MISSION ANALYSIS: THE MISSING LINK IN OPERATIONAL TRAINING SYSTEM DESIGN

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ABSTRACT

Because tactical missions are becoming increasingly complex, designing instructional systems to competently address complex mission based training needs is emerging as a significant problem. The need, for instance, to conduct a comprehensive, formal analysis of mission related training requirements as a prerequisite to actual system design is self-evident; yet, as indicated in a recent GAO Report (GAO / FPCD-83-4) this is rarely accomplished. Furthermore, in this and similar treatments on the subject (Olson, 1982; Smith, 1982; Beagles, 1982) a clear imperative emerges to formalize the process and conduct a professional examination of user needs first, then provide training systems that - and this is important - analytically correlate to these explicite user needs. Responding to this critique, a methodology, presented in this concept paper, has been developed and represents a structured, systematic approach for the formal analysis, definition, and prioritization of mission based training requirements, providing in the process an operationally focused analytical framework for the design and development of operational training systems that will satisfy significant user needs. Briefly, this methodology: 1) Structures the mission and defines and exercises significant threat impacted scenarios; 2) establishes boundary conditions, if necessary, to provide specific focus for the indepth analysis to follow; 3) specifies operator tasks germane to the application; 4) defines task characteristics where task loading and task complexity are examined, quantified and combined to form a task difficulty rating; 5) then combining task difficulty with mission importance (a collateral analysis that quantifies relative importance of mission segments), critical mission area statements are developed along with a fully supportable, prioritizated set of mission tasks and concomitant training requirements.

INTRODUCTION

Because of recent advancements in flight simulation and instrumented range technologies, the capability to go well beyond procedural training into the more complex domain of mission training is now possible. These developments represent exciting opportunities, since comprehensive, systematic "system supported" training in such critical mission areas as energy management, situational awareness, offensive / defensive tactics and threat neutralization, to name a few, are now entirely within the realm of possibility.

Background and Discussion

Capitalizing on current technological state-of-the-art, training systems are now being designed to specifically address complex "mission" oriented training. In fact, systems such as the TACTS / ACMI (a sophisticated instrumented range for Air-to-Air and Air-to-Ground tactical training) that is capable of tracking a large number of High Activity Aircraft, as well as Advanced Flight Simulators, that are capable of addressing Higher Order, Multi Aircraft, Air Combat Training, are currently being built. Unfortunately, many of these very systems are exhibiting significant shortcomings that are (or will) seriously diminish their instructional value (Smith, 1982(1), Olson, 1982(2), Charles, 1983(3)).

Problem Statement

We are, it appears, dealing with an interesting, sobering paradox; technical advances have enabled us to develop sophisticated training systems for a wide range of uses and yet the ultimate user of these systems remain unsatisfied and largely incapable of extracting significant levels of instruction from these devices. It is becoming increasingly apparent that while some of the reasons for this dissatisfaction are technical in nature, the majority, falling well outside the area of "insufficiently defined Mission and Training Requirements." For example:

1. The latest state-of-the-art instrumented range (TACTS / ACMI) is being designed without a formal mission based analysis of debriefing display requirements resulting in random, unstructured, display formats substantially lacking mission focus. The ability, therefore, of this

training system to deliver significant levels of mission training (especially coordinated strike training) is presently in jeopardy.

2. Recently installed Full Mission Flight Simulators do not provide realistic threat training, have limited battle problem training capabilities, and do not adequately address Post Mission debrief needs. The instructional value of many of these devices is further diminished by an Instructor Operator Station (IOS) that is at once unnecessarily complex and incapable of displaying a whole range of critical instructor information (Charles, 1983(3)).

To us users, the foregoing profoundly suggests that our concepts for operational training system design are in need of a major overhaul. Clearly, rapid technical advancements have not been met with corresponding efforts to specifically and comprehensively define explicit user requirements and analytically correlate these needs to system concepts and characteristics. Thus the fundamental problem appears as follows:

Advanced Tactical Training Systems are not being designed from a mission perspective and therefore cannot adequately address many important mission areas largely because a mission requirements definition study was never performed and thus never integrated into the System Specification Document.

The problem is further compounded by the fact that "Mission Analysis and Correlation Concepts" are not widely understood and formal treatments, of these subjects has, up to now, been insufficient; thus the reason for this paper.

