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EVALUATION OF THE USTRANSCOM DEPLOYMENT ANALYSIS PROTOTYPE (DAP)

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1 INTRODUCTION

This report provides an overview and concept evaluation of the Deployment Analysis Prototype (DAP). Section 1 considers the DAP in the context of the deployment planning environment. Section 2 provides an overview and evaluation of the DAP structures as well as specific algorithmic, computer, and interface issues. Sections 2 and 3 also provide recommendations for improvement of the DAP.

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2 DEPLOYMENT PLANNING

2.1 Deployment Planning Environment

2.1.1 Variation in Size and Time Frame

The size of a deployment ranges from the movement of a small rescue team to the movement of millions of tons of material for the reinforcement of Europe. Movement of a small rescue team may take only a few hours, while reinforcement of Europe can take several months. Movement of a small rescue team may require precise scheduling to within a few minutes, while reinforcement of Europe may only require scheduling by week. Limitation of assets would not normally be an issue with movement of a rescue team, but would be one of the critical factors in the reinforcement of Europe.

Because the DAP is implemented on a PC, it will be necessary to (1) model relatively small deployment scenarios, (2) consider a number of small time frames, or (3) utilize a fairly high level of aggregation of the input data. As currently constituted, the DAP doesn't have the ability to either "aggregate" or use "rolling horizons." These are features which might be considered as future enhancements. The current DAP seems most appropriate for smaller deployments.

2.1.2 Uncertainty

While much of deliberate planning assumes a static environment (i.e., the future is known with certainty), the actual environment is very dynamic. At best the future can be predicted for only a very short horizon. For short duration deployments, such as rescue operations, reasonably accurate predictions regarding availability of requirements and location of assets can be expected. However, as the planning horizon becomes longer than a few days, it becomes very unlikely that the status of the system can be predicted with much precision. Even if requirements remain as projected, it seems very unlikely that scheduled arrivals and departures of ships and planes several weeks in the future could be closely followed.

The current DAP uses the same level of resolution throughout the horizon. The notion of varying resolution by time needs further study. Its clear that the assumption made in deliberate planning - that the future is known with certainty - can cause problems for the DAP in actual execution planning.

2.1.3 Multiple Decision Makers

There are a variety of decision makers with only limited central control. The Joint Chiefs of Staff make strategic decisions including whether or not to undertake an operation and what resources are to be allocated to the operation. The supported commander makes decisions regarding what material is required, where it is required, when it is required, and what mode it takes. The supporting commanders make decisions regarding the sources of these materials. USTRANSCOM makes transportation coordination decisions. The Transportation Operating Agencies make decisions regarding specific routing and scheduling.

The DAP is intended to aid in making a basic decision concerning the choice of mode. Hence, in its present form it seems to be a tool oriented to the Supported Commander. However, it is not clear that the DAP addresses a significant portion of the decisions with which the Supported Commander is faced.

2.2 Types of Decisions

A useful way to characterize deployment related decisions is in terms of the time frame to be considered. As the deployment planning effort extends further into the future then (1) the degree of uncertainty regarding data will increase, (2) the level of detail of available data will decrease, and (3) the specificity of decisions will decrease.

2.2.1 Short Term Decisions

Examples of short term decisions include specific scheduling and routing of individual transportation units (e.g., where will a ship load, when will it load, what cargos will be loaded, how will they be loaded, when will it sail, and what will be its route?). These decisions require very specific detailed data regarding the ship and its cargos (e.g., for planes, the items are actually weighed before they are loaded).

2.2.2 Medium Term Decisions

Examples of medium term decisions include allocation of assets to deployments, sourcing of material, transportation mode selection, general scheduling and routing of material movement, and general scheduling and routing of transportation assets. While it would be comforting to have precise detailed data to support these decisions, the best one can expect is some approximation as planning extends into the future. Particularly with regard to time estimates (e.g., arrival and departure times at ports), estimates are not very accurate except for regularly scheduled assets. In general reasonably accurate data will exist for the near term with diminishing accuracy further into the future.

2.2.3 Long Term Decisions

Examples of long term decisions include sizing of port capacity, acquisition of transportation assets, acquisition and positioning of material, and assessing long term strategic feasibility. For these decisions the available data is generally very aggregate with little resolution with regard to timing issues.

2.2.4 DAP Decisions

The level of resolution of the data used by the DAP seems most appropriate for medium term decisions. However, there is some inconsistency between the data resolution and the modeling resolution. (The modeling resolution, for example, appears to track individual ships.)

The DAP considers, to some degree, decisions such as port selection, MR scheduling, asset allocation and scheduling. In its new role, USTRANSCOM should decide who the ultimate user of the DAP will be and orient its decision support capabilities to fit the needs of that user.

