel, while the evaluation planners would come from the facility as well as from outside agencies involved with whatever questions were the focus of evaluation.

This preparatory activity eventually culminates in the exercise itself, and during the exercise period most activity at the facility

would be focused on running and monitoring the exercise. Appropriate data would be gathered both on-line and by human observers. This would include data specific to that exercise as well as general documentation data gathered routinely. The human observers would be alert to notice things which were important to the play of the exercise but which had not been anticipated in the evaluation design.

Following the exercise the evaluation team would debrief significant participants, including players, key support team personnel, and observer/evaluators. Debriefings would include a combination of items specific to that evaluation plan, items required for the ongoing history/comparison database, and participants' serendipitous observations. They might take the form of one-on-one or group debriefings, of post-exercise questionnaires or other survey instruments, or of combinations of these. The evaluation team would then prepare one or more evaluation reports for that exercise as well as the summaries and database updates necessary for historical/comparative purposes.

The structure of the exercise itself is shown in Fig. 3. The Command and Control Components (C2 Components) being exercised are embedded within an Exercise Driver which simulates the war and the rest of the world to the C2 Components and receives and implements force allocations and other command and control actions from it. Sitting across the top of both is the Evaluation Unit, collecting data on which to base later evaluation as well as providing whatever guidance to the course of the exercise is necessary to ensure that evaluation objectives are adequately met.

Each of these--the C2 Components, Exercise Driver, and Evaluation Unit--should be thought of as integrated man/machine units composed of both humans and computers and computer programs. In terms of the distinctions usually associated with military exercises, the C2 Components consist of the "players" and the systems and facilities they employ, such as communications systems and facilities,

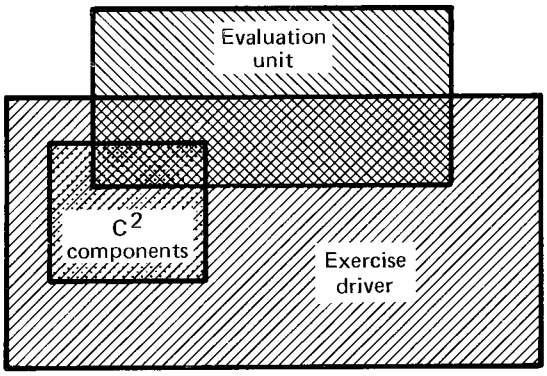

Fig. 3 — Computer aided evalution exercise

intelligence databases, and weaponeering computers. The Exercise Driver encompasses much of the "control team" and the computer support to provide the kind of responsive exercise environment necessary for effective evaluation. The Evaluation Unit includes the "evaluators" and the computer subsystems which support their functions. The Exercise Driver and the Evaluation Unit must overlap somewhat, in that the Evaluation Unit must maintain sufficient management control over

the course of the exercise to ensure that evaluation objectives are met.

A primary issue to be faced in the design of the CAEF is the relative role of man and machine in the conduct and control of the exercise. At one extreme, one could envision a fully automated Exercise Driver and Evaluation Unit in which all necessary human choices and decisions were made prior to the exercise and the only role for human beings during the course of the exercise was to act as intermediaries between the computer and the C2 Components when voice communication was required. At the other extreme, one can imagine an essentially manual exercise, with a great deal of automated bookkeeping support allowing a human control team to run a far more flexible and responsive exercise than is now generally the case.

The first extreme is probably not feasible, and would not be desirable even if it were. The second is feasible, but falls far short of the the kinds of capabilities which an evaluation exercise should have. The proper mix of man and machine lies somewhere in the middle, with the machine making many routine decisions and providing more than bookeeping support for others, but with human controllers retaining ultimate responsibility for the management and direction of the exercise.

The evaluation exercise can be thought of as consisting of two distinct parts--the exercise per se as a simulated conflict involving only the interaction of the C2 Components and the Exercise Driver, and the evaluation of the role of command and control in that conflict by the Evaluation Unit. The overall problem of designing the evaluation exercise can then be broken down into distinct simulation and

evaluation problems. Each of these will be discussed separately below.

III. THE EXERCISE DRIVER

The Exercise Driver is the core of the evaluation exercise. It must be able to provide a simulated conflict environment which is sufficiently realistic and challenging to the C2 Components to encourage realistic performance, and which is sufficiently responsive to actions taken by the C2 Components to allow that performance to affect the course of the conflict in reasonable ways.

To do this, the Exercise Driver must maintain a picture of the conflict and the state of the world in general on an up-to-date basis. It must accept directions from the C2 Components for force allocations or other actions under their control, and must itself take appropriate actions for other actors in the conflict process. These include the enemy, neutrals and allies, higher headquarters, and elements of friendly forces not represented by the C2 Components. It must update its picture of the state of the world appropriately to account for these actions. It must also feed back appropriate information concerning these changes to the C2 Components in the same formats and with the same distortions and time delays which would be expected in the real world.

The design of an Exercise Driver to perform these functions requires a number of choices for which there is no single best solution. Some of these choices revolve around such issues as the relative roles of man and machine, the degree of automation, and the appropriate degree of modularity in the design of the CAEF as a whole as well as its components. More will be said about these issues in what follows, to set the stage for a preliminary design from which to develop a functioning CAEF.

The approach to the design itself must necessarily be different from the normal research and analysis approach because the processing requirements, manual and computer, are driven primarily by on-line human information needs. In particular, the players have to be serviced with information which is in both form and substance like that they would receive in actual practice. Likewise, the staff of the Exercise Driver must have information continually to perform their tasks. For both groups, the information must be available in "live" time rather than an arbitrary "simulation" time. Furthermore, the live play aspect of this approach dictates that events (such as aircraft takeoffs, target strikes, ground force movements, etc.), be paced to live time as well, since nearly all events can be affected by decisions at any time. And also, the simulation must be interruptible to be responsive to the man-machine interactions which dominate this mode of operation.

Functionally, the Exercise Driver can be thought of as having a structure like that depicted in Fig. 4. It consists of three modules -- the Conflict Module, the Interface Module and the Control Module. The Conflict Module simulates and keeps track of the conflict environment. The Interface Module provides the interfaces between the Exercise Driver and the C2 Components. The Control Module plays the roles of other participants and generally oversees the functioning of the exercise.

THE CONFLICT MODULE

The Conflict Module must simulate and monitor the entire conflict environment (including the location and operational status of the C2 Components and their supporting systems) in sufficient detail to drive the exercise with an acceptable degree of realism and challenge. In addition to modeling the interactions between opposing forces, it must

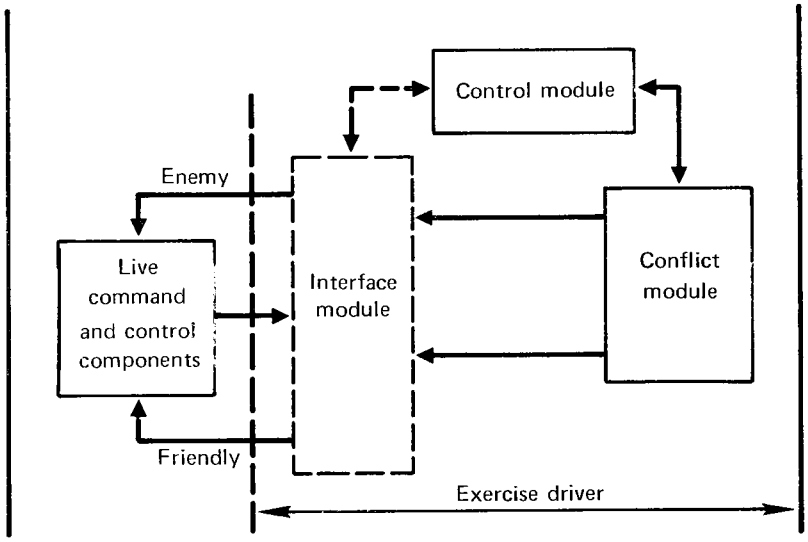

Fig. 4 — Exercise conflict structure

keep track of status and movement of friendly and enemy force elements and the status and actions of all decision making participants in the conflict, live or simulated, including the C2 Components. The Conflict Module maintains the primary data base of information about the conflict environment.

