The Use Of Simulation Modeling In Determining Defense Manpower

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Abstract

Accurate determinations of manpower requirements of a combat unit such as a tactical fighter wing or a carrier task force is a stated goal of the Department of Defense. Such determinations must be defensible to both the Executive Branch (Office of Management and Budget and the President) and Congress. In order to assess manpower requirements under various combat conditions, the three services have adopted computer simulation models. While Monte Carlo simulation has provided a means of estimating wartime manpower, it has also introduced several problems which must be overcome if simulation is to continue to play an important role in assessing Department of Defense requirements. These problems have centered on the need for extensive computer and personnel resources, the lack of responsiveness to changing scenarios, the collection of reliable and accurate data, and the increasing complexity and sophistication of the models.

INTRODUCTION

The use of simulation in establishing Defense manpower requirements dates back to the early seventies. The Human Resources Laboratory (HRL) and the Aeronautical Systems Division (ASD), both part of the Air Force Systems Command and both located at Wright-Patterson AFB, Ohio, adopted the Logistics Composite Model (LCOM) to determine maintenance manpower requirements for emerging aircraft (1). The LCOM model was developed originally by RAND and the Air Force Logistics Command to simulate the interaction of logistics resources and operational requirements of a fighter wing. It was not until the Tactical Air Command (TAC) adopted LCOM in 1971 and completed its first manpower study in 1973 that computer simulation became an accepted method for establishing Defense manpower requirements.

Following acceptance of the LCOM model by the Air Force and the Department of Defense, the use of simulation has increased although limited primarily to determining aircraft and munitions maintenance requirements. The Air Force used LCOM to determine the manning levels needed to support programmed combat sortie rates for its fighter wings while the Navy used LCOM to assess carrier based maintenance requirements. Meanwhile the Army developed a similar computer simulation known as the Aircraft Reliability and Maintainability Simulation (ARMS) Model. This simulation has been used primarily to determine maintenance manning requirements for the Army's helicopter battalions (2). More recently, the Navy has developed the Comprehensive Aircraft Support Effectiveness Evaluation (CASEE) while the Marines developed the Marine Operational V/STOL Environment Simulation (MOVES). Both are similar to LCOM in that they simulate aircraft operations and maintenance (3). Over the past several years, the Air Force has developed a second major simulation known as the TAC FLIER. This computer simulation is used in conjunction with LCOM to estimate aircrew ratios-the number of aircrews required per aircraft of a certain type and model. Its use has been limited to tactical fighter wings. The Military Airlift Command (MAC) has developed a similar simulation for determining aircrew requirements for the C-5A and C-141 aircraft. The Navy appears on the verge of adopting the TAC FLIER model for their own use. They have recently completed a study to determine the aircrew requirements for the carrier based F-14.

Other simulations have been used on a onetime basis for establishing Defense manpower. However, the simulations discussed above have had some acceptance within the Defense Department, are used on a reoccurring basis, and collectively address the majority of the manpower positions established through the use of computer simulation. For these reasons, this paper will be limited to experience in applying the above models. In particular, the LCOM simulation will provide a focal point for assessing the role which computer simulation can play in the manpower determination process. The need for computer simulation, problems encountered in its application, and the prospects for future use of simulation in Defense manpower will be addressed.

THE NEED FOR COMPUTER SIMULATION

As is the case for many simulations, the use of the above manpower models is motivated by the lack of an observable system available for analysis. This is true for new weapon systems which are still in the conceptual stage of development and for existing combat units whose manpower requirements are based upon wartime conditions. For example, initial maintenance manning requirements for the F-16 fighter aircraft was based upon LCOM simulations conducted before the aircraft had ever flown. Component failure rates and repair times were established from contractor estimates and comparability analysis with existing aircraft. Operational parameters were based upon the Air Force's estimates of the aircraft's capability and its planned operational use. On the other hand, aircraft munitions and maintenance requirements for the F-4E, a 20 year old fighter airplane, was also based upon LCOM. Although peacetime failure and repair data were used, a wartime combat scenario was modeled in order to determine the manpower needed to support wartime sorties in a NATO/WARSAW conventional war. Inability to establish wartime manpower requirements from direct measurements continues to provide a need for simulation.

