Distributed Mission Training: Modeling and Analysis of Training Effectiveness, Costs and Resource Allocations

R. Ramesh
SUNY at Buffalo
Buffalo, NY 14260

Dee H. Andrews
Air Force Research Laboratory
Mesa, AZ 85206

ABSTRACT

Distributed Mission Training (DMT) is a revolutionary training paradigm currently evolving at the Department of Defense, especially at the Air force. DMT combines virtual, live and constructive assets so that warfighters can train as they intend to fight. While the dimensions and complexity of modern warfare are expanding, the ability of the defense services to train forces in a realistic environment is being increasingly constrained. The primary constraints arise from limited resources for team skill training using actual equipment such as aircraft, safety limitations of live training events and security constraints due to operational conditions. Consequently, DMT is strongly emerging as an alternate but effective mode of team training in the defense services. In this research, we develop models and a spreadsheet decision support system to assess the training effectiveness, costs and resource allocations in DMT environments. The modeling framework performs parametric sensitivity analysis on (i) aircraft - DMT flying time tradeoffs, (ii) Training capacity analysis for joint aircraft - DMT training, and (iii) high level cost analysis of DMT configurations.

Dr. Ramesh is an Associate Professor of Management Science & Systems at SUNY, Buffalo. His primary areas of research are Operations Research, Training Systems Design and Information Systems. His current research programs include: client/server infrastructure planning, optimal configuration and cost/benefit assessments of DMT technologies, and design and analysis of distributed systems. His publications appear in leading academic journals such as *Management Science, ACM Transactions on Database Systems, Information Systems Research, INFORMS Journal on Computing, IEEE Transactions on Knowledge and Data Engineering, IEEE Transactions on Systems, Man and Cybernetics* and *Naval Research Logistics* among others. He and Dee H. Andrews guest edited a special section of the *Communications of the ACM* on the theme "Distributed Mission Training: Emerging Training Systems of the Next Millennium". He edited two volumes of the *Annals of Operations Research* on the theme: "Interfaces between OR and IS" and is an editor-in-chief of *Information Systems Frontiers: A Journal of Research & Innovation.*

Dr. Dee Andrews is the Technical Advisor of the Warfighter Training Research Division of the Air Force Research Laboratory. He has held that position for the last ten years. Prior to his current position he held management and research positions in the Army Research Institute of the Behavioral and Social Sciences, and the Naval Training Systems Center. His Ph.D. is in Instructional Systems from Florida State University. His research interests include; training system development, simulator development and evaluation, training cost-benefit analysis, and learning theory.

Distributed Mission Training: Modeling and Analysis of Training Effectiveness, Costs and Resource Allocations

INTRODUCTION

Distributed Mission Training (DMT) is a revolutionary team training paradigm currently evolving at the Department of Defense, especially at the Air force. The fundamental technologies on which DMT systems are built are: *virtual reality*, *networks of distributed training systems* and *multimedia communication*. The objective of DMT is to concurrently train people in team efforts involving coordination, communication and decision making. The teams may not necessarily be co-located and could be engaged in independent as well as coordinated tasks at remote sites.

The rationale for DMT is derived from the characteristics of contemporary warfare and the increasing emphasis on creating technology based training environments that realistically capture the complexities and demands of modern military operations. For example, the range and performance of modern aerial weapons systems enable domination of larger areas. Tighter linkages between sensors like AWACS or JSTARS and shooters like fighters and bombers require increased emphasis on teamwork for successful mission execution. Tactics are increasingly based on the technology and behavior of an adversary's integrated defense systems rather than individual platforms. Taken together, these trends are blurring the distinction between operational and tactical levels of training and mission preparedness. DMT is an evolution from this rapidly advancing technology driven warfare whose primary thrust is on team training.

While the dimensions and complexity of modern warfare are expanding, the ability of the defense services to train forces in a realistic environment is being increasingly constrained. The primary constraints arise from limited resources for team skill training using actual equipment such as aircraft, safety limitations of live training events such as air-to-air missiles for instance, and security constraints due to operational conditions. Consequently, DMT is strongly emerging as an alternate but effective mode of team training in the defense services. Distributed networks of advanced simulators of various military equipment such as fighters, bombers, battle tanks and even ships and aircraft carriers are being developed with a principal focus on team training.