The scope of the conflict will be determined by the evaluation requirements, but for design sizing considerations the Conflict Module should be capable of representing "theater" level air/land warfare. It should be able to represent two corps areas in detail and additional corps on an aggregated basis. It must include theater level airfields and rear area targets on both sides and be capable of representing two-sided tactical air operations throughout the theater. It should be capable of simulating theater intelligence assets, and of supporting the simulation of non-theater assets such as national intelligence systems. That is to say, if these assets are not simulated directly, the Conflict Module should be capable of interacting with appropriate external simulations and ensuring that data bases used by those simulations are consistent with that maintained by the Conflict Module. Logistics and logistic support systems should also be represented.

The level of detail required of the Conflict Module will vary to meet information needs of the players, the support staff and the evaluation. The requirement will depend not only on operational considerations, such as type of air mission, but also on which command and control activities are being played live and which are being represented by the Control Module. In many cases an aggregated or expected value calculation will suffice for determining force engagement outcomes or satisfying evaluation estimates, but such things as aircraft attrition and bomb damage assessment must be reported in specifics to provide the players realistic reports. Some form of hierarchical structure of detail in handling the conflict environment data will probably be required for the simulation to be efficient.

The pace of the conflict must reasonably reflect the capabilities of both sides. This is of particular importance in the ground conflict, which may be expected to proceed in a more "unattended" fashion than the air operations since the latter are paced by the C2 Components being played.* Events must occur no faster than live time in order to assure that the multiplicity of independent, parallel activities taking place are consistent. Since decisions on force application can be made at any time by either the players or supporting staff, it is never possible to predict future events with certainty. In fact, it is the purpose of command and control to manipulate force elements in response to perceived actions, events and situations as they are recognized, and do that in unpredictable ways.

Although a principal function of the Conflict Module is to simulate and keep track of the conflict environment during the course of an exercise, it has additional "off line" functions which impact on its design characteristics. It may be used by the Control Module during the exercise for "look ahead" to assess the potential impact of Control Module actions before they are actually taken, and may be used by the CAEF between manned exercises for replays and variations on past exercises run for analytical purposes. In addition, it will be used during exercises to collect and summarize exercise history data for later use by the evaluation unit. It should therefore be designed with appropriate "pick off" points and other collection capabilities.

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*This is not to rule out the live participation of ground force decisionmakers playing as an adjunct to the C2 Components. That would be most desirable, and perhaps essential to some evaluations, and should be considered for inclusion as the CAEF is developed.

Design Considerations

What, then, should be the underlying design of the Conflict Module? We have already committed to a man/machine structure, but the issues are how much man, how much machine, and how should the two be structured. Resolution of those issues is the heart of the research problem and no specific conclusions are yet available, but some key considerations are worthy of mention. Foremost is the question of the degree of modularity, particularly in the computerized portions.

At one end of the spectrum is a very large, self-contained combat model which essentially does everything internally, including interpreting the air tasking order and other action orders, determining the effect of the associated military actions, updating the databases, providing output in appropriate form and interacting with the supporting staff. At the other end is a collection of relatively small, distinct function modules (man, machine or both) which are interconnected to perform the many necessary operations required of the Conflict Module.

Design around a single large combat model as a core is attractive on the surface because it appears to provide a possibility of exploiting some completed work, since research and analysis combat models already exist which provide many of the required functions. In the best case, a saving of time and money to implement a first-cut system with extensive processing capability could be realized. Unfortunately, such savings would depend on being able to use a model pretty much as it stands. As noted above, however, the necessity to

satisfy human information needs dominates this processing task, and any existing model would have to be adapted to that concept. Adaptations would likely include man/machine interaction and generation of fine-grained force element accounting and operation in live time as a minimum. So the relative efficiency of adapting an existing model versus building a new model (perhaps from pieces of existing ones) is an open question for detailed consideration if a single model design were to be selected.

Another factor to be considered is the facility of the model for modification. It can be expected that each evaluation exercise will have special requirements not included in the Conflict Module, regardless of the design or model being used; hence, it would be expected that the model would have to be changed. Changing large models is a nontrivial task in most cases. So, either a major effort will need to be made or the model itself will have a tendency to inhibit the flexibility of the Conflict Module or, worse, overly influence the design of the evaluation exercise, possibly to the point of restricting evaluation goals. Certainly, some of this will occur under any design, but exercise designs that encourage it should be avoided.

Modular Design

A more modular design would have several advantages. A modular design lends itself readily to evolutionary development in a computer-aided exercise environment. The modules would be man/machine systems, with greater or lesser degrees of automation. (A manual exercise environment can be thought of as a modular design in which

all the modules are fully manual.) As a basis for a carefully coordinated, systematic evolution, an overall, comprehensive modular design of the Conflict Module would have to be developed first. At least initially, depending on the time and resources available for implementation, many of the functions could be purely manual with selected modules automated fully and others to some extent. The Conflict Module would then be evolved by upgrading modules in line with the overall design to maintain coherence and interoperability among modules. Lessons learned in implementing each new module would be applied to upgrading and installing the next modules. Development of the Conflict Module in this fashion would permit pacing consistent with technological advancements and the availability of funds, facilities, equipment and personnel.*

A modular design would also provide flexibility in tailoring the exercise environment to particular evaluation needs by having the computer aids in small hardware/software packages which, generally, are easier to modify than large ones. Also, different versions of the modules, tailored for specific applications, could be maintained and used selectively as needed. Updating and modernization would be facilitated since individual modules could be revised one at a time. And there is the potential that integrating automated command and control systems into the CAEF would be relatively straightforward, since the modules would be designed to accept and work with a variety

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*To some extent this process is occurring now anyway, as automated aids of various kinds are introduced into the exercise environment. But most of these introductions are ad hoc and uncoordinated, while under the CAEF concept the development would be design-based, systematic and explicit.

of interfaces. Modular design might be significantly facilitated by the selective use of newer programming technologies such as rule-based programming in place of more traditional programming techniques where they apply.

One way to structure a modular design would be to organize it around the functions which the Conflict Module needs to perform in running an exercise. One such list might be:

- o Database modules to establish and maintain the primary databases and deal with different data aspects such as own force status, enemy force status, missions in progress, etc. They retain sole authority to update or otherwise change the databases and have responsibility to provide all information from the databases to all users.
- o Activity modules to determine (simulate, compute, estimate, etc.) the effects of various types of activity such as force engagements, mobility, and attrition; provision of logistics; and reconnaissance, surveillance and other intelligence gathering activities.
- o Management modules to interleave the database and activity modules as appropriate to simulate the results of the activities on the conflict environment, cause database updates and generate output as appropriate.

Within this basic framework, a number of different design configurations using differing amounts of human and machine resources would be possible. And even a minimal design consisting of only a few

automated database modules would provide a significant increase in capability over a manual exercise facility.

Finally, it must be noted that most likely the best and probably most feasible design will lie somewhere between a monolithic model and an exhaustive modularization. There will always be a large degree of modularity, but perhaps with some rather large pieces.

THE INTERFACE MODULE

In order to successfully evaluate a command and control system using the CAEF approach, the C2 Components must operate in essentially the same environment with the same capabilities and constraints as would be the case in war. To the maximum extent possible, the players should perceive and interact with the conflict being simulated in the same way that they would perceive and interact with a real conflict in the field. This places two requirements on the Exercise Driver. One is that the simulated conflict environment be realistic. The other is that information about the conflict should enter the C2 Components the same as it would in actual conflict and information sent out by the C2 Components should go out in the same way, in the same form and via the same equipment as in a real situation.

It is the job of the Interface Module to see that the interactions between the C2 Components and the conflict being simulated meet these criteria. As indicated in the design shown in Fig. 4, all communications between the C2 Components and the Exercise Driver are processed through the Interface Module. Furthermore, to enable simulated degradation of communications, most communications strictly between individual C2 Components ultimately should also be

routed through the Interface Module. The Interface Module directs C2 Components' outputs to either the Conflict Module or Control Module for appropriate action. Going the other way, the Interface Module assures that inputs to the C2 Components are in the proper form and transmits them by correct media with accuracy consistent with the current simulated state of the communications systems being used.

Inputs to the C2 Components are of four general types: (1) data about the enemy, (2) data about friendly forces, both ground and air but particularly details of own air resources, (3) guidance, direction and planning factors from other command and control activities and (4) intercommunications among the C2 Components concerning their functional and procedural needs. Additionally, there are miscellaneous inputs such as administrative information, weather data, terrain conditions, sea states and other items not falling into the four given above but used in the command and control processes. The majority of these inputs are in some form of hardcopy report whose content and format are specified in military manuals.