A second reason for adopting a simulation approach is the need to tie manpower levels to some measure of output. For a tactical fighter wing, the most meaningful output measure is sorties produced. Through the use of a computer simulation, the effect of various maintenance specialties (such as jet engine mechanic and avionics repairman), their manning levels, and their interaction with one another on sortie production can be analyzed. It takes between twenty-five and thirty-five different maintenance specialists to support a typical fighter wing. It is extremely difficult to analytically measure their combined ability to generate sorties. Other output measures such as flying hours accomplished and fully mission capable rate can at the same time be determined.

Perhaps the most compelling reason for the adoption of simulation has been the (perceived) need to realistically model a complex environment. These simulations are quite sophisticated in that they enable various missions, weather patterns, aircraft configurations, and resource mixes to be modeled. Further, failure rates of systems and subsystems, repair times, abort rates, attrition rates, weather cancels, munitions expenditure rates, and missions flown by time of day can all be determined randomly based upon input probability distributions. Whether this degree of complexity and realism is needed to accurately determine manpower or to add credence to the models is not clear. Certainly studies are easier to defend when it can be pointed out that European weather patterns were modeled and the proper mix of air-to-ground and air-to-air combat missions were flown in the simulation. When compared to the less sophisticated methods used in the past for establishing these same manpower requirements (such as a man-hour per flying hour factor), the improved accuracy cannot be denied.

The fact that simulation can be understood by high level management should not be overlooked. It is relatively more difficult to explain how a linear program or queuing model is used to establish manpower. However, with a simulation described in terms of the system being modeled, not only can the decision maker understand the technique but he also can appreciate the model's subtleties. I have often felt that a system of differential equations which model the same aircraft maintenance environment as the LCOM model would never be adopted. In fact, at one time the RAND Corporation did develop a set of queuing formulas which were designed to supplement LCOM (4). They have never been adopted by the manpower community.

A distinct advantage of simulation is the ability to conduct various trade-off studies. For example, the Air Force Test and Evaluation Center (AFTEC) has done a deficiency analysis on the F-16 where they looked at trade-offs between manpower requirements and component reliability and repairability and their effect on sortie generation. The results of this analysis formed the basis for prioritizing aircraft deficiencies. Limited funds were then allocated for correcting these deficiencies based upon these priorities. The McDonnell-Douglas Corporation has been developing a set of resource interaction models for the Department of Defense (Manpower, Reserve Affairs and Logistics). These models, in the form of regression equations, estimate the trade-offs between manpower, spare parts, and equipment relative to various measures of performance for a fighter wing. Other trade-off studies have analyzed the manpower requirement as a function of the number of sets of test equipment assigned to a unit, as a function of the programmed sortie rate or mission length, and as a function of the number of aircraft assigned to a wing or squadron. Such trade-off analysis is crucial for supporting decisions being made on unit deployment and employment plans.

LIMITATIONS ON THE USE OF SIMULATION

The most serious restriction on the use of simulation in assessing Defense manpower requirements is its cost. A typical LCOM manpower study will take from 12 to 18 months. Although some studies have been completed in 6 months, others have required over two years. Much of this time is spent in obtaining the detailed data required for the simulation, coordinating the operational factors which drive the model, and developing the data base. An average data base for a fighter squadron would include about 5000 individual manpower tasks and require 150-170K (word) core on a Honeywell 6000 System. It will run in about 40-60 minutes of Central Processing Unit (CPU) time. On the other hand, the C-5A study being done by the Military Air Command (MAC) modeled 16,000 tasks, had to be compressed to a 200K maximum core, and averaged 7½ CPU hours per simulation. It is not unusual to perform several hundred simulation runs in support of a single study. The process of constraining manpower, i.e., determining the minimum shift requirement for each specialty being modeled, is more of an art than a science. To date, a systematic trial and error procedure has been developed but it requires numerous simulation runs to implement. All of this adds up to a considerable computer requirement. Decisions over which weapon systems to simulate versus use of some other management engineering approach should not be made lightly.

In defense of the large investment required of a simulation manpower study is the fact that such a study addresses a large number of manpower authorizations. A typical fighter wing will include about 1500 maintenance manpower spaces with about 70 to 75 percent of these spaces actually modeled in the simulation. Over twenty percent of TAC's combat personnel are assigned to aircraft and munitions maintenance. If combat aircrews are also included, then the LCOM simulation process alone can address about 18 percent of TAC's total resources or about 18,000 spaces. To develop convention management engineering manpower standards for these authorizations may also be expensive and may result in less accurate, less defensible estimates of wartime requirements.