2.3 Determining Transportation Mode

Since the primary focus of the DAP is on model selection, there are two fundamental questions it should address: (1) for a given mode assignment can everything be delivered as requested, and (2) if not, how can mode assignment be altered to deliver as much as possible on time? If mode is arbitrarily assigned, then the danger is that an insufficient amount of the assigned mode will be assigned to transport the material so that it will arrive at the times required but that some other mode assignment would allow all of the movement requirements to be transported on schedule. There is also the possibility that there is no possible assignment of mode that will allow all of the movement requirements to be transported on schedule.

2.3.1 Mode Assignment Feasibility

The first natural question is to determine if a given mode assignment will allow all of the movement requirements to be transported so that they arrive when desired. To make this determination it is necessary for the system to make at least a gross allocation of ships and planes to transportation legs over time and a gross routing of the movement requirements through these transportation legs. The models implemented in the DAP seem weak in this regard.

To determine if a mode assignment is feasible, one might consider simply assigning available assets to movement requirements according to some schedule, (e.g.,as they become available to move) as long as the assignment would deliver the movement requirement within the time interval required, (e.g., using the route having the minimum transportation time). In doing this, there is the danger is that the movement requirement schedule will cause the use of transportation assets now to move material which is not currently time critical and then later (less than one cycle later) have insufficient assets to move material which is time critical. This issue can be avoided by requiring the user to assign the exact period (e.g., day, week, etc.) that he wants the movement requirement to arrive at its destination. However, there are also questions of when to dispatch the plane or ship if the available movement requirements do not constitute a full load, how to choose between different types of ships and planes, and how to handle delays caused by ports being at capacity. Again, the DAP models appear to require some improvement in this area.

2.3.2 Simultaneous Scheduling of Assets and MRs

The question of how to optimally make an initial mode assignment or how to improve a mode assignment which is infeasible (i.e., not all movement requirements are delivered on time) is extremely difficult. In order to optimally make a mode assignment, it is necessary to simultaneously consider both air and sea, as well as simultaneously considering both the scheduling of assets on legs and the scheduling of movement requirements on the assets. Unfortunat-ly, this is simply not possible to accomplish in an optimal manner.

First, there is a data problem. For long deployments it is very unlikely that the movements of the assets or the movement requirements could be predicted with any reasonable accuracy.

Second, even if this is possible if individual ships and planes are considered, the mathematical models required to optimize the mode assignment are orders-of-magnitude beyond what can be solved with today's technology.

The question then becomes "what levels of approximation can be made to generate models which would be useful in making mode decisions and which can be solved in a reasonable amount of time?" The DAP provides further insights into this question, but does not as yet provide what appears to be an acceptable solution.

3 THE DAP STRUCTURE

The current DAP consists of a controlling module, database management system, airlift configuration model, sealift configuration model, a movement requirement assignment model (the MRMATE model), and a reporting module.

As with any "first version", the DAP has some "rough edges." This section will focus on some possibilities for improving the DAP.

3.1 Microcomputer Selection

The IBM PC microcomputer environment was a reasonable choice for the implementation of the DAP. There are a wide range of high quality software and peripherals for the IBM PC which provide flexibility in implementing the DAP.

USTRANSCOM should consider migrating the DAP to a 386 class machine with a VGA monitor. The faster machine (preferably 20-25 mh) will cause the DAP to run approximately two and one-half to three times faster than the current AT. The VGA monitor will accommodate better graphics as the DAP evolves. It would also be attractive to use a portable computer which would allow USTRANSCOM personnel to take the DAP "on the road."

3.2 Flow Control

The DAP has a driver which controls the flow through the system. The current level of control is awkward for the user. Additional effort could be applied to enhance the flexibility to move through the system according to user desires and needs.

3.3 Database Management and Reporting

The selection of dBASE III Plus was a good idea. dBASE allows great flexibility in designing a database management system on an IBM microcomputer. Some of the screens are, at times, "user unfriendly." Sometimes, required inputs and responses are a mystery.

The DAP currently offers some capability for examining the data. It would be nice to provide an enhanced capability to view the data in various ways according to the user's needs.

The dBASE screens and functions should be redesigned to provide greater flexibility.

3.4 Graphics

The graphics in the DAP needs considerable rework. This is an opportunity for USTRANSCOM to use the DAP to impress potential users and it should not be wasted. More than anything else, this sets the tone of the DAP.

Considerable effort should be applied to improving and enhancing the graphics. Graphics packages such as GSS or Metawindows are excellent choices for a graphics "platform" on which a set of new screens can be designed. Graphics similar to that in the MTMC STRADS prototype should be considered for inclusion in the DAP.

3.5 User Interface

The user interface for the DAP consists of utilizing certain input fields under dBASE. The DAP, following the design of MODES, was not intended as an interactive system. Without major effort, it is unlikely that an interactive component can be added to the DAP. Yet this feature is essential to make the system work in the field.