Outputs from the C2 Components include the air tasking order for the following day's operations; pre-mission modifications to the air tasking order; real time diversions of aircraft to other missions, targets or recovery bases; and other operations orders such as force deployments. Depending on the level and components being played, outputs may also include direct radio communications with (simulated) aircraft. Also, coordination actions and discussions with other forces' command and control activities, intercommunications among the C2 Components and requests for additional/updated input information from various sources generate outgoing communication requirements.

Communications Interfaces

Currently, this information is transmitted to, from and within the command and control system primarily by teletype (TWX), telephone (voice), and in some cases radio (also voice) means. Utilization of computer-to-computer communications is increasingly being developed and can be expected to carry a large portion of the traffic, eventually. The form of the information varies from rigid formatted data entries and/or free flowing text in standard reports to conversational style in either voice or TWX mode.

The Interface Module must be able to perform every combination of communications mode and form appropriate for any given situation. Interfaces can be characterized as automated, manual or combined depending on the degree to which people must be involved in either preparing or transmitting the information. An example of an automated input interface would be one in which the information was completely determined by computer, correctly formatted by computer and directly transmitted by computer from the Exercise Driver to a C2 Component via teletype or computer-to-computer means. Some of the highly formatted intelligence and force status reports are candidates. A manual input interface would be one in which the entire process of data extraction, formatting and transmission was performed by people. On-line responses to telephonic queries and open discussions with Control Module personnel acting as other command elements would be examples.

At least in the initial phases of CAEF development, most input interfaces would fall into the combined category wherein the computer performs data extraction from the data bases via a man/machine interaction but that information must be interpreted and formatted by

a person. Textual and conversational inputs would generally be in this category, although computer generation of textual materials is a feasible capability which can, and should, be developed. Voice transmission would always require a direct human interface; however, in many cases, the determination of both the information and the need to send it, as well as the formatting, could be done by computer. Verbal mission reports and high priority critical damage (from enemy action) reports are examples where the condition could be recognized by the computer as the event is processed and a report automatically generated and provided to appropriate personnel for voice transmission.

Until more automated systems are incorporated into the tactical air command and control system, the air tasking order and changes thereto will probably be the only candidates for automated output interfaces (those that require no interaction by the Exercise Driver personnel to execute the indicated actions) from the C2 Components. Most other teletype messages will be received from the C2 Components over digital circuits, but are likely to require a person to read and interpret them. It should be recognized that regardless of the form and media actually used at the receiving end of an output to the real world, if the Exercise Driver is the receiver of the output during the exercise, the form and media can be different. Eventually the preferred method of receiving things in the Exercise Driver will be directly into a computer for display on a terminal at a work station, whether or not it is processed automatically. Paper shuffling needs to be minimized during high intensity operations.

One of the tasks in designing the Interface Module is to determine what form, substance and communications media are

appropriate for all data passed between the C2 Components and the Exercise Driver and develop the necessary interfaces--automated, manual or combined. The elimination of most purely manual interfaces will be one of the most important advances realized in the construction of a CAEF. The evolution of the Interface Module should emphasize reducing dependency on manual activity wherever possible to expedite and increase the accuracy of information transfers. However, the degree of automation possible for the Interface Modules would vary somewhat with the nature of the C2 system being exercised. Exercises simulating the current system with its heavy dependence on voice communications would require far more manual interface than exercises simulating systems more heavily dependent on digital communications.

The Interface Module would also be responsible for simulating the capabilities of the communications systems used to support the command and control system. It must introduce such noise, interference and interruption as would be experienced in a real communications system under the simulated conflict. This must be done in both directions, into and out of the C2 Components. Communications sent in must include transmission errors such as garbling and omissions, and those sent out must also be degraded to represent real world problems in working with imperfect communications.*

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*This type of degradation should not be confused with imperfect information about the status and posture of friendly and enemy forces gathered by less than perfect collection systems. The accuracy and completeness of information provided to the C2 Components will depend on the the quality of collection and reporting systems and how they are applied. Determination of what information to make available for transmission to the C2 Components is a function of the Conflict and Control Modules.

Design Considerations

The advantages of modularity discussed earlier apply to the Interface Module as well. The Interface Module requirements suggest modularization along the following functional lines.

- o Communications module to perform the actual transmission of information to and from the C2 Components. It would represent the capabilities of the communications systems being played in the exercise and reflect degradation to those systems as appropriate from enemy actions or other causes.

- o Processing module to interact with the Control and Conflict Modules to acquire information for transmission to the C2 Components. Processing would be initiated both on demand from requests for information and on a normal reporting schedule driven by either time or events.

Again, the modularity approach would support an evolutionary development of the CAEF by permitting small automated modules to be activated and installed as resources allow, while maintaining an operational capability with decreasing manual effort.

THE CONTROL MODULE

The Control Module has responsibility for online control of the exercise. The exercise plan prepared in the pre-exercise period provides the basis for conducting the exercise but the free play approach essential to the CAEF concept will demand continual real time adjustments to achieve the established goals. The Control Module will continuously monitor actions taken by the C2 Components and events taking place in the conflict environment in order to provide the necessary direction to the Conflict and Interface Modules to keep the exercise on track.

Although it is the responsibility of the Evaluation Unit to establish evaluation goals and ensure the accomplishment of those goals during the exercise, the Control Module should have sole authority and responsibility for the conduct of the exercise. Close coordination between the Control Module and the Evaluation Unit is imperative, and either group can identify actual or potential discrepancies which would endanger successful evaluation. However, once the new exercise requirement has been established, it is up to the Control Module to determine what adjustments are necessary and make them.

The Control Module also performs the roles of command and control actors not represented by the C2 Components. These might include Air Force and joint authorities higher in the command chain, any lateral or lower Air Force command and control elements not being played, friendly ground force commanders and enemy decisionmakers. The actions taken in the name of these actors must be representative of their expected actions in the air/land conflict being simulated. But

furthermore, the actions must recognize the exercise objectives and the overall plans, strategies and goals of the conflict set forth in the exercise plan and maintain consistency with them. So, actions must be carefully chosen based on both the current conflict situation and what effect those actions are likely to have in the future.

Information available to the surrogate decisionmakers could either be absolute "ground truth" from the Conflict Module or degraded as it is to the C2 Components; however, the actions of friendly authorities should reflect no more information than would reasonably be available to the entities being simulated. This is especially important during telephonic conversations between players and simulated higher headquarters. Actions by enemy decisionmakers should be in line with estimates of enemy capability to collect and promulgate information. Even adjustments to the course of the exercise to pursue evaluation goals must be accomplished through realistic events and actions.

Design Considerations

Modularity in designing the Control Module would follow functional lines suggested above.

- o Monitor module to provide the capability to selectively monitor exercise actions and events and situational and status factors pertaining to the simulated conflict.

- o Look-ahead module to provide the capability to forecast future conflict situations under assumed courses of action or event occurrences.
- o Friendly decisionmaking module to provide the capability to make friendly command and control decisions and effectively interact by voice with the C2 Components.
- o Enemy decisionmaking module to provide the capability to make command and control decisions for the enemy air and land forces.

As with the Conflict and Interface Modules, such a modular design would aid the evolutionary development of the CAEF.

IV. THE COMMAND AND CONTROL COMPONENTS

The purpose of a computer-aided evaluation exercise is to provide a simulated environment within which to exercise and evaluate the performance of the tactical air command and control elements contained in the C2 Components. In any given exercise these components consist of the people, organizational structure and supporting systems corresponding to the elements being played.

During the early stages of development of the CAEF, the focus may be on playing a Tactical Air Control Center (TACC) or its NATO counterparts. As development proceeds, capabilities to play additional elements, possibly including Army, would be added. The particular elements which play as part of the C2 Components will, of course, vary with the exercise and exercise objectives, and relevant portions not being played as part of the C2 Components will be simulated by the Exercise Driver. For example, when the questions being investigated revolve primarily around the management of tactical air resources for interdiction or offensive counter air, the C2 Components might consist of nothing but a Tactical Air Control Center (TACC) or its NATO counterparts, with all other elements simulated within the Exercise Driver. On the other hand, when questions related to offensive air support operations are being investigated, it would be important to include such elements as the Direct Air Support Centers (DASC) in the C2 Components as well. And for some purposes, it might be desirable to play even more elements, such as a Control and Reporting Center (CRC) and Wing Operations Centers (WOC).