In this research, we focus on the following key questions surrounding the design, development, and implementation of DMT systems:

1. **Under the DMT concept, which includes aircraft flying training, virtual simulation and constructive modeling, how much training can best be accomplished on each of these media?**
2. **What is the extent to which additional training can be accomplished with DMT on tasks that are not trainable on original equipment alone due to safety and other reasons?**
3. **What are the various training configurations under which DMT can be used together to achieve enhanced levels of mission readiness over what is currently possible?**
4. **What are the specific life cycle costs associated with the DMT systems? How much life extension to the original equipment can be attained by introducing DMT as part of a training program?**

The above questions lead to a set of cost-effectiveness analyses and models on DMT systems. In this research, we develop a modeling framework for DMT systems in general. A proof-of-concept decision support system for DMT application decisions has also been developed. For purposes of illustration, we employ continuation/replacement training in F-16 airframes in describing the framework and the system.

This paper is organized as follows. The next section presents the research plan and the methodology. The following section presents the overall cost-effectiveness modeling framework for DMT systems. Finally, the last section presents some of the key results of our analyses with F-16 training and illustrates the modeling framework through a case analysis.

RESEARCH PLAN AND METHODOLOGY

The research plan consisted of four phases with the first three phases pertaining to data collection and analysis and the last phase dealing with system development and testing. The phases are organized as follows.

- ***Phase 1:*** *Initial data collection on DMT characteristics, training requirements and strategies, and cost/performance indicators.* This has been accomplished through a series of interviews with subject matter experts at ARL, ACC/DO, ACC/DR and ASC/YW. This phase resulted in a broad framework of the subsequent data collection on the structural details of DMT based training.
- ***Phase 2:*** *Detailed data collection on DMT cost and effectiveness measures.* This involved a series of interviews with the experts at ARL and a detailed analysis of DMT related documentation. Putting all these studies together, a systematic and controlled field data collection strategy using subject matter experts and the DMT prototype at ARL emerged.
- ***Phase 3:*** *SME data collection from the Roadrunner'98 exercises.* ARL conducted these exercises between July 13 - 20, 1998 at Mesa. Roadrunner'98 combined virtual (man-in-the-loop) training events at DMT platforms with computer generated constructive models. The DMT platforms consisted of four F-16, one A-10, four F-15 and one AWACS simulators at different locations that were networked both locally and over wide area. Our study has been part of these exercises. Six questionnaires were designed for our study and administered to 15 subject matter experts who participated in Roadrunner'98 after they have had significant first hand experience with the DMT systems. The assessments they provided formed a substantial basis for the training effectiveness analyses embedded in the decision support system developed in the next phase.
- ***Phase 4:*** *The development of a spreadsheet based decision support system to evaluate the costs and benefits of DMT systems and perform parametrical sensitivity analyses.* This system has been developed using MS Excel, is applicable to the analysis of DMT systems in general, and has been demonstrated as a proof-of-concept using the F-16 case.

COST-EFFECTIVENESS MODELING FRAMEWORK

We present the following components of the modeling framework in this discussion: the system database, assumptions underlying the analyses and the models embedded in the system.

System Database

The database consists of two data sets: training effectiveness data and cost data. The effectiveness data has been collected from the six questionnaires used in the Roadrunner study. The questionnaires employ a set of 45 major training events in F-16 combat training. These events, referred to as *Mission Elements*, have been identified using the F-16 RAP. The key elements of this database are:

- A magnitude scale rating of the mission elements on their importance to combat readiness (Questionnaire 1)
- An evaluation of the training experience with the aircraft to actual combat experience in each mission element using a 0-4 scale, where 0 represents "Total Negative Training", 2 represents "Acceptable Training", 3 represents "Superior Training" and 4 represents "Total Positive Training" (Questionnaire 2). Questionnaires 3 and 4 yielded the similar evaluations for 2-ship and 4-ship DMT systems, respectively.
- An evaluation of the minimum number of sorties required in each mission element for combat readiness when: (i) only the aircraft is used, (ii) aircraft and 2-ship DMT are used, and (iii) aircraft and 4-ship DMT are used. The experts specified the break up of sorties between the aircraft and DMT sorties in (ii) and (iii). Questionnaire 5 obtained the tradeoff data between aircraft and DMT sorties in the case of *inexperienced pilot training* and Questionnaire 6 for *experienced pilot training.*

The cost database has been compiled from detailed discussions with SMEs in DMT systems and other relevant multi-ship cost data sources and reports. This database consists of the following estimates of 2-ship and 4-ship F-16 DMT systems:

- Nonrecurring initial fixed costs
- Long term recurring fixed costs
- Direct operating costs
- Indirect operating costs

Putting training effectiveness and costs together, the models embedded in the system provide a direct cost - benefit analysis of 2-ship and 4-ship DMT systems under various levels of DMT usage.

