These relationships will be general ones, resting on common properties of man and machine which we can then use in specifying and designing our training simulators. I think this a more useful as well as a necessary alternative to the hi-fi design approach. The t_e construct is a small but promising beginning.

I would like to end on a note by the former Secretary of Health, Education and Welfare, John Gardner, in his book "No Easy Victories."

"A...subtle exit from the grimy problems of the day is to immerse yourself so deeply in a specialized professional field that the larger community virtually ceases to exist. This is a particularly good way out because the rewards of professional specialization are very great today, so you may become rich and famous while you are ignoring the nation's problems." This is a point to which we may well give some thought in our own smaller world of simulators and trainers.

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A GENERAL PURPOSE SIMULATION SYSTEM

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The General Purpose Simulation System is an International Business Machines Application Program based upon statistical techniques, primarily queuing and probability theory. The program is written in a language similar to Fortran, The General Purpose Simulation System Processor.

The General Purpose Simulation System has been structured by Conductron-Missouri to provide a means of examining the loads placed upon an instructor in any specific training system and to make a determination of student to instructor ratios based upon the demands placed upon the instructor by the specific training system.

The program will manipulate input parameters, simulate all interactions between students and instructors, and tabulate and print out all transactions and their associated elapsed times. Any transactions between student and instructor which were delayed because of other student-instructor transactions will be listed with their associated delay time.

Once the parameters associated with a specific training program are defined and quantified, they may be incorporated into the General Purpose Simulation System program. The program will simulate the training situation, exercise the parameters and print out the desired data which describes the loading placed upon the instructor. Different instructor/student ratios may be simulated, and trade offs made based on student waiting time and instructor loading. Because it involves an iterative process, the program can be run effectively with any progression of student/instructor ratios, and by examination of the output, a decision can be made as to the most effective ratio. The program may be applied to any training system when the parameters of the system are defined sufficiently to allow the training system to be simulated.

In the simulation of any particular system, the first requirement is the isolation of the system's elements and a formulation of the rules which govern their interaction. This formulation will serve as the model of the system. Manipulation of this model provides a means of exercising a training system by simulation, without the cost in both money and time of this process by means of operational evaluation. This type of simulation is symbolic rather than a precise analog of the actual system and it can simulate, in a matter of minutes, operations which would take weeks or months for an actual system to accomplish.

The General Purpose Simulation System is comprised of four parts, dynamic, equipment, statistical and operational.

The dynamic entities are those interactions which take place between the students and the instructor. They are primarily voice communication, but also include such things as inputs to the instructor's equipment for display to the student. These dynamic entities may be thought of as transactions causing actions to occur as they move through the system.

System equipment entities are elements of specific equipment in the system which is being simulated. If, for example, the training system being simulated is an airborne navigational trainer, system equipment would consist of Tacan, Radar, bubble sextants, and other related navigation equipment. Each element of system equipment is acted upon by transactions.

Statistical entities consist of two types: queues and tables. Queues maintain a list of transactions that are delayed in the system, and keep a record of the length of the delays and the average number of transactions which are delayed. Tables employed in the General Purpose Simulation System may be used to contain any appropriate frequency distribution data that is desired, according to the particular system being simulated.

The steps which are involved in the construction of the General Purpose Simulation System are as follows:

First, an Event Analysis comprises discrete loading, which is a part of the overall instructor loading. Total instructor loading includes both the required discrete loading from the Event Analysis, and a probability loading. Probability loading is a function of unsatisfactory or unsafe student performance, or the student's request for assistance from the instructor.

It can be seen in Figure 81 that the General Purpose Simulation System serves as a means of combining the discrete loading of the detailed Event Analysis with probability loading to arrive at a total instructor loading figure. It should be noted that percentage of Total Problem Time minus the percentage of Instructor loading will equal the percentage of availability of the instructor for other necessary functions, such as monitoring displays.