STRUCTURED APPROACH FOR THE ANALYSIS OF MISSION AND THE CORRELATION OF MISSION REQUIREMENTS WITH SYSTEM CONCEPTS

The major goal of conducting a Mission / System Correlation Analysis is to (1) define, as precisely as possible, the Mission Requirements (including critical Mission Areas) and (2) correlate these needs into System

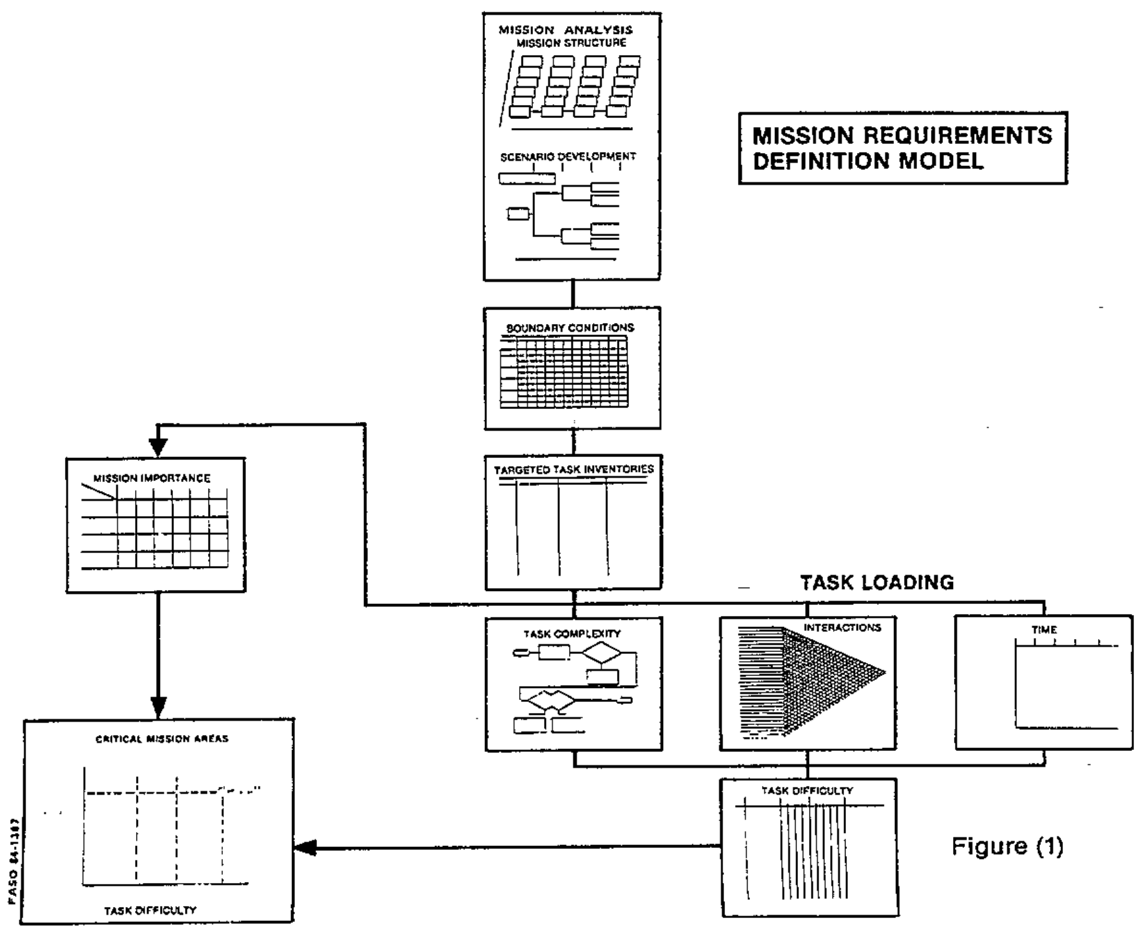

Figure (1)

Design Concepts. Design teams (including Fleet Project Teams) clearly need to be provided with the necessary data and methodologies to formulate formal system concept definitions (often referred to as Military Characteristics) that specifically address important mission considerations. In order to accomplish this important task, moreover, a disciplined, structured, approach is needed to deal with such areas as (1) structuring the mission and defining and exercising threat impacted scenarios, (2) establishing boundary conditions, as necessary, for project focus, (3) defining operator task characteristics including task loading and task complexity, (4) developing a fully supportable, prioritized set of mission based task requirment statements and (5) providing correlation justifications for system design concepts. Accordingly, the methodology that follows represents a structured, systematic approach to guide the analyst in this crucial effort.

Mission Requirements Definition

Figure 1 graphically displays the outline of the Mission Analysis Model. A more detailed treatment of each element follows in subsequent paragraphs and figures. Although initially appearing complex, the model has been designed to be straightforward and not requiring complex analytical techniques. The major thrust of the model is to define operator task characteristics and task performance difficulties - high task loading, high degree of complexity, critically - to provide sufficient operational requirements data to correlate with system design characteristics and specifications.

Mission Structure

The first step of the process is to structure the mission element under study (i.e., air-to-air ACM, air-to-ground, etc.) in a systematic sequence as shown in Figure 2. The specification of significant mission objectives and broad task requirements should be developed at this time. Detailing and structuring the mission, similiar to this method, provides for a firm foundation and helps organize subsequent analytical steps.