Modeling Assumptions

The following assumptions are made in the development of the various models embedded in the Decision Support System.

1. All mission elements are trainable on the aircraft. However, the effectiveness of aircraft training may vary among the mission elements.
2. It is possible to reach full combat readiness in each mission element by training on the aircraft.
3. The level of combat readiness in a mission element depends on the effectiveness of the training medium (aircraft, in this case). If the training effectiveness of the aircraft in a mission element is low, then the mission element should be practiced a large number of times on the aircraft, in order to reach the full level of combat readiness.
4. No assumptions are made regarding: (i) trainability of mission elements, (ii) ability to reach full combat readiness, and (iii) training effectiveness of DMT. Hence, given the assumptions (1)-(3) on aircraft training, the benefits of these assumptions are fully in favor of the aircraft.
5. Only the training of mission qualified wingmen (inexperienced or experienced) is considered. Training for mission qualification and positional upgrades (flight leads, IP, etc.) are not included in this study, and are intended for future research.
6. No specific resource constraints (such as aircraft, DMT availabilities) are employed in assessing the training requirements. The SMEs have been asked to assess the tradeoffs among the training systems by (i) focusing only on combat readiness, and (ii) ignoring any resource constraints on achieving total combat readiness.
7. The SME evaluations are weighted by the number of flying hours they have put in. The influence of the evaluations of a SME in the final assessments is directly proportional to his flying experience.
8. The learning curve in reaching combat readiness in the mission elements has been taken into account by the SMEs in determining the levels of practice required in the aircraft and the DMT.
9. We recognize the fact that there can be significant variabilities among the pilots in a squadron in terms of their coginitive/psychomotor abilities, aptitude for combat and other flight combat characteristics. We expect these variabilities to be smaller among the experienced pilots than the inexperienced pilots. Further, within a squadron of about 20 pilots, we assume that the training programs will decrease these differences. Consequently, the practice requirements in the mission elements for combat readiness (as specified by the SMEs) are intended for a typical pilot within a squadron, who represents any pilot (experienced or inexperienced, as the case may be) on average.
10. The 45 mission elements considered in this study constitute the bulk of the training that takes place in a typical squadron. There may be mission elements that are not considered here, and either (i) they do not occur frequently, or (ii) if they do, they may be addressed in a future study.
11. All training sorties (on the aircraft or the DMT) are conducted as 4-ship. Accordingly, the SMEs have been asked to treat the training in each mission element as part of 4-ship sorties in responding to the effectiveness/tradeoff questions. Again, the assumption here is that the bulk of the training in a typical squadron is conducted as 4-ship sorties.
12. The bulk of the training events in a typical squadron are captured by the 4-ship sorties involving the 45 mission elements. Deviations from this model, such as red flags (which normally occur once in 2 years) are not considered mainstream training events, and hence are not included in this analysis. However, the differences will even out over a period of training time.

13. The importance of a mission element to combat readiness will depend on where and how a squadron operates. For example, squadrons in Korea and Bosnia could emphasize totally different sets of mission elements in their total training. This emphasis would conform to the Directed Operational Capability (DOC) defined for specific squadrons/wings. However, the differences will even out over a period of training time.
14. The training in mission elements is usually *bundled* into training sorties. A mission element could be practiced as part of *many* different 4-ship training events, and a 4-ship training event could involve *many* mission elements. Hence, the relationships between the mission elements and training events are *many-to-many*.
15. Based on the above assumption, we also assume that the set of practice requirements on the mission elements for combat readiness can be bundled in to a set of 4-ship sortie requirements. Note that the way the training events are designed is dependent on several factors: the instructors and students involved, their existing proficiency levels, resource availability and the commander's prerogatives. Consequently, there will be a tremendous variability among the tasks accomplished among 4-ship events in a squadron. However, we assume that these differences will even out over a period of time, leading to average levels of bundling mission elements into training events.
16. The number of times the mission elements are practiced in the aircraft and DMT will be distributed according to the proportions indicated by the SME data.
17. If the total number of sorties required for combat readiness (as specified by the SMEs) are not available (either in the aircraft or DMT), then whatever is available will be used, and the sorties will be distributed among the mission elements along the lines of the proportionality assumption above.