We are conceptualizing the CAEF as an Air Force facility intended to exercise tactical air command and control, with other command and control elements present only as part of the Exercise Driver. There is no reason in principle, however, why Army C2 elements as well could not be accommodated within the C2 Components. This might be done by expanding the CAEF itself to include Army elements, or by establishing appropriate interfaces between the CAEF and a comparable Army facility.

The command and control system elements played in the C2 Components and those simulated by the Exercise Driver must be treated differently in that a realistic and challenging conflict environment must be provided for the C2 Components, while the Exercise Driver is the thing which provides that environment. Thus elements simulated by the Exercise Driver may be very different in form and function from their real life counterparts--one man may operate an entire simulated DASC or several simulated WOCs, for example.

The elements in the C2 Components, however, should be as close as possible in form and function to their real life counterparts. They should have the same manning, the same equipment, the same physical layout, and should follow the same procedures. When variations from existing systems or procedures are exercised, they should conform as closely as possible to what would be expected to be fielded.

This means, in particular, that systems or procedures which would be employed in the field by personnel experienced in their use should not be employed in evaluation exercises by players who have not previously used them. This suggests that the pre-exercise preparation for exercises in which new systems or procedures are to be evaluated

might include a series of training and familiarization runs to bring the C2 Components personnel up to an appropriate experience level with those new systems or procedures. This type of pre-exercise training should be much easier to design and conduct with the CAEF than it is with existing manual exercise facilities.

V. COMMAND AND CONTROL EVALUATION

The purpose of the CAEF is to conduct exercises as a foundation for the understanding and evaluation of command and control processes and systems. However, the evaluation of the contribution of command and control to the combat effectiveness of military forces is an ill-defined and poorly understood area, in need of considerable conceptual and intellectual development. Sufficient development of concepts and techniques needs to be completed to provide a basis on which to establish an initial capability, but the CAEF, and in particular the Evaluation Unit, should be thought of in part as a testbed within which further development can take place. The evaluation approach, then, is not something which can be laid out fully before the CAEF is built. Rather, it requires the articulation of some initial exercise evaluation concepts and a design permitting, and specifying the responsibility for, self-evolution.

THE NATURE OF TACTICAL COMMAND AND CONTROL EVALUATION

Although any particular evaluation that is conducted will necessarily be tailored to respond to the specific context and purpose of the questions or issues which generate the evaluation requirement, there are some basic, general concepts and contexts which provide the fabric on which this tailoring is done.

There are three broad areas of interest from which an evaluation requirement would likely be generated. One is the internal operation of the command and control system, focussing on the efficiency of the system in executing its assigned functions. A second is the

operational arena, focussing on the ability of a fielded command and control system to support tactical air operations requirements. And the third is the management decision process, focussing on the selection and acquisition of major alternatives to achieving command and control functions. Common to successful evaluation within these three interests is the need to relate command and control capabilities to the effective employment of the tactical air resources.

Herein lies the major conceptual and practical difficulty in the evaluation of command and control. A successful approach to evaluation and the definition of evaluation criteria depends on the existence of well-defined relationships between the command and control elements characterizing the systems being evaluated and the outcomes of actions in which those systems are employed. But such relationships are usually not obvious. In some cases they may not exist, even in principle, because of the extremely complex interaction of men, procedures, and equipment and the fact that the effectiveness of that interaction in a particular conflict situation may be determined by unique idiosyncratic characteristics of that situation to a much greater extent than for most other military systems. The kinds of system characteristics which can be laid down most clearly in a set of specifications may affect the outcome only indirectly, through the support they provide to the more elusive human decision processes directing the battle.

One way of conceptualizing this is to think of the command and control system as "permissive," in the sense that it allows the human decisionmakers directing the battle latitude in what they can do with the forces available. Changes in command and control capabilities

which broaden that latitude in previously constrained directions will allow a difference in outcomes, but whether that difference is realized or not will depend on how that latitude is utilized. (This is also dependent on whether or not the particular conflict scenario is one which calls for latitude in that particular direction. The relationship between command and control capabilities and conflict outcomes may be much more sensitive to variations in scenario and tactics than is the case for, say, weapons system performance parameters.)

This does not imply that command and control cannot be evaluated, nor that that evaluation cannot be careful and systematic with a large quantitative component. But it does imply that the evaluation of command and control must necessarily have a large subjective component, and is likely to be better done and more meaningful in the long run if that subjective component is acknowledged and dealt with carefully than if it is not.

Relating Command and Control to Outcomes

Tactical air command and control may be seen as constituted of Elements of doctrine, organizational structure, procedures, personnel, facilities, equipment and communications to provide authorities at all command levels the capability to perform the Functions of planning, directing and controlling necessary to accomplish their Purpose, meeting mission objectives through the performance of tactical air operations. This representation is shown in Fig. 5.

Some important observations can be made from this representation. Only the Elements have well-defined, measurable attributes--quantity,

performance factors, physical characteristics, etc.--which, taken together, form the description of a command and control system. Only the Elements can be added to, manipulated, and modified to produce

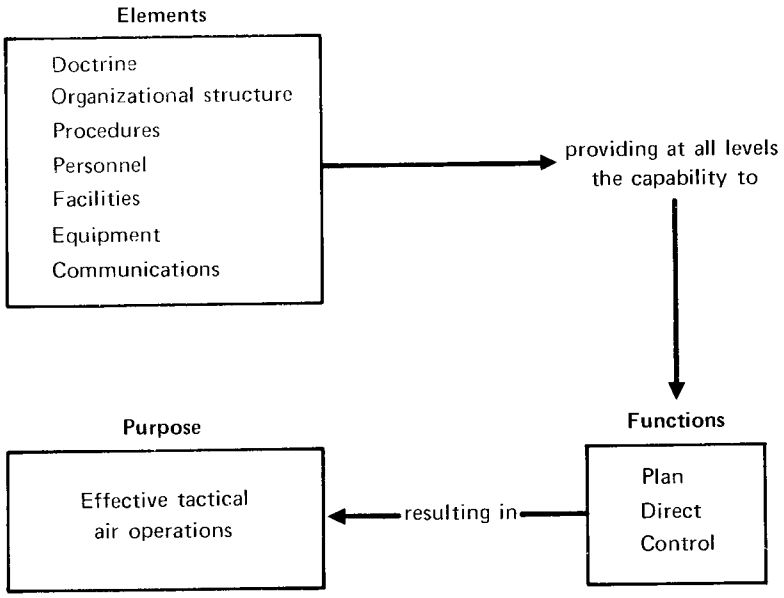

Fig. 5--Tactical air command and control

variations in the capabilities of command and control. However, the crucial output of command and control is its contribution to mission accomplishment, and the impact of the Elements on that output is not direct, but indirect through the Functions. Performance of the Functions is dependent not only on the existence but also on the utilization of the Elements, on such factors as how procedures are

followed and what information is communicated. But even more, performance of the Functions depends heavily on human judgment processes. Planning, directing and controlling make use of the Elements and what they provide, but plans, directions and control actions are products of decisions by people.

According to this representation the Elements are the basis of command and control capability and are the only controllable part. Changes can be made to Elements, and decisions that are made about alternative command and control processes or systems are usually decisions about the characteristics of the Elements making up that process or system. On the other hand, relevant evaluation criteria for command and control must focus on its effect on the employment of the tactical air resources, and the accomplishment of the tactical air mission. So the key is to relate the Elements to mission accomplishment. But the relationship is indirect through the Functions, which depend on the interaction of the Elements and human decisionmaking. The Elements support both the decisionmaking process and the implementation of decisions made by that process. Any evaluation method must handle this indirect relationship to determine cause and effect between Elements and measures of mission accomplishment.

Mission accomplishment can be considered at two levels--tactical air operations and major military actions. Tactical air operations are the basic missions flown by the Air Force and are categorized by general objectives and, further, by target and force management characteristics. Close Air Support, Interdiction and Air Defense are examples. Measures of mission accomplishment at this level focus on

the ability to conduct the air missions themselves, individually or in the aggregate, rather than on the effect of those missions on combat outcome or the course of the conflict.

By a major military action we mean a well-defined and bounded air or joint air/land action requiring deliberate planning and execution of persistent tactical air operations to accomplish particular objectives considered to be of significant military value. Included would be land battles; air interdiction campaigns with specific goals (such as isolation of battle zones); counter air campaigns; and aspects of a land battle considered crucial by a ground commander and designated by him to be primarily an air support responsibility (such as neutralization of all long-range artillery, a quota of armored vehicles or locally critical lines of communication).