The Event Analysis shown in Figure 82 is broken down into multiple columns, including, Function, the Type of task, which includes Communications, Motor, Monitor and Cognitive tasks, a description of the task and the Equipment Panels which are used, Cathode ray tubes, Problem panel, Radio Aid Panel, Digital Message Generator panel, Score Insertion, Intercom,

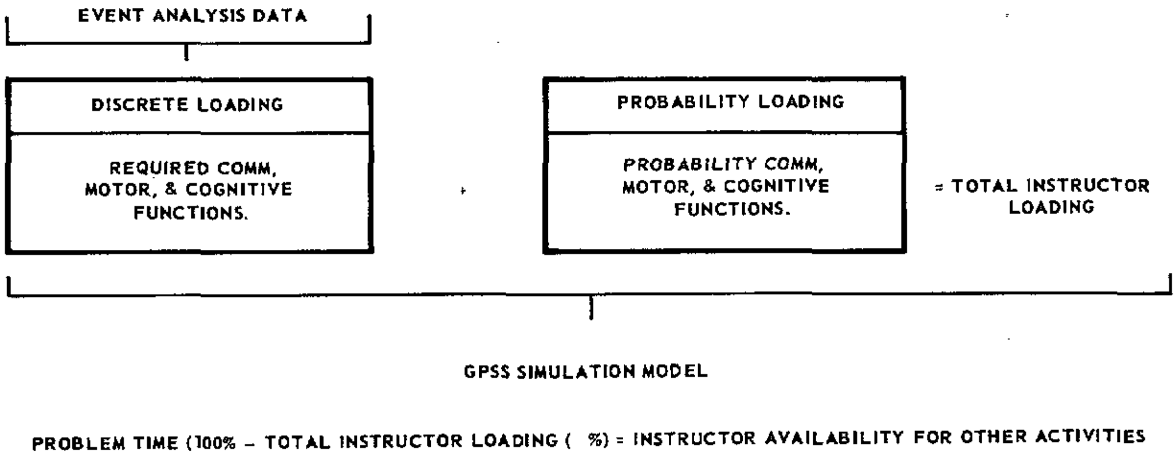

Figure 81. GPSS Simulation Model Chart

FUNCTION	INSTRUCTOR / OPERATOR: TYPE: COMP	MOTOR	MONITOR	COGNITIVE	TASK	EQUIPMENT PANELS: CRT	PROBLEM	RADIO AID	COMM: M.G.D.	COMM: S.I.	COMM: INTER	COMM: TAPED	S.C.P.: POWER	S.C.P.: TRAIN	S.C.P.: COMP	S.C.P.: PERIPH	MISC	TIME: I/O ΔT	TIME: ACCUM	TIME: P ΔT	PILOT TASK	INTERFACE EQUIPMENT: TYPE: COMPUTER	M.GEN.	RECORD	PLOTTER	REQUIREMENTS
4.0 STANDARD INSTRUMENT DEPARTURE AND VOR APPROACH DEFINITION: THIS EXERCISE WILL INTRODUCE SID'S AND VOR APPROACHES TO THE STUDENT. HE WILL PLAN AND EXECUTE AN IFR FLIGHT FROM CAIRNS AAF TO DOTHAN AIRPORT VIA EUFAULA. THE VOR APPROACH TO DOTHAN AIRPORT WILL INCLUDE A RADAR VECTOR TO THE FINAL APPROACH COURSE AFTER EXECUTING A MISSED APPROACH AT DOTHAN. ISSUE CLEARANCE TO HIS ALTERNATE (CAIRNS AAF) WHERE HE WILL EXECUTE A STANDARD VOR APPROACH PERFORMANCE OBJECTIVES: 1 STANDARD INSTRUMENT DEPARTURES 2 VOR TRACKING 3 RADIAL INTERCEPTION AT A 45° ANGLE 4. USE OF RADAR VECTOR TO FINAL APPROACH COURSE 5. USE OF ALTERNATE AIRFIELD 6. EXECUTION OF VOR APPROACH			X		1.0 MONITOR PROBLEM, DESCRIPTION, AND DEMO SELECTIONS.	X	X											0.15 (0.1) (0.05)	7.2 (1.2)	(0.2) (1.0) (5.0) (0.8) (0.2)	1.0 SELECT PROBLEM 1.1 OPTION - SELECT PROBLEM DESCRIPTION (TAPED FLIGHT PLAN) 1.2 OPTION - SELECT DEMONSTRATION. 1.3 TUNE RADIO, AND CROSS-CHECK INSTRUMENTS. 1.4 SELECT RUN	X	X	X	X	CONSTANT REQUIREMENT.
		X			1.1 PUSH RECEIVE INTERCOMM.			X			X															
		X			2.0 SCORE VOICE TRANSMISSION.			X		X								0.2 (0.15)	7.4 (1.35)	0.2 (0.15)	2.0 COMM- "CAIRNS GROUND CONTROL RC1234 EAST RAMP, READY TO TAXI INSTRUMENT FLIGHT TO DOTHAN OVER."					
		X			3.0 TAPED COMM- "RC1234 CAIRNS GROUND CONTROL, RUNWAY 6, WIND 030° DEGREES 5 ALTIMETER 30.02, TIME____. CONTACT CLEARANCE DELIVERY 370.3 FOR IFR CLEARANCE."							X						0.01	7.8 (1.65)	0.5 (0.3)	3.0 RECEIVE INSTRUCTIONS. 3.1 TUNE RADIO.					
		X			4.0 SCORE VOICE TRANSMISSION.			X		X								1.25 (.6)	9.15 (2.25)	1.25 (.6)	4.0 COMM- "CAIRNS CLEARANCE DELIVERY RC 1234. REQUEST CLEARANCE INSTRUMENT FLIGHT TO DOTHAN."					
		X			4.1 TAPED COMM- "RC1234 CAIRNS CLEARANCE DELIVERY HAVE YOUR CLEARANCE." "RC1234 CLEARED TO THE EUFAULA VOR VIA V-70 EUF. MAINTAIN 6000, CLAYTON #3 DEPARTURE. TURN LEFT AFTER TAKE OFF HEADING 360 UNTIL INTERCEPTING CAIRNS 022 RADIAL, READ BACK.							X									4.1 RECEIVE AND COPY CLEARANCE.					
		X			4.2 SCORE VOICE TRANSMISSION.					X											4.2 COMM- "READ BACK CLEARANCE FROM IFR SHORTHAND."					