Training Effectiveness Models

A set of four models addresses the analysis of the training effectiveness of DMT systems as shown in Figure 1. We present the salient features of these models in the following discussion.

Transfer of Training Estimation Model

This model estimates the transfer of training from aircraft to DMT for each mission element. The input data for this model is derived from the SME estimates of training effectiveness (questionnaires 2, 3 and 4) and flight tradeoff data (questionnaires 5 and 6). Consider a mission element k. Without loss of generality, we use the following generalized notations in describing the transfer of training model:

EFAC(k) = Training effectiveness of the aircraft in mission element k
AC(k) = # of aircraft sorties needed for mission element k if no DMT is available.
D_AC(k) = # of aircraft sorties needed for mission element k if a DMT is also used
D_D(k) = # of DMT sorties needed for mission element k

In this notation, we have suppressed (1) the types of DMT and (2) types of training (inexperienced/experienced) for simplicity. Specific DMT and trainee types can be incorporated by appropriately specifying them in the model. We model the transfer of training using two dimensions: # of aircraft sorties and # of DMT sorties. We have two points on this transfer curve from the SME data as follows: (0, AC(k)) and (D_D(k), D_AC(k)). We denote the point (0, AC(k)) as the case where *no DMT is used*, and the point (D_D(k), D_AC(k)) as *the limiting case of DMT use as specified by the SMEs*. We assume the commonly used exponential transfer function. The exponential function has been very well studied in the literature, and has been in wide use in the training area. The transfer function in this case is modeled as $y = Ae^{-Bx}+C$, where x and y denote the # of DMT and aircraft sorties, respectively, and A, B and C are the transfer function constants. Using the two points along this curve available from the SME data and the transfer effectiveness of aircraft (EFAC(k)) determined from the SMEs earlier, we determine A, B and C as follows: A_k = {EFAC(k)}{AC(k)}, C_k = {1-EFAC(k)}{AC(k)}.

Now, plugging in the other SME point {x = D_D(k), y = D_AC(k)}on the transfer curve, we get B_k as: B_k = -{1/D_D(k)}{ln[{1/EFAC(k)}{(D_AC(k)/AC(k)) +EFAC(k)-1}]}. For the sake of simplicity, we will denote the transfer curve for mission element k as: $\mathbf{y}_k = A_k e^{-B_k \mathbf{x}_k} + C_k$.

Composite Transfer of Training Estimation Model

We now turn our attention to the determination of an *overall transfer curve*: from total number of aircraft sorties to total number of DMT sorties, putting all the missions together. Clearly, this is a very complex issue, as (1) many mission elements could be performed in a mission sortie, and (2) a mission element could be needed in many missions. However, from the point of view of *estimation*, we assume that the number of sorties indicated by the SMEs in each category represents the approximate proportion of the time a pilot is required to spend in each mission element during training for combat ready preparation. Consequently, we deal with the normalized percentage values of the sorties requirements in the following analysis.

Consider a two dimensional plot of normalized total aircraft sorties time versus normalized total DMT time. We approximate sorties data for time, as the analysis is considered for a long run period such as a year. Consider any training system configuration with x(k) and y(k) sorties used for mission element k on the DMT and aircraft, respectively. These two parameters are the same as those defined in the transfer curve estimation above. Let TY denote the ratio of the total time actually spent in aircraft training when DMT is used to the total time when no DMT is used. Similarly, let TX denote the ratio of the total time actually spent in DMT training when DMT is used to the total time when DMT is used in the limiting case as specified by the SMEs. Using this, we define TY and TX as follows:

$$TY = \Sigma_{\kappa=1,45}\ y(k)/\Sigma_{\kappa=1,45} AC(k)$$
$$TX = \Sigma_{\kappa=1,45} x(k)/\Sigma_{\kappa=1,45} D\_D(k)$$

When TX = 0, the value of TY = 1. This corresponds to the case where no DMT is used. Similarly, when TX = 1, TY = $\Sigma_{\kappa=1,45}$ D_AC(k)/$\Sigma_{\kappa=1,45}$ AC(k). This corresponds to the limiting case of DMT use as specified by the SMEs. Hence, TX and TY range between 0 and 1 in this normalized plot.