Scenario Analysis ★ ★

To provide focus for important mission considerations such as (1) threat imposed constraints; (2) survival probabilities; (3) tactical and resource employment, etc., a Scenario Analysis is considered necessary and is exemplified in Figure 3. This scenario example relates to a threat system and utilizes an "event tree" format. Note that the posture is defensive. Also for each node a probability of occurrence is estimated, however, for the upper branch, where each event will always occur, a probability of one is assumed. In this simplified example (which should be backed up by textual

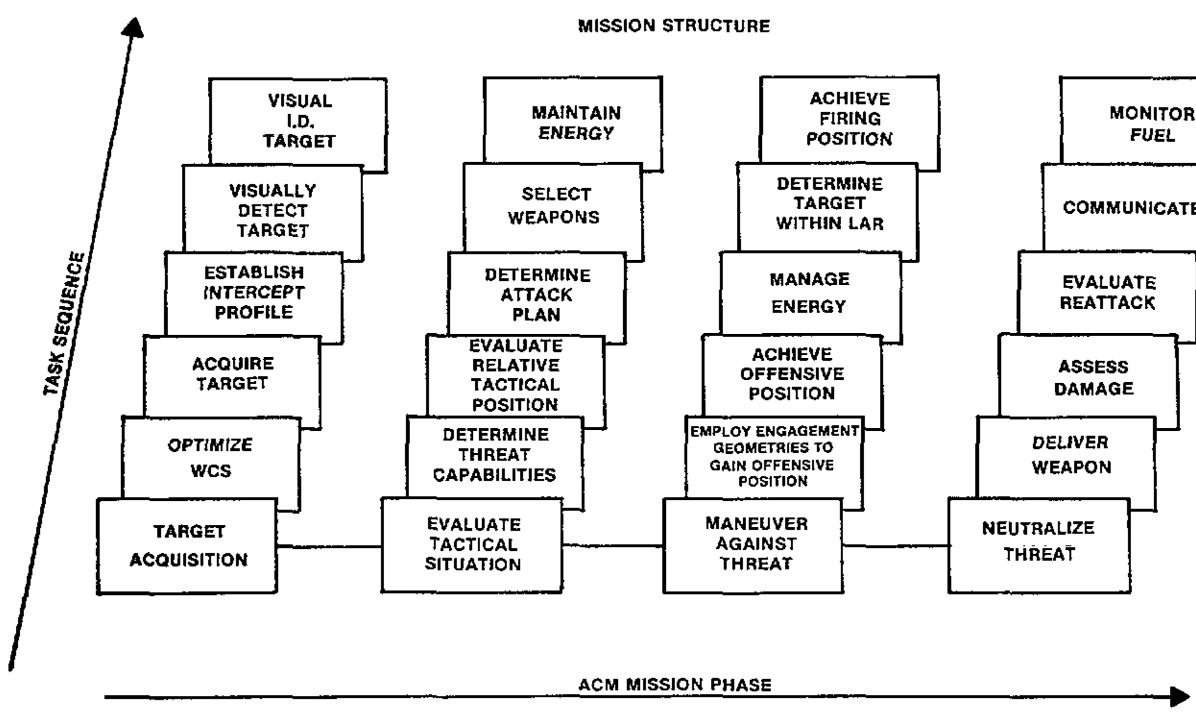

Figure (2)

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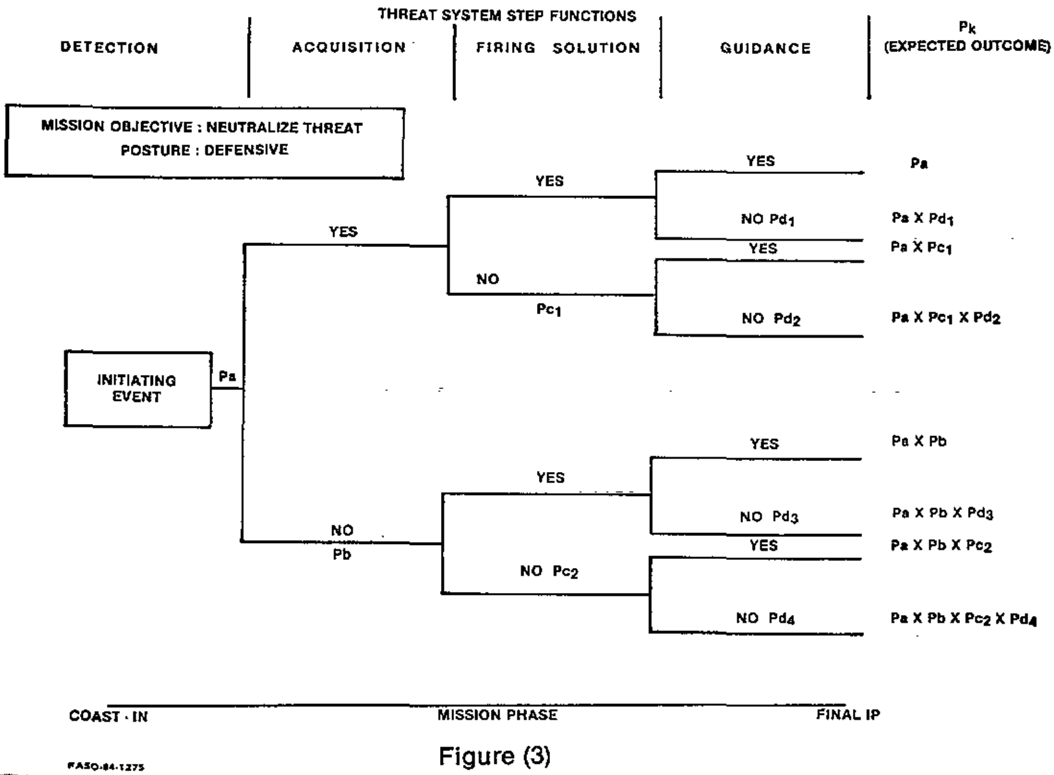