In addition to computer resources is the need for experienced people to develop the simulation data bases and to perform the analysis. Not only must an individual have a knowledge of computer simulation, he must also be able to perform statistical analysis and have an understanding of the manpower determination process. In addition, a successful analyst must also be familiar with the environment he is modeling. To this end, TAC has attempted to recruit a mix of specialists in several career fields-aircraft maintenance, munitions maintenance, operations research, flying operations, and logistics. While this interdisciplinary team approach has been advocated in operations research/management science, it is somewhat a new concept for manpower managers. Traditionally management engineers have developed manpower standards for all career fields without necessarily having background or experience in the field being analyzed. The ability to obtain and retain individuals having the aptitude for computer simulation and a knowledge of aircraft maintenance has limited the use of simulation.

The length of the study process highlights another difficulty. Computer simulation has not been very responsive to tasking by higher headquarters. A method for quickly answering a variety of "what if" type questions is needed. For example, questions on how manpower requirements are affected by changes in missions, flying hour programs, or deployment tasking must be addressed. What happens if different aircraft attrition factors are assumed or if ground (manpower) attrition is permitted? What is the change in munitions personnel if a fighter aircraft has a predominate air-to-ground role rather than a mix of air-to-ground and air-to-air missions? Does aircraft maintenance requirements change if we equip an attack aircraft to fly more night missions? Do we need more aircrews if we attempt to fly higher surge sortie rates? How many more? These and other like questions are difficult to answer in a timely fashion with the current complex models. Back of the envelope calculations are frequently made to answer such questions although quite often they are based upon previous simulation experience. In a few instances if the proper data base is available, simulation has been used effectively. In other instances the ability to answer some of these questions has been made part of the original manpower study. Although in this later instance, a trade-off between study time and the scope of the study must be made. More effort should be devoted to increasing the responsiveness of simulation. Military operational requirements change frequently as the perceived threat changes. The impact on defense manpower must be assessed with less delay.

The size and detail of the data bases has caused considerable problems in obtaining accurate and reliable input data. For emerging weapon systems, this data must come from contractor estimates and comparability studies which attempt to match aircraft subsystems with those on older, operational weapon systems. Contractor estimates of component failure rates and repair times have tended to be overly optimistic. In the early stages of the weapon system acquisition process, it is impossible to obtain detailed data on subassemblies, the individual units which collectively comprise a major subsystem. It is only when a prototype has been developed and is in the test and evaluation stage that the first hard data can be obtained.

For existing weapon systems in which perhaps several years data has been collected, the accuracy of that data is being questioned. The input data for the LCOM simulations of existing aircraft come from two sources, the Air Force's maintenance data collection (MDC) system and on-site field measurements. The MDC system has been challenged numerous times for biasedness particular with respect to task times and crew sizes (the number of individuals normally required to perform a specified task). LCOM has traditionally based failure rates only on this data source and has sent management engineers to the field to obtain task duration and crew size information. More recently, management engineers have been developing job standards for those tasks which occur frequently enough to justify the expenditure of this manpower. These job standards have by necessity been limited to scheduled maintenance activities. Unscheduled maintenance activities occur too infrequently to efficiently measure by a stop watch their duration. Structured interviews with experienced maintenance personnel have provided the only means to date to obtain this type of data. The reliability of this data depends to a large extent on the ability of the individuals conducting the interviews and their knowledge of the environment which they are measuring. The validity of the simulation model depends in part on valid input data. For many of the computer models, such as LCOM and ARMS, logical validity has been established. Detailed scenarios which outline model assumptions are coordinated throughout the using command and higher headquarters. However more effort must be devoted to validating input data, or it will continue to be the weak link in the modeling process.

Because simulation has the ability to model extreme detail, there is a tendency to over complicate the model. While this adds to its realism and thus its credibility, it may not enhance the accuracy by which manpower is determined. The addition of irrelevant variables to the model causes an unnecessary complication. Not only does this increase the data base requirements and model development time, it also requires additional training and expertise on the part of the analyst to master additional features of the model. For example, weather patterns are modeled in LCOM as a Markov process. Analysts experienced it determining manpower requirements feel that weather could be handled in a less sophisticated fashion without affecting the manpower answer. Recent software additions to LCOM included more realistic treatment of aircraft reconfiguration (munitions loads, external fuel tanks and pods, and internal equipment requirements). This has resulted in several additional data files and has required one to two weeks of additional debug simulations in order to determine the proper reconfiguration parameters (mission lead times, cancel times, and reconfiguration search patterns) to use in exercising the model. Other enhancements being considered include the ability to cannibalize not only parts from aircraft but also parts from systems removed from the aircraft (such as a jet engine). While these changes have added to the realism of the model, a cost in terms of data base requirements, study time as well as personnel training has been incurred. Before other features are added to these models, a determination needs to be made as to their relevance in establishing accurate manpower requirements. An old management science axiom is not to build a complicated model when a simple one will do.