For any value of TX between 0 and 1, we can determine the corresponding total aircraft time required (TY) from the individual transfer functions developed in the above analysis. However, we can get into a serious combinatorial problem leading to inconsistencies in estimating the total times when they are *assembled* from individual mission element transfer functions. Hence, we use the following procedure to systematically capture the tradeoffs.

First, starting from (TX=0, TY=1), consider transfers from aircraft to DMT in steps of P%. For instance, the first point on this curve is aggregated from a decrease in aircraft time in **all** the mission elements by P% of the difference between the maximum and minimum aircraft practice requirements specified by the SMEs {AC(k)-D_AC(k)}. Computing TX and TY values at each P% reduction as far as possible, all the points thus generated are joined with a smooth curve. We call this transfer curve as a ***P% step reduction curve***, as this stepwise reduction is universally applied to all the mission elements.

Training Load Estimation Model

This model estimates lower bounds on the number of pilots that can be trained using the existing aircraft and DMT resources over a period of time, say a year. Using a *mission element bundling* concept, we derive a sensitivity analysis on the estimated sorties requirements. This analysis is developed as follows.

Let N_AC and N_D denote the number of aircraft and DMT sorties available in a year for training. To begin with, we make the following assumptions:

1. All aircraft sorties are flown as 4-ship, in order to establish a common basis for our comparative analysis.
2. The number of times the mission elements are performed in the aircraft and DMT will be distributed according to the proportions indicated by the SME data.
3. If the total number of sorties required for combat readiness (as specified by the SMEs) are not available (either in the aircraft or DMT), then whatever is available will be used, and the sorties will be distributed among the missions along the proportionality assumption above.
4. The set of sortie requirements on the mission elements can be *bundled* into a set of sortie requirements over broad combat missions.

Now, based on assumptions 3 and 4, we introduce two parameters as follows:

- An **aircraft sortie reduction factor δ_a,** which ranges between 0 and 1, indicating the level to which the required total number of aircraft sorties for a given training load that can be accomplished with the available number of aircraft sorties.
- A **DMT sortie reduction factor δ_s,** which ranges between 0 and 1, indicating the level to which the required total number of DMT sorties for a given training load that can be accomplished with the available number of DMT sorties.
- A **mission element bundling factor γ,** which ranges between 0 and 1, indicating the proportion of the total number of mission element rehearsals that can be *bundled* into mission sorties. For example, if 1000 mission element rehearsals in total are required for combat readiness, and if these can be organized into 800 mission sorties (by fitting many mission elements into a mission sortie), then the bundling factor $\gamma = 0.8$.

Using the above, we can now determine the minimum number of pilots that can be trained for a given training system configuration as follows. Let NTY = $TY\{\Sigma_{\kappa=1,45} AC(k)\}$ denote the actual number of aircraft sorties required in a training system configuration. Similarly, let NTX = $TX\{\Sigma_{\kappa=1,45} D\_D(k)\}$ denote the actual number of DMT sorties required. Therefore, we have:

$MIN\_PILOTS\_AC = N\_AC/\{NTY*\delta_a*\gamma\}$
$MIN\_PILOTS\_D = N\_D/\{NTX*\delta_s*\gamma\}$

MIN_PILOTS_AC and MIN_PILOTS_D denote the minimum number of pilots that can be trained with the available aircraft and DMT resources respectively, for given levels of the sortie reduction and mission bundling factors. Also, if NTY< N_AC, then we can simply set $\delta_a = 1$. Similarly, if NTX< N_D, then we can simply set $\delta_s = 1$. These cases represent situations where the available sorties exceed the training requirements. We need the reduction factors only when these resources are not adequately available.

Level of Training Estimation Model

This analysis is the converse of the capacity estimation model. In this case, we fix the available resources (such as aircraft and DMT) and estimate the level of practice in the mission elements that can be accomplished if we need to train a given set of pilots in the inexperienced and experienced categories. The data inputs to this model are as follows.