Figure 82. Event Analysis

STEPS (N)	CORRESPONDING "EVENT ANALYSIS" ITEMS	PROBABILITY OF STUDENT SELECTS SELF DIAGNOSIS	STUDENT TASK			INSTRUCTOR/STUDENT TASK		
			T MAX	T MIN	PROBABILITY OF UNSAFE PERFORMANCE OR STUDENT REQUESTS ASSISTANCE	T MAX	T MIN	PROBABILITY OF UNSAFE PERFORMANCE OR STUDENT REQUESTS ASSISTANCE
1	1.0, 2.0	0.95	1.0	0.8	0.85	0.2	0.15	0.15
2	3.0, 4.0	0.05	0.5	0.3	0.15	1.25	0.6	0.45
3	5.0, 6.0	0.05	1.5	0.5	0.15	0.6	0.4	0.15
4	7.0, 8.0	0.05	1.0	0.6	0.65	0.21	0.2	0.65
5	8.1, 9.0, 10.0	0.05	19.54	15.13	0.15	0.25	0.2	0.15
6	10.1, 11.0	0.05	9.75	6.44	0.15	1.0	0.5	0.05
7	12.0, 13.0	0.05	10.5	7.07	0.15	1.0	0.75	0.05
8	14.0, 15.0	0.05	30.5	23.65	0.35	2.5	1.7	0.15
9	16.0, 17.0	0.05	12.0	9.3	0.35	3.7	3.0	0.15
10	18.0, 19.0	0.25	0.7	0.6	0.45	0.2	0.1	0.45
11	20.0, 21.0	0.25	1.5	1.25	0.65	3.0	2.0	0.65
12	22.0, 23.0	0.05	5.3	3.8	0.15	0.15	0.1	0.15
13	24.0, 25.0	0.25	8.6	6.6	0.65	0.15	0.1	0.35
14	26.0, 27.0, 28.0	0.25	4.5	3.8	0.45	0.6	0.2	0.05