At this level the focus is on the course of the conflict and the combat outcome, and the term "mission accomplishment" has the larger meaning of goals or objectives in the overall combat scene. Measures of mission accomplishment in the sense of achieving these broader objectives are concerned with what overall effect tactical air operations might have. In the light of this discussion, then, Fig. 5 might be modified as shown in Fig. 6.

Command and control plays a role in the conduct of tactical air operations in many ways, including determining which will be conducted, when, where, and, to a great degree, how, and providing direct inflight support. Its role in affecting major military actions includes not only the conduct of tactical air operations but also the decisions on what must be done to achieve the desired effect with the available resources. Furthermore, command and control performs the

operational management of the tactical forces, and how it performs that task will influence what resources are available to accomplish missions.

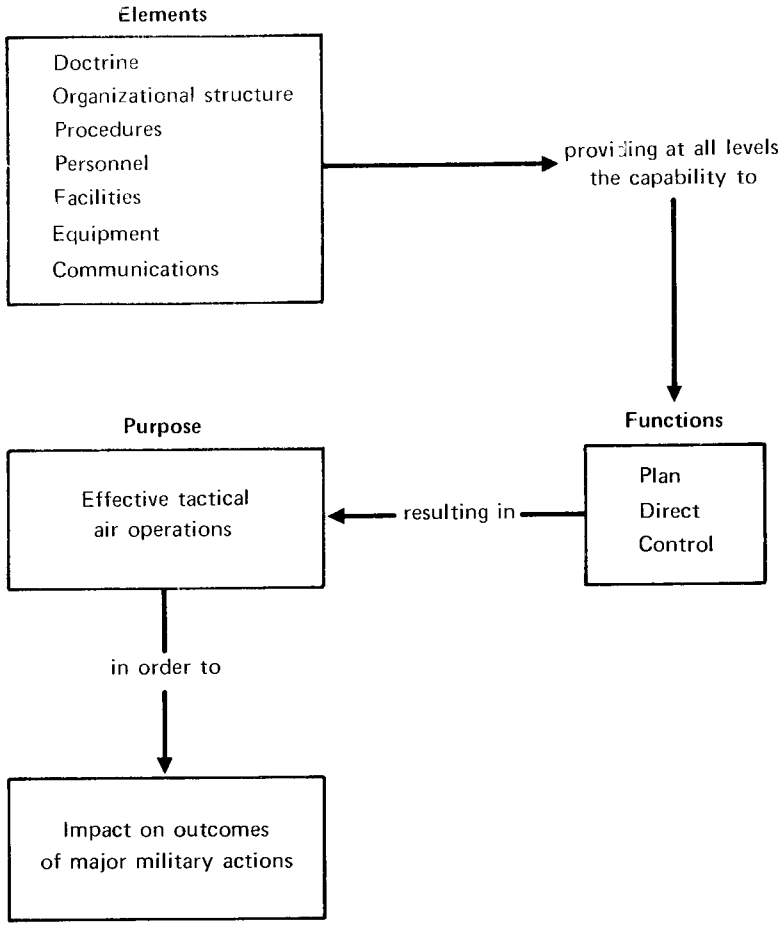

Fig. 6 — Tactical air command and control related to outcomes

So, evaluation criteria reflecting effectiveness of force employment can encompass measures of how well the force is operationally managed (resource status) as well as of the effectiveness of individual air operations per se. Measures of effects on major military actions will need to be based on a composite of tactical air operation effectiveness and a comprehension of how that effectiveness impacts on the outcomes of those major actions. For completeness, observe that resource status can influence tactical air operation effectiveness, so measures linking these two may also provide measurable links between command and control and both levels of mission accomplishment.

Relating Criteria to Real Combat

Whatever criteria are used, the tie to combat outcome must be retained. There should be a great deal of commonality, at least in principle, between the problem of evaluating the command and control processes in a computer-aided evaluation exercise and evaluating command and control processes in an actual combat situation. In each case, it makes sense to ask what role command and control played in the resultant outcome, and why, and whether variations in command and control would have produced significantly different outcomes. The value of an exercise as an evaluative tool, after all, is heavily dependent on its ability to simulate a real combat environment and to reflect the impact of command and control processes in that environment.

There are also important differences between an exercise environment and a real combat environment which need to be considered

in designing and conducting command and control evaluations. Evaluation of most real combat is retrospective, taking place after the combat is over using data which happens to be available at that time. Evaluation of exercises, on the other hand, can be structured and thought through in advance, allowing a degree of planning and rigor not achievable with real combat. Data collection can likewise be planned in advance, and the exercise can be instrumented and monitored to a degree which would be impossible with real combat.

Real combat is a one-time affair, with only the combat as it occurred to look at. Exercises, on the other hand, can be repeated and systematically varied to provide something akin to multiple samples of the same basic combat process. The structure and unfolding of the scenario and the combat problems faced by the C2 Components can be optimized for the study of the particular evaluation question of interest, which can never be done in actual combat. The Evaluation Unit and the evaluations it conducts should be designed in such a way as to take maximal advantage of these differences in the evaluation process.

But the similarities should not be ignored, and the fact that the exercise is only an artificial proxy for a real combat environment should not be forgotten. The basic questions are the same in either case, and an approach to evaluation which does not make sense when applied to real combat probably should not be applied to exercise evaluation either. A good test to apply to any evaluation plan proposed for an exercise evaluation, perhaps, is to ask what kind of sense the evaluation concepts being employed (measures of merit, etc.) would make when applied to a real combat situation.

EVALUATION USING THE CAEF

The CAEF may operate in a number of evaluative modes, some of which are familiar and traditional and others of which are not. It may be used, for example, to perform evaluations of command and control systems or procedures based on the running of a single exercise, as is sometimes done now with existing manual exercises. In this mode, the CAEF not only provides a richer and more responsive combat environment against which to pit the C2 Components than does a conventional exercise, it also provides a capability to measure and record what goes on during the exercise to a degree of detail which is not possible during a manual exercise, and to reduce the resulting data to manageable form and produce usable evaluation analyses from it.

Systematic variations may be performed on a particular exercise or exercise theme, using a "mixed medium" of computer-aided manned exercises and fully computerized simulation runs. Time may be stopped and restarted, slowed down or speeded up. Selected portions of the exercise may be rerun with some variation, either with manned C2 Components or as a pure simulation with necessary command and control inputs supplied by the evaluators. This mode is analogous to (though far richer in possibilities than) making multiple runs of a computer simulation for sensitivity analysis, but has no counterpart in manned exercises as they are currently conducted.

The facility may also be used to collect and compare similar situations occurring in a number of exercises over time, providing systematic longitudinal evaluation of a sort not currently available. Because of the ability of the computerized facility to retain and

retrieve detailed descriptions of past exercises according to a wide variety of criteria, this type of analysis will be feasible to an extent not possible without such capabilities.

Other modes of operation are likely to be discovered and developed as the facility is utilized. The important point here, perhaps, is that this kind of facility provides capabilities for comparison and evaluation of a sort which do not currently exist, and the use of these capabilities over time is likely to bring about fundamental changes in our concepts of what exercises and evaluations are and how they should be interconnected. How fully the potential of these capabilities is realized, of course, will depend on the CAEF staff responsible for their utilization. This strengthens the point made earlier that the ultimate responsibility for evaluation rests with people and not with methods or computers, which should properly be seen as aids and tools for the people.

THE EVALUATION UNIT

Within the CAEF, evaluation will be performed by the Evaluation Unit. This Unit will be responsible for preparing an evaluation design prior to each exercise, collecting necessary data during the exercise, and analyzing that data to produce evaluation reports following the exercise. The activities and functions of the Evaluation Unit fall into two distinct classes--those associated with individual exercises and those associated with the operation of the CAEF as a long-term ongoing facility.

Evaluation Unit activities associated with a particular exercise start long before the exercise itself begins. From the very beginning

of the exercise cycle, Evaluation Unit personnel will be involved in defining and laying out evaluation goals and objectives, and in ensuring that the developing exercise design will meet those objectives. During the pre-exercise period, they will interact with exercise designers from the exercise driver staff as well as with others from staff and operational units concerned one way or another with the upcoming exercise and with the evaluation scheduled to be performed.