3.6 Optimization Models

The DAP contains three major optimization models. Two of the models (airlift and sealift configuration) are new. The third (MR assignment) is the MRMATE model from MODES.

3.6.1 Airlift

The airlift model appears to have some significant weaknesses which are being addressed by Oak Ridge National Laboratories (ORNL). This model should definitely be replaced as a result of that effort.

3.6.2 Sealift

Georgia Tech PDRC Report No. 88-05 discussed alternative approaches for sealift modelling. It appears that the DAP can be significantly improved by implementing an approach similar to one described in that report.

3.6.3 MR Assignment

The MR assignment model is the MRMATE model from MODES (and SCOPE). This model has consistently been the most robust MODES component. Given realistic asset configurations, MRMATE provides realistic MR mode assignments and schedules.

MRMATE will run reasonably fast for small problems; however, as USTRANSCOM attempts to prototype larger scenarios MRMATE will begin to increase dramatically in execution time on a PC. In such circumstances consideration needs to be given to speeding up MRMATE where possible. Fortunately, some of the basic assumptions for the DAP permit MRMATE to be decomposed into a set of smaller problems which taken together will run faster.

To keep the size and complexity manageable it was decided that each logistics planning region (LPR) would be serviced by only a limited number of POEs. A table inside the DAP specifies this connectivity. This limited connectivity can be exploited to advantage in decomposing the MRMATE model.

3.6.3.1 Decomposing MRMATE

To illustrate the decomposition principle consider the LPR/POE connectivity implied by the following table.

LPR/POE Connectivity Table

	POE 1	POE 2
LPR 1	X	
LPR 2	X	
LPR 3		X

LPRs 1 and 2 are served by POE 1, while LPR 3 is served by POE 2. In this case, it is possible to solve the MRMATE problem as two smaller problems. One of the problems contains LPRs 1 and 2 together with POE 1. The other problem contains LPR 3 and POE 2.

3.6.3.2 Advantages of MRMATE Decomposition

Figure 1 illustrates the runtime advantages of decomposing the MRMATE problem. In the figure, X1 is the size (LPRs plus POEs) of one component, while X2 is the size of the other