Figure (3)

descriptions) the events represent a step function for a general radar controlled surface-to-air threat system expected to be encountered. This step function represents all necessary sequences that must be achieved in order to achieve a kill.

Establish Boundary Conditions

The establishment of boundary conditions, if necessary, should occur next, and is designed to provide focus for a specific application. A convienent means to conduct this analysis is to create a matrix as shown in Figure 4. Note the ACM portion of the fighter mission, selected for this example, is decomposed to a level sufficient for analysis and is arranged in a systematic sequence similar to step one. For each mission objective, candidate methods of training are identified by X-ing in appropriate boxes. In this way mission requirements can provide focus for broad training delivery concepts.

Targeted Task Inventories

Development of targeted task inventories consistent with the previous boundary conditions is the next logical step and is performed to further decompose the mission to a level sufficient for analysis. The level of decomposition will necessarily depend, however, on the type of application of the analysis. Figure 5 shows and example of a conventionally developed task inventory taken to the third level. Note that all tasks are mission based. After the mission tasks are defined, further analysis of their characteristics should follow and is explained in the following Section.

★ ★ Author's Note: The event tree format for scenario analysis was selected because it can provide fairly hard data for critical mission task determinations. It is limited in some cases by lack of known probabilities, in which case best guess estimates must be made, and the fact that this technique is binary - an event either occurs or it doesn't - which does not always reflect reality.

ESTABLISH BOUNDARY CONDITIONS: MISSION / FUNCTION MATRIX

	CANDIDATE TRAINING METHODS \ MISSION OBJECTIVES (ACM)	TARGET ACQUISITION			EVALUATE TACTICAL SITUATION			MANEUVER AGAINST THREAT				NEUTRALIZE THREAT	
		ESTABLISH EFFECTIVE RADAR PROCEDURES	ACQUIRE TARGET	VISUAL I.D. TGT	DETERMINE THREAT CAPABILITIES	EVALUATE RELATIVE TACTICAL POSITION	DETERMINE ATTACK PLAN	EMPLOY APPROPRIATE ENGAGEMENT GEOMETRY MODELS	ACHIEVE OFFENSIVE POSITION	MAINTAIN ENERGY	RECOGNIZE LAR	DELIVER WEAPON	EVALUATE REATTACK
ACFT OPS	CONVENTIONAL ACFT OPERATIONS	x	x	x			x	x	x	x	x	x	x
	RANGE SUPPORTED ACFT OPERATIONS	x	x	x			x	x	x	x	x	x	x
SIMULATION	FULL MISSION SIMULATION	x	x	x			x	x	x	x	x	x	x
	OFT	x	x								x	x	
	CPT						x						
	PTT				x	x	x		x		x	x	
GROUND TRAINING	CAI	x			x			x		x	x		
	TAPE/SLIDE/VIDEO	x			x					x			
	PROGRAMMED TEXT	x			x								
	PLATFORM	x			x								

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Figure (4)

SAMPLE TASK INVENTORY

TASK ID	TASK OBJECTIVE	TASK REQUIREMENT	COMMENTS
2.2.4.3	ACHIEVE OFFENSIVE POSITION		
2.2.4.3.1		MAINTAIN SIGHT AND TACTICAL SITUATION AWARENESS	
2.2.4.3.2		PERFORM MUTUAL SUPPORT	• DIRECTIVE COMMENTARY
2.2.4.3.3		DETERMINE MANEUVERS REQUIRED	
2.2.4.3.4		ESTIMATE TIME REQUIRED TO ACHIEVE OFFENSIVE POSITION	• THREAT VS OWN A / C ENERGY STATES • ENGAGEMENT GEOMETRY / RELATIVE POSITIONS
2.2.4.3.5		ESTIMATE TIME REMAINING IN NEUTRAL POSITION	
2.2.4.3.6		COMMUNICATE TACTICAL INFORMATION	• DIRECTIVE COMMENTARY

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Figure (5)

Determine Mission-Task Characteristics

An operational task exhibits characteristics that relate it to three possible variables (see Figure 6): (1) cognitive complexity, (2) task interactions and (3) time compression. Task interactions and time compression involve considerations of task loading, while cognitive complexity involve considerations of decisions. In the following paragraphs, techniques and methods to analyze these three variables are presented.