- Mission level transfer functions and the composite transfer function
- NPILOTS : Number of pilots to be trained in a year
- NUM_AC : Number of aircraft available
- AC_SORT: Number of available sorties/aircraft
- NUM_D : Number of DMTs available
- D_SORT: Number of available sorties/DMT
- γ : Mission bundling factor (between 0 and 1), determined from training program
- n : the number of P% reductions in aircraft time to be employed in selecting an aircraft/DMT training system configuration.

The decision parameters in this model are derived as follows:

$$\delta_a = \{NUM\_AC\}\{AC\_SORT\}/[\{NPILOTS\}\{TY(nP\%)\}\{\Sigma_{\kappa=1,45} AC(k)\}\{\gamma\}$$
$$\delta_s = \{NUM\_D\{D\_SORT\}/[\{NPILOTS\}\{TX(nP\%)\}\{\Sigma_{\kappa=1,45} D\_D(k)\}\{\gamma\}$$

where δ_a and δ_s are parameters that measure the extent to which the required level of training can be fulfilled under the conditions specified in the user specified parametric settings.

In this analysis, the following parametric sensitivity characteristics are important:

1. As n increases (greater use of DMT and less use of aircraft):
   - TY(nP%) decreases (proportion of aircraft sorties)
   - TX(nP%) increases (proportion of DMT sorties)

- Consequently, δ_a increases (the level to which the required aircraft sorties can be fulfilled with the available aircraft sorties)
- Hence, δ_s decreases (the level to which the required DMT sorties can be fulfilled with the available DMT sorties)

2. As γ increases (greater bundling leading to fewer sorties to accomplish all training)
    - Both δ_a and δ_s decrease. This indicates that the better we are able to bundle the mission element rehearsals into missions, the greater will be the level to which we can satisfy the sortie requirements for combat readiness, within the available resources.
3. As NUM_AC and/or AC_SORT increase:
    - δ_a increases. This is an expected result. By increasing the resource levels, we can better satisfy the training requirements.
4. As NUM_D and/or D_SORT increase:
    - δ_s increases. This is an expected result. By increasing the resource levels, we can better satisfy the training requirements. This result is the same as in the case of the aircraft above.
5. As NPILOTS increases:
    - Both δ_a and δ_s decrease. This indicates that greater the training load, the smaller the degrees to which we can train each pilot on both the aircraft and DMT, given the resource restrictions.

Cost Models

The costs associated with DMT systems are modeled in terms of recurring and nonrecurring acquisition costs, and direct and indirect operational costs over a time horizon. The nonrecurring acquisition costs include the physical facilities such as training center and database development center. The recurring acquisition costs include simulator hardware and software, IOS, brief/debrief facilities, visual systems, network systems, DMT control station, DMT threat system, DMT data logger system and other software support. These broad components are detailed into specific items in the spreadsheet model. The direct costs include instructional costs and the administration of the training center and database center. The indirect costs pertain to the overheads on training and management. The costs associated with each configuration of DMT systems have been compiled in the spreadsheet. The decision support component of the spreadsheet enables a user to specify the desired levels of practice in aircraft and DMT sorties, training loads, aircraft and DMT resources available and the configuration of the training program in terms of aircraft and DMT sorties to be used. The spreadsheet model estimates the annual prorated costs by taking into account the extensions to aircraft lives due to the reduction in aircraft sorties due to the introduction of DMT in the training environment. The net cash flows over a 15 year period are determined from this analysis, and a net present value of them is calculated at an user specified interest rate. The analyses show a significant positive net present value of the cash flows over this period, which substantially justifies the investments in DMT systems.

RESULTS

Figure 2 presents a bar chart of the composite transfer of training curve using aircraft and 4-ship DMT for inexperienced F-16 pilot training derived from the Roadrunner'98 SME evaluations. The AC and 4S flights represent TY and TX values at each point of this curve. Similar results have been obtained for experienced pilot training as well.