Also affecting model sophistication is the attempt to expand the scope of the model. Efforts are underway to use LCOM to address manpower requirements at multiple locations. For example, MAC's C-5A study requires the airplane to fly from its main operating base to several enroute bases to a destination base and then return. At each location some level of aircraft maintenance can be performed. TAC because of their particular maintenance concept requires the simulation model to have the capability to substitute manpower resources from one specialty to another specialty for designated tasks. This has lead to further sophistication. Another well stated adage in management science-a model should never be pressed to do, nor criticized for failing to do, that for which it was never intended-needs to be observed (5). A simulation such as ARMS or LCOM can be designed to model efficiently a particular environment. However, the scope and range of the model can only be enhanced at the expense of increased complexity. A similar situation exists in developing a data base. An efficient data base can be designed to determine manpower requirements or to assess spare part requirements. It is much more difficult to design a single data base to answer both questions without increasing the size and complexity of the model.

FUTURE TRENDS

Simulation is being used to some extent by all three services in estimating manpower requirements. The Department of Defense has indorsed this approach and in a series of memos from the Office of Manpower, Reserve Affairs and Logistics (MRA&L) has requested additional emphasis be placed on estimating manpower costs of new weapon systems. Simulation, particular the Air Force's LCOM model and the Army's ARMS model have been considered essential by the Department of Defense to adequately assess the impact of operational, design, and logistics interactions on manpower needs (6). These models support Defense Department decisions concerning development and full scale production of new weapon systems. The Air Force has formally approved the use of computer simulation (i.e., the LCOM model) for establishing maintenance manpower requirements through the publication of a regulation. The use of simulation has been briefed to congressional staff personnel and has been investigated by the General Accounting Office (GAO). It is an established and accepted technique for analyzing wartime manpower requirements. Nevertheless, the shortcomings identified above, will continue to limit its use in Defense manpower computations.

Some efforts are underway to reduce these limitations. For example, TAC has been developing statistical procedures to compress data bases in order to reduce computer run time and core requirements. These compression programs will combine tasks requiring the same resources (specialties). The identity of individual tasks are lost but all of the tasks times and crew sizes will be retain. Software improvements have been initiated by the Air Force Management Engineering Agency (AFMEA) to reduce run time. Statistical analysis has been accomplished to determine the minimum number of days which need to be simulated in order to reach steady state conditions. These efforts have enabled TAC to reduce average core size from 170K to below 140K and average run time from 2 hours to 40 minutes.

TAC is now testing some support programs which will automate much of the data base development. An automatic network generation program has been developed by the CACI Corporation and modified by TAC to generate the sequence of unscheduled maintenance tasks directly from the MDC data. A second computer program developed at TAC will automatically update this data base with data obtained from field measurements. A third program is currently being developed to enable the analyst to make changes to the data base through direct interaction with the computer on a real time basis. These data manipulation programs will reduce study time by an estimated two to three months and will eliminate errors made as a result of manual computations. A secondary benefit from these programs is the ability to perform statistical analysis among several data input sources and to check for consistency among these inputs. Efforts continue both at TAC and AFMEA to place more task times under engineered job standards. These steps should increase the reliability and accuracy of the input data.

Because of the increased sophistication of the model and the difficulty in obtaining highly qualified analysts, TAC has organized its simulation group into two branches. One branch, the data analysis branch, is tasked with data collection and data base development up through debug simulations. The second branch, the studies branch, performs productive simulations and analysis and is responsible for study reports. By specializing in either of these two areas, the amount of time required for an individual to become proficient is reduced. A better quality product should be obtained. However, more importantly, it is TAC's goal to develop and maintain current data bases on all of the commands major weapon systems. This is the charter of the data analysis branch. Having current data bases available for the studies branch to access will increase our responsiveness when tasked to address questions not programmed for in our study schedules.

Simulation is a viable means of establish defense manpower requirements. Efforts must continue to increase responsiveness, and decrease the costs of the models in use today. We must resist efforts to continue to enhance current models and to over complicate them. Finally, we must devote more resources to obtaining more accurate and reliable input data. Simulation will continue to be used in the manpower determination process. However, if it is to expand beyond its present level, more emphasis needs to be placed upon overcoming these limitations.

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