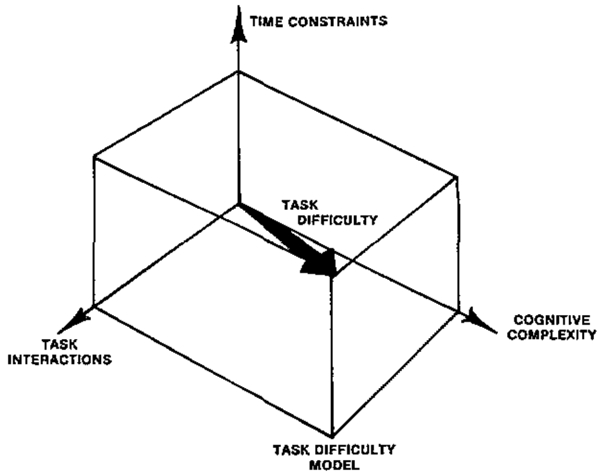

Figure (6)

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Task Loading

In the determination of the relative difficulty of a particular task, task loading must be evaluated. In determining task loading, the time available to perform this task and the number of other tasks that interact must first be examined. This examination is aided by utilizing a task interaction matrix and time line analysis, shown in Figures 7 and 8. For example, a give task is examined for: (1) the time available to perform it, and (2) the need to interact with other task areas during its performance. Scaling takes place after these two areas are examined utilizing the following notions:

1. Individual tasks performed under relaxed time conditions receives a value of 1-4.

2. Multiple tasks performed under relaxed time conditions receives a value of 5-7.

3. Multiple tasks performed under increased time compression receives a value of 8-10.

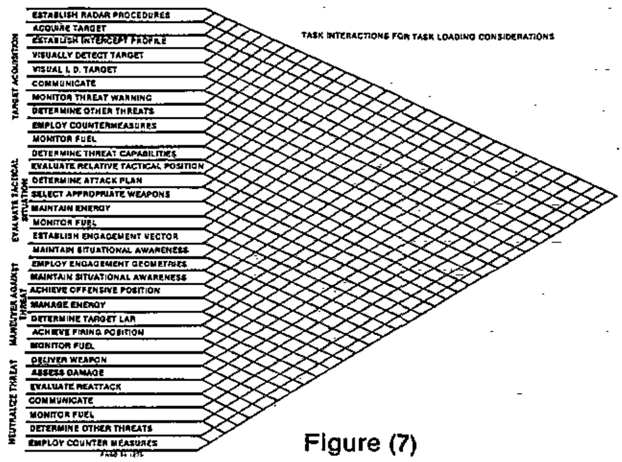

Figure (7)

Task Loading Scaling

The following scaling notion is suggested utilizing task interaction analysis and time-line analysis.

Notion	Code	Scale
Individual tasks performed under relaxed time conditions	IRT	1-4
Multiple tasks performed under relaxed time conditions	MRT	5-7
Multiple tasks performed under increased time compression	MCT	8-10

Scaling figures for task loading are finally recorded in Figure 13 under the Task Loading Column. Determining the cognitive complexity of the task follows in the next Section.

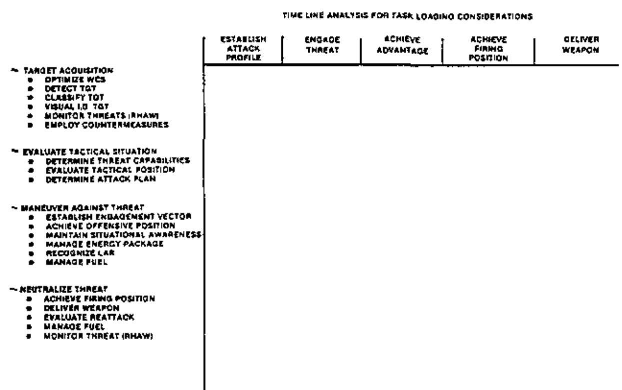

Figure (8)