The composite curve is plotted by considering only those mission elements that are trainable in both the aircraft and DMT. Therefore, by introducing DMT in a training program, it is possible to attain higher levels of combat readiness than those possible with the aircraft only since several tasks are trainable on DMT but not with the aircraft. As these curves indicate, the level of combat readiness that can be accomplished through 100% aircraft training can be equivalently achieved by replacing up to a maximum of 23% of the aircraft sorties with full DMT training. The intermediate points represent different levels of this substitution yielding the same degree of combat readiness. These assessments are very significant, since the SMEs had first hand experience with DMT prior to its evaluation. These results are very encouraging and strongly support the training potential of DMT systems. Using the composite transfer curves, we illustrate the capacity estimation process with the decision support system by means of a specific case analysis shown in Table 1. This case clearly shows the excess aircraft training capacity generated by DMT for the same level mission preparedness. By changing the parametric settings, a sensitivity analysis can be performed on the estimated training capacities. Similarly, the training level estimation model works by fixing the required training capacities in terms of pilot loads, and calculating the possible levels of training under a given set of resource limitations. Table 2 presents the format of the final cost-efffectiveness analysis generated by the decision support system. Again, by changing the parametic settings, sensitivity analyses on the overall cost-effectiveness structures can be performed.

REFERENCES

Braby, R., Charles, J., Sylla, S., Ramesh, R., Willis, R., Hunter, D., "Instructor Considerations in the Design of Optimal Training Devices", U. Army Research Institute Contract No. N61339-86-D-0009-0003, 1988.

Moor, W.C. and Andrews, D.H., "Benefit-Cost Model for the Evaluation of Simulator Based Multiship Training Alternatives", Armstrong laboratory, Williams AFB, AL-TP-1992-0023, 1992.

Aircraft Parameters:	
Number of aircraft available	30
Number of working days/year	300
Aircraft availability	0.9
Number of sorties/day/aircraft	2
Number of aircraft sorties/year	16200
DMT Parameters:	
Number of 4-ship DMT available	1
DMT availability	0.9
Number of sorties/day/ship	5
Number of DMT sorties/year	5400
Training Control Parameters:	
Mission Bundling Factor	0.6
Sortie reduction factor	0.4
Sortie distribution (Inexp/Exp) Pilots Ratio	0.5
Training Capacity Estimates:	
No DMT used:	
Number of Inexp. Pilots Trainable :	**12**
Number of Exp. Pilots Trainable :	**17**
Aircraft & DMT used:	
Number of Inexp. Pilots Trainable on A/C:	**16**
Number of Inexp. Pilots Trainable on DMT:	**12**
Number of Exp. Pilots Trainable on A/C :	**23**
Number of Exp. Pilots trainable on DMT :	**17**