If new equipment or systems are being evaluated, for example, coordination will be required between the evaluation unit and the Air Force Systems Command (AFSC) component responsible for the new system. If the evaluation is focused on new tactics or procedures, coordination with appropriate operational units may be needed. If capabilities to respond in a particular geographic area are the subject of the investigation, there may be considerable interaction with the specified command responsible for that area.

One of the major activities of the Evaluation Unit during the pre-exercise period will be development of an evaluation plan for the upcoming exercise. The evaluation plan must include a preliminary model of the exercise conflict to serve as a basis for the development of the exercise description on which the later evaluation will rest, as well as specification of the observation points (both manual and automated) required for the exercise and the data to be gathered at each. The plan should also outline the structure of the post-exercise analysis, including the measures of effectiveness to be used and the kinds of conclusions expected.

Command and control systems or processes cannot be given a fair evaluation in an exercise unless the personnel using them have a degree of familiarity and experience with those systems comparable to that which would be expected under field conditions. It will be the responsibility of the evaluation unit to determine how much pre-exercise training and familiarization the players from the C2 Components should have with any new procedures or systems, and to monitor that training in order to ensure that adequate levels of proficiency are reached prior to the exercise.

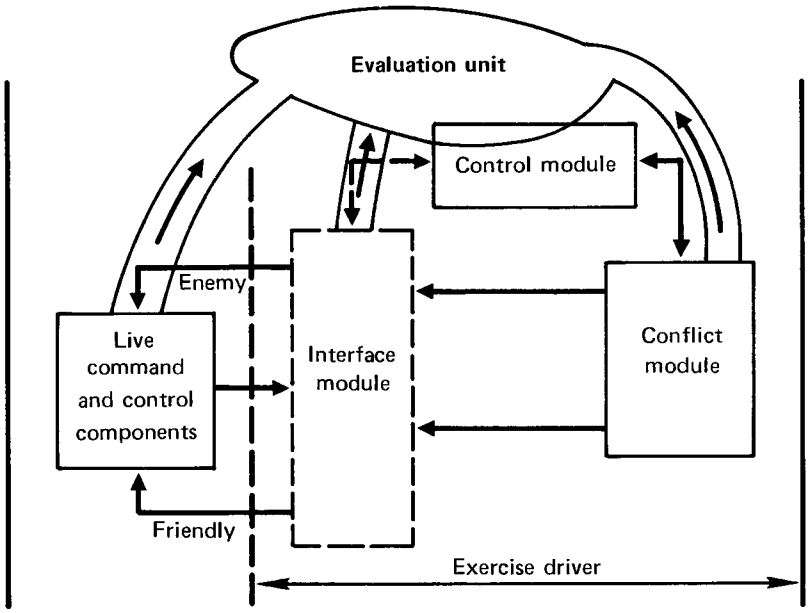

Fig. 7 — Relationship of the evaluation unit to the exercise conflict structure

During the play of the exercise, the activities of the Evaluation Unit will focus primarily on monitoring and data collection. The relationship between the Evaluation Unit and the other exercise components is shown in Fig. 7. The Evaluation Unit, in effect, sits on the top of the other components, observing and drawing data from them. In addition, there will be sufficient overlap between the Evaluation Unit and the Control Module to ensure that the exercise is managed in a manner consistent with the evaluation objectives and that those objectives are being met. Data collection will proceed in accordance with the previously developed exercise plan, though the human observers in the Evaluation Unit should remain alert for significant factors or events not previously anticipated. The fact that most of the data collection is preplanned should by no means preclude serendipitous observation. On the contrary, serendipitous observations by expert observers should be one of the most important sources of information for the Evaluation Unit.

Data collection will continue into the wind-down period immediately following the exercise, with debriefings of participants and observers alike. Some of this debriefing should be highly structured, e.g., administration of structured questionnaires designed earlier as part of the evaluation plan, while some of it should be much more loosely structured, e.g., open-ended interviews and discussions.

Some analysis may begin during the running of the exercise, but the bulk of the analytical effort will take place after the completion of the exercise itself, culminating in the production of whatever reports, briefings, or other evaluation products are called for by the

exercise plan or are otherwise appropriate for that particular exercise.

In addition to evaluations associated with particular individual exercises, the Evaluation Unit will have an ongoing responsibility for organizing and maintaining the cumulative database derived from all exercises run at the CAEF and for performing comparative evaluations across exercises using that database. At the same time, the Evaluation Unit will also have responsibilities for evolving the CAEF itself and developing and refining concepts for using it as an evaluative tool.

THE PROCESS OF EVALUATION

In an area as nonrigorous as command and control, evaluation is ultimately subjective, in the sense that it is something which takes place in the minds of the people involved. People decide, individually and collectively, on the basis of the information before them, whether particular systems, procedures, etc., are worthwhile or not; whether changes being contemplated will improve or degrade the total process; how much gain can be expected from a proposed improvement; and other similar evaluative questions. Quantitative measurement, analytic methodology, computer modeling, and the like, are useful tools in this process, both in structuring and giving meaning to the information on which evaluation is to be based and in providing a vehicle for the communication of information and conclusions. They are not, however, the ultimate basis for important substantive conclusions. These remain the responsibility of human analysts and evaluators. (Even when conclusions appear to be based

solely on the application of formal analytic techniques to objective empirical data, that remains true. Someone chose to use those techniques and to apply them to that data, and those choices were ultimately subjective. The conclusions reached are simply logical extensions and implications of those choices. See [3] for further discussion of these issues.)

Related back to the Evaluation Unit, this means that the human evaluators in the Unit are the source of the evaluations it produces, not the formal models and methods they employ, and certainly not the computer which implements those models and methods. Quantification, in particular, should not be approached as an end in itself, but rather as a means to an end. It must be guided by and interpreted with careful and considered qualitative judgment within the evaluation process if its potential value is to be fully realized.

One thing which the Evaluation Unit will require is a model of or paradigm for the process of evaluation around which the activities of the Unit can be organized. One possible paradigm which might serve that purpose is outlined below. It is not the only one imaginable, and perhaps not the best, but it seems to provide a reasonable place to start. We will focus primarily on the problem of evaluating command and control in a particular conflict or exercise situation, extending the ideas developed to problems of comparison across situations, or across systems in the same situation, as appropriate.

The process of evaluating the contribution of command and control in a particular exercise situation is conceptually similar regardless of whether the evaluator considered is a single individual performing an informal subjective process in his head or a specialized component

(e.g., the Evaluation Unit) of a large organization performing a complex and highly formalized evaluation. It is these conceptual similarities which we wish to identify, understand and use as a basis for the structure and operation of the Evaluation Unit.

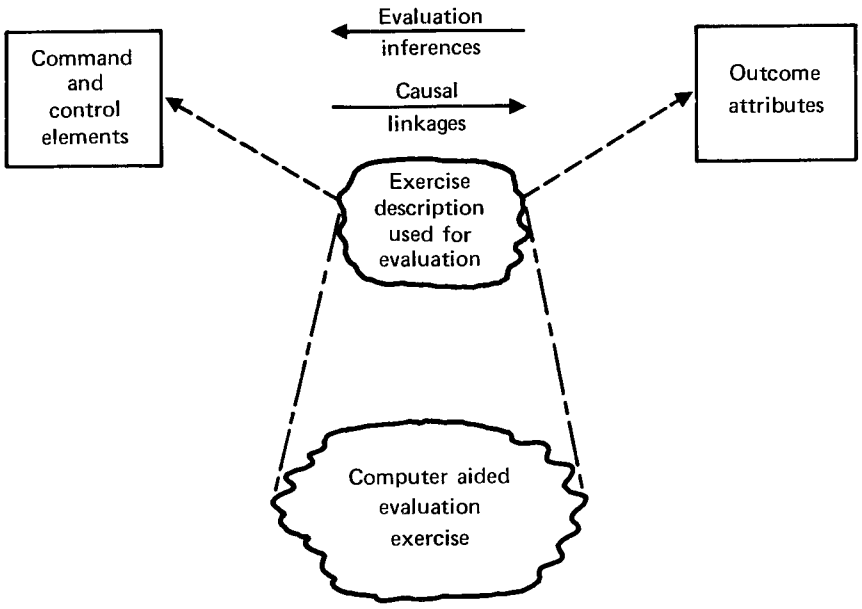

Fig. 8 — The evaluation process

Evaluation Requires Description

The nature of the evaluation process is depicted in Fig. 8. The evaluator (single individual or Evaluation Unit) creates an image or description of the exercise that has occurred (we will speak of the exercise in past tense, recognizing that some of this will take place

as the exercise is actually occurring) which will serve as the basis for the evaluation process. This describing process depends heavily, of course, on preliminary activities which take place in advance of the exercise, including pre-exercise planning for what the description will be like and how it will be built. Within that description, the evaluator identifies attributes of the outcome which he considers important, and characterizes the links between the command and control elements he wishes to evaluate and those outcome attributes. He attaches a valuation to the outcome attributes identified, and uses the links to infer valuation back to the command and control elements.