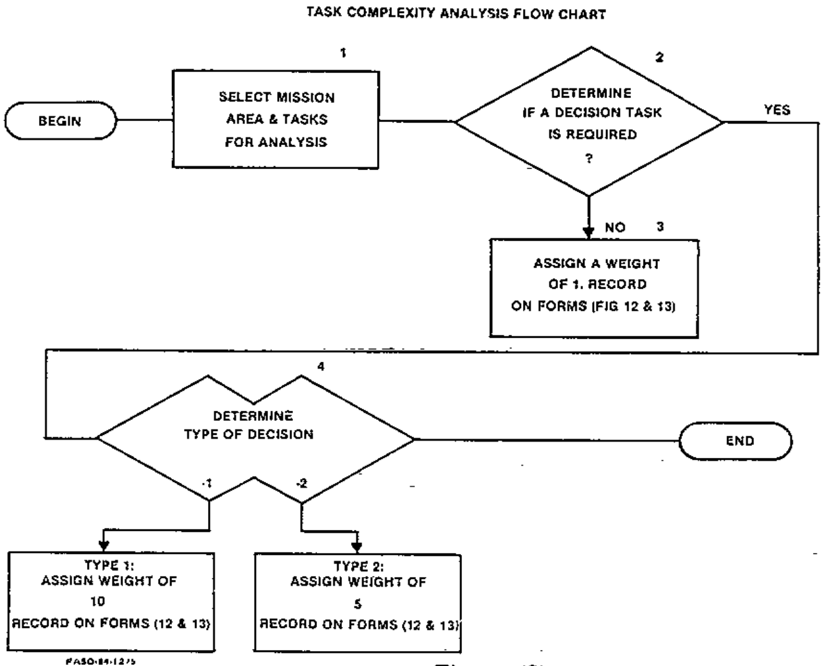

Figure (9)

Cognitive Complexity: Analyzing the Decision Task

The methodology to analyze the existence and characteristics of a decision task is presented in Figure 9. After a set of tasks are selected for analysis (Block 1) a determination is made of the need for a decision. If the task does not require a decision, it is assigned a weight of 1 (Block 3). If, however, a decision is required the analysis passes to Block 4 where a determination of the type of decision is made. Note that a Type 1 decision is assigned a weight of 10 and a Type 2 decision is assigned a weight of 5. (Figure 12 can be used for this effort) The weights are then recorded on Figure 13 under the Decision type column. A more detailed treatment of the analysis and classification of a decision is perhaps needed and is explained in the following two paragraphs.

Decision Task Processing

The processing of an operational decision task obeys the scheme presented in Figure 10. As an input to this scheme, tasks are presented to an operator (most likely in the form of a problem) that either have decision or non-decision components, and a filter mechanism, displayed as Block 1 provides this discrimination. If, for instance, a decision is not required, the task passes to Block 2 where it is assumed a defined set of procedures is available for processing. If, on the other hand, a decision is required, the task passes to Block 3 where further classification and discrimination is accomplished. Type 1 decisions, involving considerations of problem structuring and alternative generation pass to Block 4. Type 2 decisions, involving considerations of alternative generation pass to Block 5. Once this processing scheme is understood, classification is possible and is explained in the following Section.

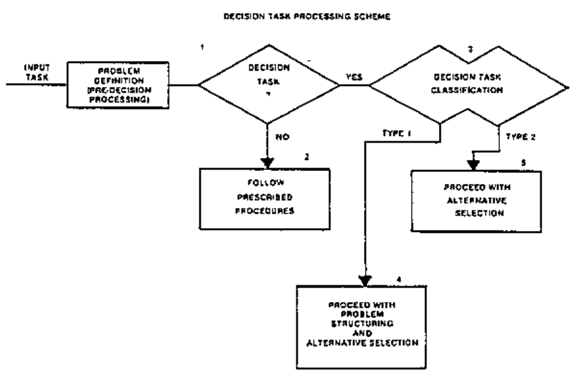

Figure (10)

Analysis and Classification of a Decision Task

A decision task involves cognitive processing of both the (1) formulation of alternatives, and (2) the action selection of alternatives, and since there is a considerable distinction between the two tasks, a plausible classification scheme exits (Saleh, et. al. 1978(4)). A decision task, then is defined as follows:

a. The objective a decision task is to select an alternative from a specified set of alternatives.

b. The selection process may require the structuring of the environment and the formulation of alternatives (problem structuring).

The further classification of a decision task involves considerations of the boundary that exists between problem structuring and alternative generation, and relates to the types of operator actions necessary to process the specific type of decision task. Figure 11 shows this classification scheme. Note that "problem structuring and alternative generation" (Type 1) involves (a) alternative formulation; (b) establishment of outcomes; (c) utility and probability assessment; (d) the application of appropriate decision rules (if they exist); and (e) finally the selection of the best alternative. A Type 2 decision is one where the alternatives are known and only steps (c) through (e) are necessary.