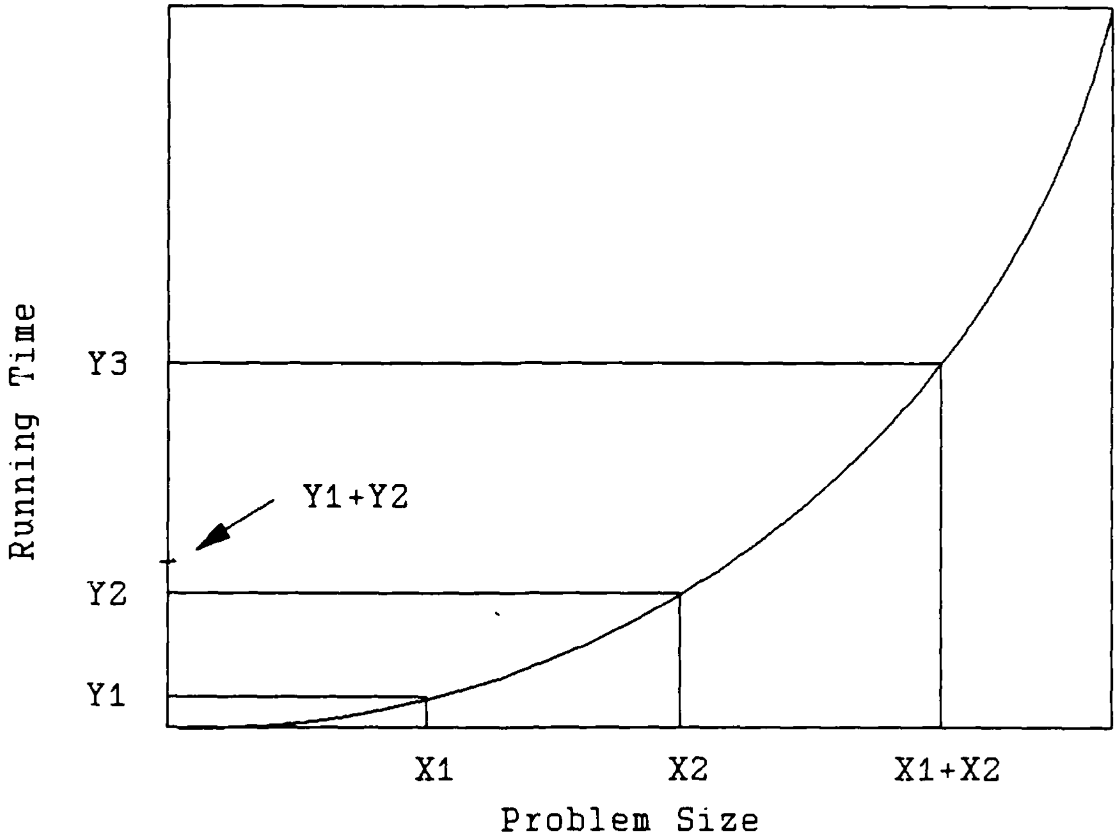

Figure 1 **MRMATE Runtimes by Problem Size**

component. For example, component 1 might be LPR3 and POE 1 above, and component 2 the rest. The curve, an upward bow, depicts generally how runtime increases with problem size. Reading horizontally from the curve at X1 one gets a runtime of Y1. The runtime for X2 is Y2. Therefore, if the components are solved separately, ignoring any overhead, the total time would be the value Y1+Y2. However, if the problem were solved all together the runtime would be Y3.

3.7 Integration

The DAP system has a design which achieves a strong linear flow. Through redesign and enhancement of the control module it is possible to achieve greater flexibility in maneuvering among the components of the system.

4 RECOMMENDATIONS

4.1 Continuous Flow Assumption

The DAP should be enhanced to take advantage of the experience gained with the MODES model and the research resulting from this experience. The fundamental approximations made in the MODES model assumed continuous transportation (e.g., instead of considering discrete ships and planes assigned to each leg, the model considered "stons of capacity" and "mtons of capacity" assigned to each leg). While this allowed the entire problem to be captured in an optimization model, there were serious difficulties interpreting the results for the very small deployments used in testing. This seems unavoidable when the model is used in a batch environment (as opposed to an interactive environment).

The major problem with MODES occurs in small deployments when the model results do not translate into whole ship loads. While there are other options which might be considered (e.g., multi-commodity flow models), it seems apparent that all tractable optimization models, in order to simultaneously consider both air and sea and the scheduling of assets on legs and the scheduling of movement requirements on the assets, would require the assumption of continuous transportation and hence would suffer from the same problem.

Based on the experience to date, the continuous flow assumption can be retained provided that the system contains substantial interactivity. It does not seem attractive to model discrete ships and planes for anything but the very short term scheduling and routing problems. For the medium and long term problems, the data resolution cannot support stronger assumptions than continuous flow. In addition, the heuristic/simulation approaches which treat discrete (individual) ships and planes suffer from very limited "look ahead" because of the time constraints under which the system must operate.

4.2 MR Scheduling

Given that the mode decision problem cannot be addressed in one piece, the logical partition is to have one model to handle the scheduling of assets on legs and another model to handle the scheduling of movement requirements on the assets. In spirit this is what MODES did with LIFTCAP scheduling the assets and MRMATE scheduling the movement requirements. This partition is also utilized in the DAP with MRMATE scheduling the movement requirements and a heuristic procedure to schedule the assets. In both cases, the MRMATE segment works very well.

Based on all of the Georgia Tech research, together with the implementations of MODES and the DAP, the MRMATE model is both robust and computationally tractable. It appears highly unlikely that any superior procedure can be developed for the problem of scheduling the movement requirements. Therefore, MRMATE should remain a central component of any future enhanced DAP.

4.3 Asset Scheduling

The problem in both MODES and the DAP is with asset scheduling. Based on recent Georgia Tech research, MODES can be significantly improved; but it is only useful as a decision aid in an interactive system. It is not likely that an all inclusive optimization model can be developed which will overcome the problems that MODES has as a result of the continuous transportation approximation.

4.4 "One Pass" vs Optimization

Evaluation of the DAP suggests that any "one-pass" concept, (i.e., make one schedule of assets and one assignment of movement requirements) such as that used in the DAP will have some serious problems in terms of the quality of the output. It is not likely that the quality of such an approach can ever be made acceptable outside an interactive environment.

A reasonable compromise between the optimization approach used in MODES and the one-pass heuristic used in the DAP is to use MRMATE for movement requirement assignment together with a new model for asset assignment which incorporates user interactivity and handles ships as discrete units. A variant of LIFTCAP could still be used for the air assignment provided that the user could interactively control the solution and force integer answers where necessary (i.e., on legs with very few assets). This would also allow some limited but productive iteration between the movement requirement assignment and the asset scheduling.

For sealift, the basic DAP models would focus on determining and displaying aggregate time-phased transportation requirements (needs); and the user would utilize this information in conjunction with other interactive aids to develop ship schedules and routes which integrate with the air scheduling in MRMATE.

This approach is a variation of the concept recommended in the original SCOPE design (Georgia Tech PDRC Report 82-22 and 84-09). It would retain the elements of MODES and the DAP which have been proven to work and provide an enhanced solution to the remaining problems based on lessons learned from the MODES and DAP experiences.