Even from this relatively crude conceptual model a number of interesting and useful observations can be drawn. Note, for example, the fact that the evaluator works with a description of the conflict and not with the conflict itself, and that this description will always be partial and incomplete. This implies that the process of forming this description is itself an important part of the evaluation process, which deserves careful and explicit consideration in its own right.

It also implies that when we go beyond evaluation of a single exercise and consider cross comparison between a number of different exercises, the degree of comparability between the descriptions which are available of the different exercises to be compared will be important. For this reason, the nature of the description forming process per se needs more attention in designing the CAEF as an ongoing facility than might be necessary for the evaluation of an individual exercise.

The description forming process is composed of two principal components, data collection and description generation from the

collected data. In the case of the individual evaluator, the description is his subjective image of the exercise, and the processes of data collection and description generation go on simultaneously as he observes the exercise and forms impressions of what is happening and why. He collects data through his eyes and ears, and those incoming data contribute to and modify his description of the ongoing exercise. But at the same time, the data he collects and the way he interprets those data are themselves conditioned by his present description--by his expectations and impressions of what is occurring and of what is important to observe and pay attention to.

In the case of the Evaluation Unit the description is a more formal summary and description of what went on during the course of the exercise. The situation at first glance appears simpler than in the case of the individual, with most of the data collection occurring during the course of the exercise and most of the description generation occurring after the exercise as those data are summarized and analyzed. But even here the individual members of the Evaluation Unit are forming descriptions and opinions as the exercise goes on, and these will contribute to the collective description of the Evaluation Unit on which the exercise evaluation will be based. There may also be some post-exercise data collection, such as debriefing of players. Even the individual phenomenon of prior expectations influencing the data collection process has a parallel in group evaluation, in that prior expectations of how the exercise would go and what would be important to observe (which can be thought of as a prior description) will have influenced the data collection design.

Though the describing process appears to take place primarily during and after the exercise, it rests heavily on activities taking place much earlier. In the case of the individual evaluator these include the earlier acquisition of the background and experience necessary to filter and interpret what he sees, as well as the preparation he puts into getting ready for this particular exercise. In the case of the Evaluation Unit, it includes these things as they relate to the individual members of the Unit, as well as the organizational planning and preparation put into the development of the Evaluation Plan for the exercise. Careful and thoughtful prior planning is particularly necessary if the descriptions of individual exercises are to have enough in common to support good longitudinal analyses across many exercises.

The Logic of Evaluation

Identifying the outcome attributes of interest and linking them to the command and control elements under investigation lies at the heart of the evaluation process. In some cases, this linkage may be made in a single direct step, while in others (and this will probably be more frequent), it will be indirect and depend on one or more intervening variables. In some cases, it may be possible to identify and describe the link very directly, while in others it can only be assumed to exist and its characteristics measured by inference. (This is what is being done, for example, when statistical techniques are applied to a sample of several similar exercises.)

In all cases, however, the underlying logic of evaluation is the same. Command and control is assumed to exert an influence on the

outcome of the exercise, as indicated by the right-pointing arrow in Fig. 8, which can be measured or otherwise inferred from the exercise description. It is also assumed that the outcome itself can be valued in a meaningful way. This valuation on the outcome can then be transferred back to a valuation on the command and control process which produced that outcome, as indicated by the left-pointing arrow in Fig. 8.

For the full potential of the CAEF to be realized, an evaluation paradigm that can guide the evaluation function across exercises over time, as well as the evaluation of individual exercises, will be required. The final form of this paradigm can only evolve with experience, and must be developed by the Evaluation Unit itself.

VI. DEVELOPMENTAL ISSUES

In the preceding, we have outlined the philosophy and general structure for a CAEF. That discussion necessarily omitted consideration of a number of practical issues related to the establishment of such a facility, such as location, computer support, and manning. We now briefly consider these issues. Remember that we are thinking of the CAEF not simply as a facility for conducting a series of conceptually distinct one-time exercises, but as an ongoing and evolving instrument for the exploration and evaluation of command and control systems and processes.

LOCATION

In principle, the CAEF could be thought of as a completely new facility, built from the ground up at any location where suitable real estate is available. In practice, the choices available are not unlimited, and the CAEF should be developed in conjunction with existing Air Force training and evaluative activities which it can draw from and mutually support. The most obvious location for such a facility would be at Hurlburt Field, Fla., as part of the Tactical Air Warfare Center (TAWC). The exercise facility itself should probably be part of the C3I Complex now developing at Hurlburt Field.

COMPUTER SUPPORT

The CAEF will require extensive computer support, particularly during the actual conduct of exercises, and a number of options exist for providing that support. The facility might be provided with one

large computer mainframe to support all its activities, or it might have several smaller ones. These could be dedicated computers, or could be shared with other users. And if the latter, they could be located at the CAEF, or at remote locations. These choices obviously affect the operations of the facility, and its cost.

These questions interact strongly with some of the Exercise Driver design issues raised earlier. If the Driver has a relatively fixed structure based around a single large combat model, then a single dedicated mainframe capable of handling that model in real time would appear to be the natural choice. On the other hand, if the Driver is highly modular, it might be just as efficient to internet a number of different computers, each handling different modules, through a central controlling computer.

It does seem clear that the CAEF will require some dedicated computational capability, at least enough to support the functions of evaluation and exercise development on an ongoing basis (between as well as during exercises). It is less clear, however, that the CAEF needs to possess the much larger computational capability required to support an exercise in real time, when this capability is likely to be required only relatively infrequently. If the system were modular, the controlling computer might belong to the CAEF and serve to support CAEF functions between exercises, with other computers netted into the facility as required during exercises. One consideration favoring this kind of architecture is that it would allow the Exercise Driver to draw from and utilize some of the same operational systems which would support command and control functions during actual combat. Another is the fact that many of the systems being evaluated will be

computerized systems, which the CAEF will need to be able to interact with and integrate into its operation.

Another consideration which might favor providing the CAEF with one or more small computers rather than a single large mainframe is the fact that the C3I Complex appears to be the end destination for a number of computers (largely PDP 11/70s) which the Air Force has purchased and used for a variety of developmental programs. One or more of these computers might easily be made available for the facility without the cost of purchasing a new mainframe.

MODES OF OPERATION

During the early phases of its operation, the CAEF would probably operate in a mode similar to the way Blue Flag exercises are currently conducted. That is to say that it would conduct exercises on a regularly scheduled basis, each exercise more or less independent of the others. The individual exercises themselves would initially be straightforward computerized extensions of the kinds of manual Command Post Exercises run today.

As the CAEF was used and experience was gained with it, we would expect it to evolve a very different style of operation from anything which exists today. New forms of exercises and of man/machine analysis should evolve, combining aspects of exercises and aspects of computer modeling analysis in a manner appropriate to the hybrid facility which the CAEF will become. Some of the possibilities have been briefly alluded to earlier.

Taking advantage of these new possibilities will require the development of new concepts and procedures, and we would expect this

development to occupy a major place in the operation of the CAEF. The CAEF will have to work out its own style of operation as it goes, and evolve ways of utilizing the capabilities it provides.

The CAEF will have the inherent capability to collect and process masses of data for each exercise. Effectively utilizing this capability will require more elaborate description and documentation (and the ability to retrieve selected data) of individual exercises than is done at present, and ways to do this will have to be developed by the CAEF itself. Once in place, however, they should pay significant dividends in the productivity of the facility. In addition, the development of the necessary concepts and procedures for describing individual exercises and making comparisons between them should itself enhance Air Force understanding of the role of command and control in conflict.