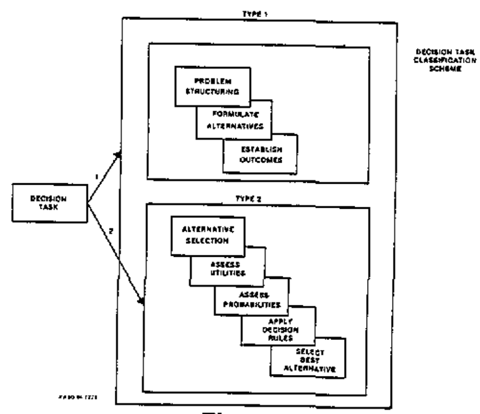

Figure (11)

DECISION - TASK ANALYSIS

TASK NO.	TASK DESCRIPTION	DECISION	TYPE	ALTERNATIVE	TASK SUPPORT
2.5	Maintain energy				
2.6	Monitor fuel				
2.7	Establish engagement vector				
2.8	Maintain Situational Awareness				
3.0	Maneuver against threat				
3.1	Employ engagement geometries				
3.2	Maintain Situational Awareness				
3.3	Achieve offensive position				
3.4	Manage energy				
3.5	Determine Target LAR				
3.6	Achieve firing position				
3.7	Monitor fuel				
4.0	Neutralize threat				
4.1	Deliver Weapon				
4.2	Assess Damage				
4.3	Evaluate Reattack				
4.4	Communicate				
4.5	Monitor fuel				
4.6	Determine other threat systems				
4.7	Employ Countermeasures				

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Figure (12)

Task Difficulty

The weighted value of both task complexity and task loading are now combined to determine "task difficulty". The task(s) or task module(s) that require complex processing and must be processed under increased time compression are of course given the highest value.

Utilizing the results from the decision task analysis and task loading analysis sections, a form is utilized (Figure 13) depicting these tasks along with a specified loading category and its respective weight; and the decision type and its respective weight.

The weights for loading and decision (complexity) are then multiplied to arrive at a task difficulty rating. Task difficulty = task loading x cognitive complexity where task loading = f (interactions x time compression). For example, the task "detemine attack plan" was assigned a task loading weight of 10, a decision (cognitive complexity) weight of 10. Multiplied together, this task moddule assumes a difficulty rating of 100. This is then plotted along the X axis of Figure 15.

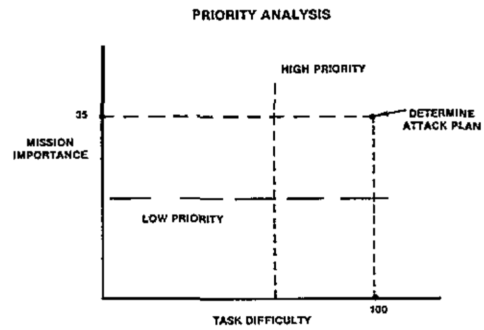

Figure (15)

Mission Importance Rating

In order to ensure that complex or difficult tasks, previously analyzed, are embedded within a mission area that directly contributes to tactical success, a mission importance rating scheme has been developed. Figure 14 depicts the rating form. Briefly, mission objectives (or phases) are related to the five generic tactical objectives and given relative values. The values are then combined to arrive at an overall relative value for each mission objective. (Far right column) As indicated in Figure 1, this is a collateral analysis and is intended to provide correlation for the determination of critical mission areas to follow.

TASK DIFFICULTY ANALYSIS

TASK NO.	TASK DESCRIPTION	TASK LOADING				DECISION TYPE					TASK DIFFICULTY RATING
		IRT	MRT	MCT	WT	DEC	0	1	2	WT	
1.0	Target Acquisition										
1.1	*Establish effective radar* procedures										
1.2	Acquire Target										
1.3	Establish intercept profile										
1.4	Visually Detect Target										
1.5	Visual I.D. Target										
1.6	Communicate										
1.7	Monitor Threat Warning										
1.8	Determine presence of other threat system										
1.9	Employ Countermeasures										
1.10	Monitor Fuel										
1.11	Determine Continuation										
2.0	Evaluate TACTICAL situation										
2.1	Determine threat capabilities										
2.2	Evaluate relative TACTICAL POSITION										
2.3	Determine attack plan			X	10				X	10	100
	Determine Continuation criteria										
2.4	Select weapons										

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Figure (13)

MISSION IMPORTANCE RATING ANALYSIS

ACM MISSION OBJECTIVES \ GENERAL TACTICAL OBJECTIVES	TIMELY ACQUISITION	ACHIEVE ADVANTAGE	AVOID THREAT(S)	SUCCEED IN CONFLICT	CONSERVE RESOURCES	WEIGHT
TARGET ACQUISITION	10	0	8	5	2	25
EVALUATE TACTICAL SITUATION	0	10	10	10	5	35
MANEUVER AGAINST THREAT	0	10	10	10	10	40
NEUTRALIZE THREAT	0	5	8	10	10	33

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Figure (14)

Determination of Critical Mission Areas

When the mission importance values and task difficulty values are combined (plotted) as shown in Figure 15, a determination of critical mission areas is clearly possible. For example, we saw that the task module "determine attack plan" was assigned a task difficulty weight of 100. This task module is embedded within the Mission Objective "Evaluate tactical situation" which is hypothetically assigned a value of 35. Plotting these two values as shown in Figure 15, we can then identify this mission task's relative importance and critically. Therefore, mission phase / task module plots which fall in the upper right quadrant represent the highest priority areas where design efforts should be focused and where maximum mission effectiveness will most likely be achieved. Conversely, plots which fall in the lower left quadrant represent the lowest priority rating suggesting not more than a modest investment in resources is needed.