Table 1. Training Capacity Estimation: An Illustration

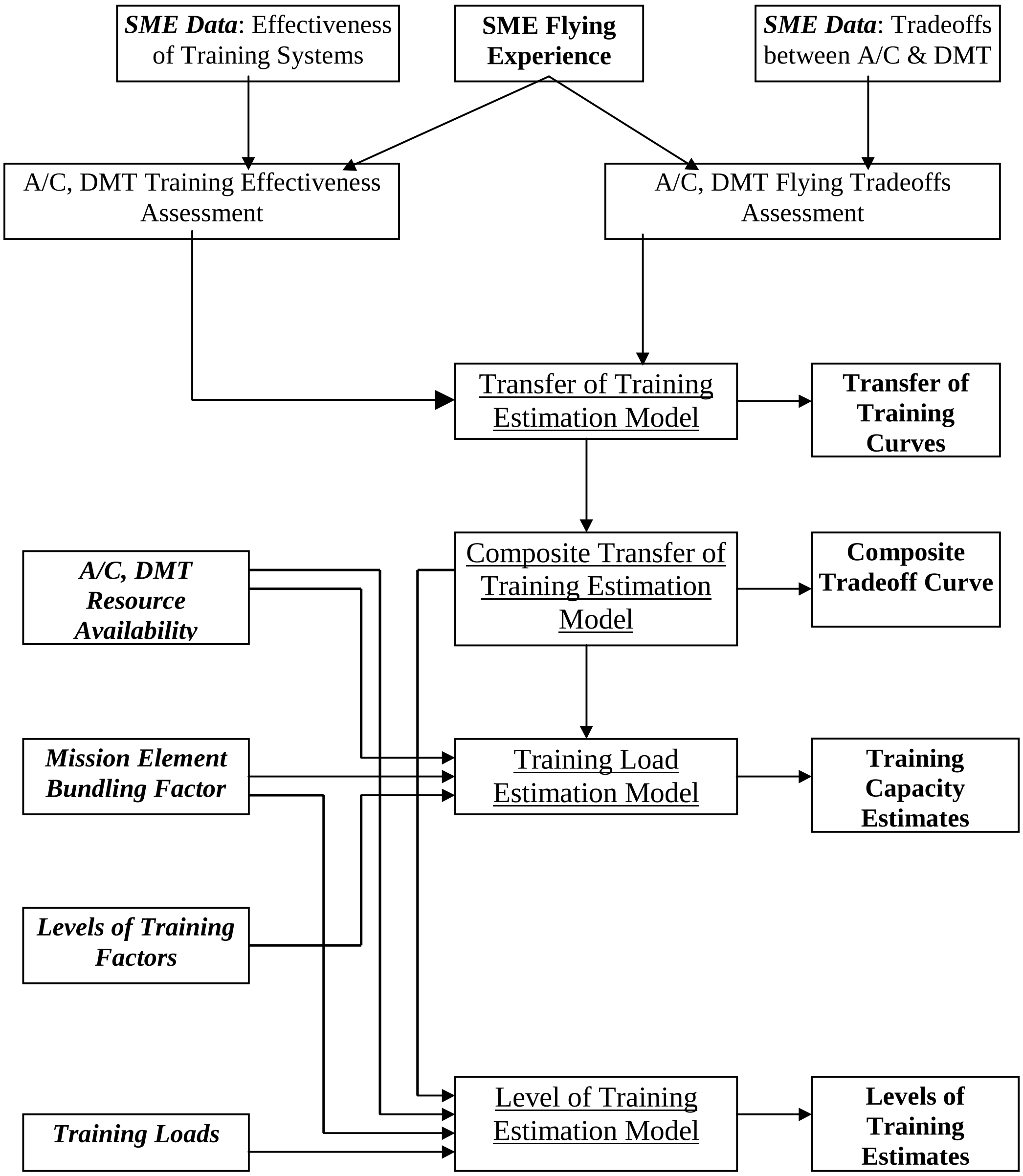

Figure 1. TRAINING EFFECTIVENESS AND A/C-DMT TRADEOFF MODELING FRAMEWORK

USER INPUT DATA: Aircraft Parameters (see table 1) DMT Parameters (see table 1) Design Life of an Aircraft Cost of an Aircraft Inexp./Exp. Pilots loads DMT Costs: - Acquisition, Direct, Indirect
ANALYSES OF SAVINGS: No. of sorties reduced/aircraft/year Life Extension for each aircraft Cost savings/year due to aircraft sortie reduction Cumulative cost savings over aircraft lifetime Cash flows over a chosen number of years Net Present values

Table 2. Overall Analysis Framework

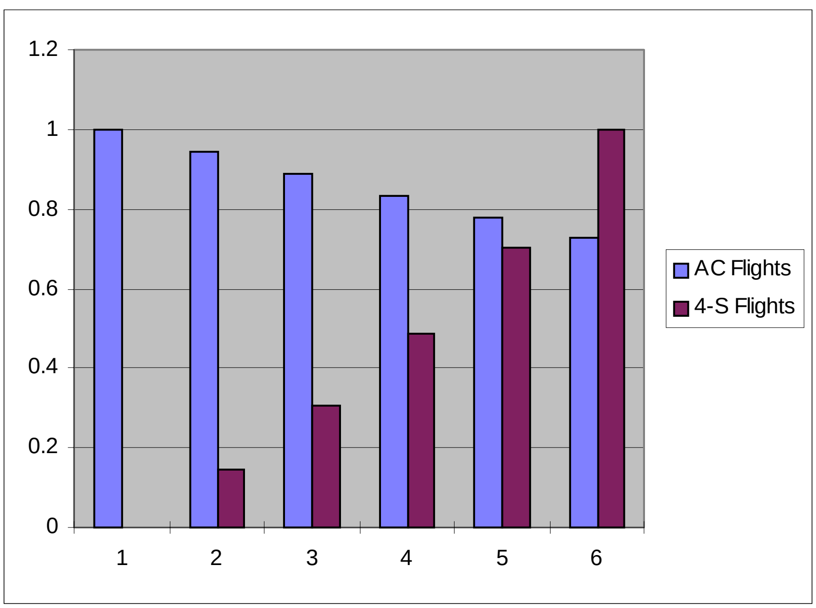

Figure 2. Composite Transfer Curve: Inexperienced Pilot Training