A series of standard scenarios might be developed, for example, which could be used repeatedly in different exercises against different command and control process alternatives. If each of these exercise runs were documented in a standard way, then replication could be obtained across runs more economically than would be possible if all needed replications had to be run separately each time an evaluation requiring replication was made. If a new sensor or communications system were to be evaluated, past runs of the same scenario in which that system had not been played could provide the control cases against which its effects could be compared. Command and control vulnerability could be explored with repeated runs of the same or similar exercises in which different command and control elements were attacked and put out of action.

A further base for replication and comparison could be obtained by identifying and keeping track of key situations or situation/response combinations occurring more than once in an individual exercise. A database of low-level, action-effect measurements could be built up, which could then be aggregated as appropriate in different ways. Suppose, for example, it were necessary to evaluate the effectiveness of a new sensor system which provided timely identification and targeting of second echelon movers. Evaluating the effectivness of the system in terms of impact on outcomes might be made much easier if the exercise measurement of the performance of the system (in terms of fraction of movers identified) could be combined with estimates made over a number of past exercises of effectiveness as a function of fraction of targets known.

MANNING AND EQUIPPING THE CAEF

All this implies a need for a high-quality innovative staff for the CAEF, particularly during its early phases, and for a higher degree of staff continuity than is sometimes the case in military organizations. One way in which this continuity can be achieved is through mixed military/civilian staffing, with the civilians providing some of the continuity and institutional memory. For the military personnel, tours should probably be fairly long and staggered enough so that large staff turnover during a short period is avoided. In particular, personnel initially assigned to the CAEF should have staggered tour lengths, in order to avoid the problem of suddenly having a large fraction of the staff turn over at the end of everybody's first tour.

It seems likely that the cadre associated with the Exercise Driver--the people responsible for putting together and running the exercises--should be permanent party staff. This would include not only scenario designers and exercise management personnel, but also the operations analysts, computer analysts, and programmers responsible for creating and maintaining the computer models and programs necessary for the Exercise Driver. This permanent party might or might not need to be augmented during the exercise by TDY personnel, depending on the nature of the exercise and the manpower required by the Exercise Driver.

In the case of the Evaluation Unit, it seems plausible that a mixture of permanent party and TDY personnel will be required. Much of the advantage of the CAEF as an evaluation vehicle comes about as a result of its ability to create and exploit a growing body of data about the impacts of command and control on exercise outcomes, and to utilize appropriate segments of past data in the design and evaluation of each new exercise. This imposes a requirement for a highly competent permanent party staff to provide the continuity necessary to evolve the facility on an ongoing basis and to provide a knowledgeable and experienced cadre at each exercise. It is not reasonable to expect this staff to be large enough or experienced enough in the wide variety of command and control questions likely to be evaluated using the CAEF, however, to fully man the Evaluation Unit during exercises. They would probably be supplemented for each exercise with experts on the systems or issues under evaluation in that exercise, and might draw additional observers and data collectors from other sources as needed.

There are a variety of options for manning and equipping the C2 Components, all of which have both merits and weaknesses. There are reasonable arguments both for and against a permanently designated exercise team manning the C2 Components on a regular basis who are expertly qualified in its operation and functioning. On the one hand, such a team would minimize the need for pre-exercise familiarization with the facility itself and would reduce the variation in performance attributable to variations in manning. On the other hand, such a team might in time become too familiar with the CAEF, and begin "playing against the Exercise Driver" rather than behaving as they would in a real conflict environment. Using the same team all the time also complicates rerunning minor variations of the same scenario, since having played that scenario in the past would affect their responses to it.

Other manning sources which should be considered might include the use of personnel from operational TACS units or the assembling of ad hoc C2 Components teams for exercises for which that seemed appropriate. In exercises involving the employment of new or experimental systems, manning might also include personnel already familiar with the particular system being tested. We would expect that the appropriate mix of these manning sources, and procedures for selecting the right one for each particular exercise, would evolve over time with the evolution of the CAEF itself.

With respect to equipment, it seems clear that the CAEF should provide the basic equipment and facilities required by the C2 Components. In order to provide maximum flexibility in utilizing the CAEF, however, its operation should not be irrevocably tied to the use

of this equipment. Rather, it should be able to feed and receive information from C2 elements via standard C2 communications channels, so that operational elements can be exercised using their own facilities and equipment as well as those of the CAEF. In addition, the CAEF should have sufficient flexibility to accommodate and adapt to new systems and equipment played in the C2 Components.

THE EVOLUTIONARY PROCESS

The CAEF will not be created in a workable finished form in a single stroke, but will evolve through a series of updates, changes, and modifications from today's existing exercise capabilities, as outlined in Fig. 9. The structure which eventually emerges will have many general features in common with what exists today, but will also differ from what now exists in significant and important ways.

At present, exercises are manually supported and heavily pre-scripted, conducted primarily for training with whatever evaluation is performed added on in a fairly ad hoc way. The world outside the manned C2 elements is handled by a manual control team working from a canned scenario which permits only minor changes from a pre-scripted time history of conflict independent of the actions taken by the C2 elements. Waiting in the wings for test or evaluation there are always a variety of C2 systems, in various stages of development. Some of these will be inserted in each exercise to see how they work out. During the course of the exercise, informal evaluations, perceptions, and policy implications are evolved. These generally are mentioned and discussed at the exercise debriefing, but most slip away

and only a small portion of the potential knowledge which might be gained from the exercise is systematically retained.

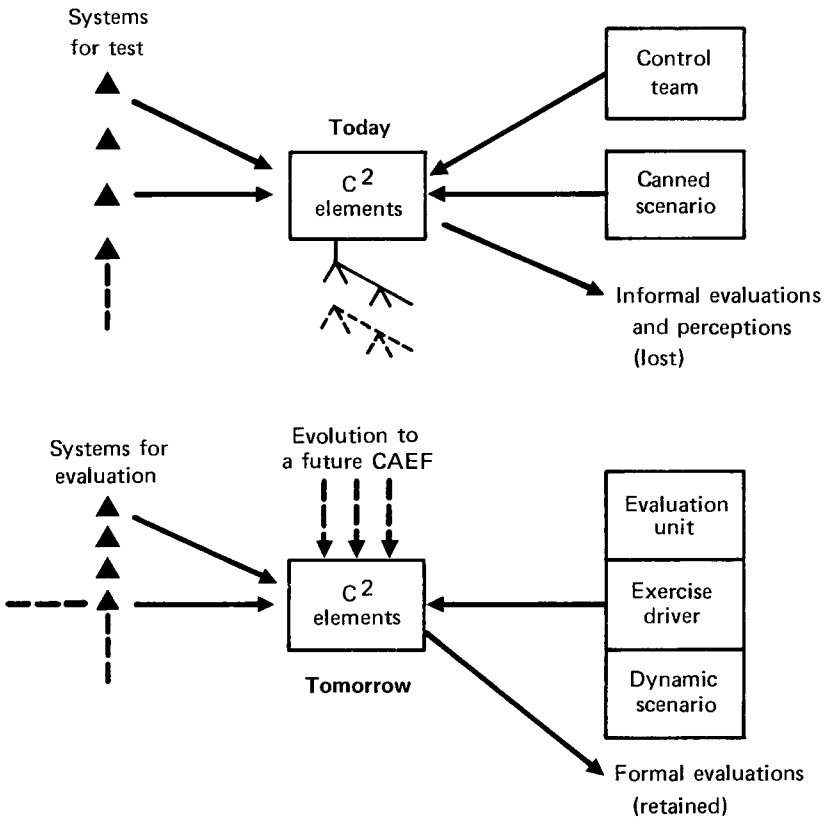

Fig. 9 — Evolution of CAEF

In a mature and functional CAEF, the manual control team will have been replaced by a man-machine exercise driver and the canned scenario will have been replaced by a dynamic scenario responsive to the action and decisions of the C2 Components. New command and

control systems and components will continue to require test and evaluation, and evaluation will be more of a primary exercise objective than is currently the case. An ongoing Evaluation Unit will have been added which will design and conduct evaluations in a far more rigorous and consistent manner than is possible today. These evaluations and the knowledge gained from them will be retained and utilized in the design and evolution of more effective and capable command and control systems for U.S. tactical air forces.

Getting from here to there will be a complex and difficult task, requiring choices at a number of branch points as the facility evolves. The eventual path can be only dimly perceived at present. What we hope to do is to cast a little more light on that path and point out good directions to start out, recognizing that we cannot supply a complete roadmap at the outset.

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