ORGANIZING AND RANK-ORDERING

Critical Mission Areas and / or Mission Tasks can be rank ordered according to four broad categories. Notice that in Figure 15 the prioritization graph is organized into four cells. With this in mind, these four cells can be given the following definitions:

1. Upper Right Cell: Highly critical
2. Upper Left Cell: Critical
3. Lower Right Cell: Difficult but not as critical
4. Lower Left Cell: Least critical

Once mission areas / task modules are rank ordered into these four broad categories, the following generalized notion can be established:

Highly critical tasks: Major and substantial efforts needed to ensure all appropriate training systems provide the necessary levels of instruction to ensure Mission success. As a subset to this category, the full spectrum of training programs (i.e., curiculum, simulators, instrumented ranges) must be designed as an integral system to specifically address these tasks in a building block format.

Critical: Enhanced instructional methods needed such as:

1. Improved media

2. Improved performance feedback methods

3. Improved visual simulations

4. Improved range displays

Difficult but not as critical: Need to ensure rehearsal opportunities are provided in sufficient depth and duration; with an additional requirement to provide for part-task training as a separate and / or integral part of the OFT / WST simulator suite.

Least critical: Conventional instructional methods considered appropriate.

NOTE: A more precise correlation between task characteristics and importance and system design concepts and specifications is considered necessary. Formal work in this and related areas is strongly encouraged.

SUMMARY AND CONCLUSION

Providing analytically supported correlations between mission requirements and system design concepts and characteristics is the critical task at hand; and is thus the reason for this concept paper.

In the treatment of this subject an attempt has been made to provide a systematic, analytical framework whereby "Mission Logic" is organized and quanitified in such a way so as to support the justification of operational system design objectives and ultimately design specifications.

Driving design features from an operational perspective, moveover, will require, 1) the availability of the necessary analytical tools, coupled with, 2) sufficient motivation to utilize such an approach. The foregoing concepts are considered to represent at least some of the needed tools. The motivation for their use, however, will require a change of mind-set from an exclusive technical focus to one that embraces significant operational (non-technical) considerations on an equal footing.

This will not be easy, but nevertheless, its importance cannot be overstated. Training and operational systems must clearly be designed in a way that will contribute, directly and significantly to mission success. Otherwise, we will be designing and building systems that, while perhaps highly sophisticated technically, will inevitably exhibit diminished operational value.

ABOUT THE AUTHOR

CDR Kevin M. Smith is presently on special assignment to Commander, Fighter Airborne Early Warning Wing, U. S. Pacific Fleet as the Special Project Officer for training development. He is currently working on various projects to improve the instructional performance and capabilities of the Tactical Air Combat Training System (TACTS) and the 2F112 simulators. Graduating from flight training in 1965, CDR Smith spent 14 years on active duty in various assignments flying the F-8 Crusader, accumulating over 2400 hours in type. His major fleet assignments included Officer-in-Charge, Light Photographic Squadron Sixty Three Detachment One (VFP-63 DET 1) deployed in USS CONSTELLATION, as well as numerous department head positions. As a reserve officer, CDR Smith is also the Commanding Officer of the Naval Reserve Fighter Wing 185 which trains as an augment unit for COMFITAEWWINGPAC. When not performing his Naval Reserve duties, CDR Smith in civilian life is employed as an airline pilot, currently flying the B727. Holding a degree in Electronic Engineering, CDR Smith is also a graduate of the Naval Air Training Command, Tactical Fighter and Tactical Reconnaissance Training, and holds and Airline Transport Pilot Rating.

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Graduating from the Naval Air Training Command in 1970, CDR Hull has made numerous deployments in Fighter Squadrons VF-161, VF-24, VF-1, accumulating over 3,000 hrs in carrier fighter aircraft (F-14, F-4) including 250 combat missions. CDR Hull's shore assignments included Project Officer for the F-14A and AIM-9L OPEVALS while a member of VX-4.

CDR Hull is authorized to wear five air medals, and having been recently selected for command is the prospective Executive Officer for VF-211.

Mr. Russell H. Irvine is an educational specialist with the Analysis and Design Branch, Aviation / Electrical Warfare Programs, Naval Training Equipment Center, Orlando, FL. He is currently involved in the determination of training requirements and system concept definitions for various weapons systems including the F-14D and A-6E Update Programs. Mr. Irvine has been actively involved in instructional system design and aircrew training programs for a number of years with numerous aerospace corporations and airlines, working specifically on mission and training requirements analysis, media analysis, curriculum development and system functional analysis.

Mr. Irvine is a graduate of the Naval Air Training Command, Navy Fighter Training, Navy Fighter Weapons School (TOPGUN) and remains active as a Naval Reserve Officer at NAS Jacksonville, FL.

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