Table 1. Estimated Variable Times and Probabilities
For Event Analysis Program

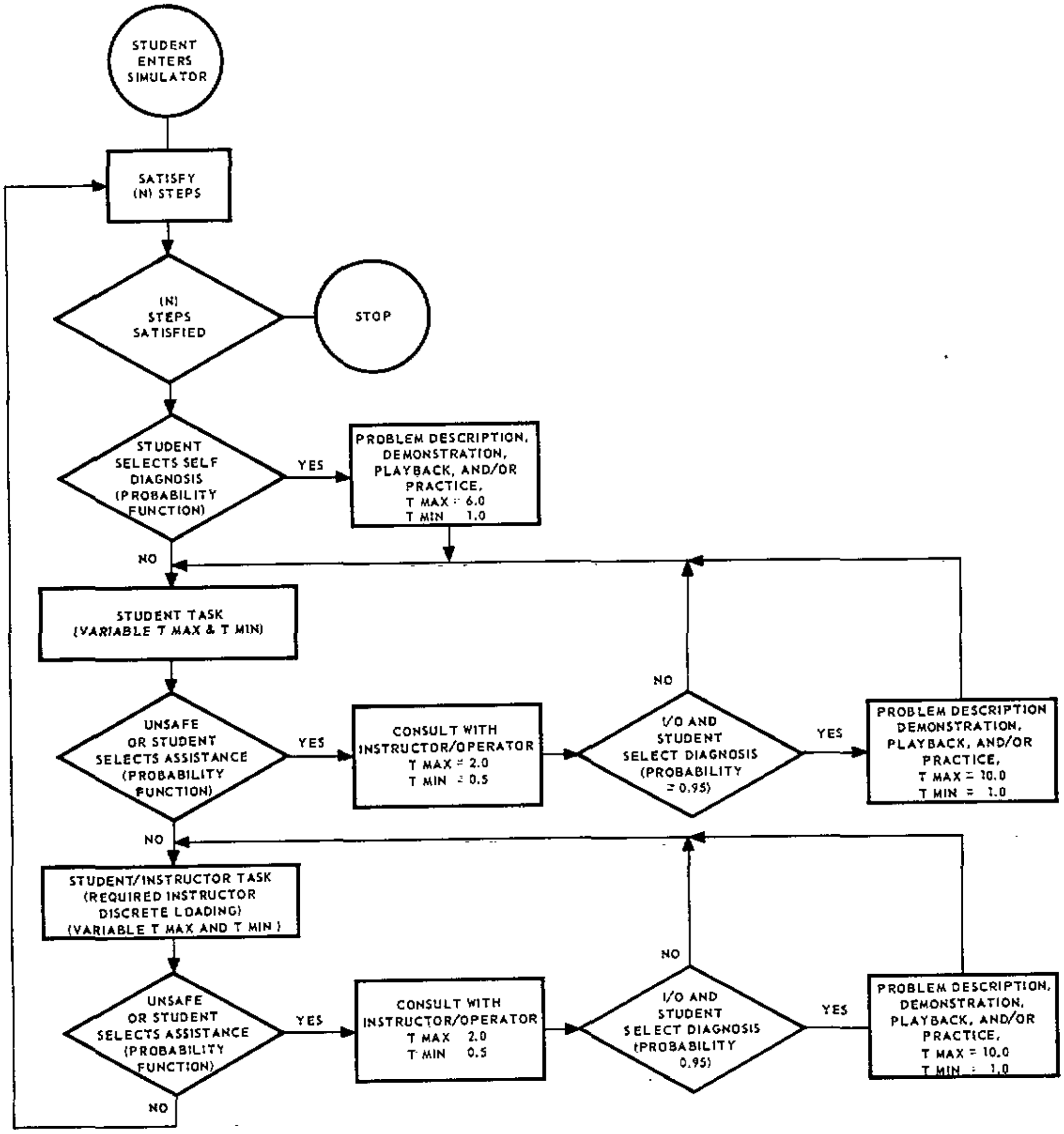

Figure 83. Steps of Event Analysis

Taped messages, Power panel, Training panel, Computer, and Peripheral Equipment associated with the Student Control Panel. "Time" column depicts instructor time, the Accumulated time, and the Student Time. Student tasks are listed. Each particular task is numbered.

Table 1 depicts the estimated variable times and probabilities associated with the event analysis. Each task within the event analysis is numbered and is associated across the rows with corresponding event analysis items. Associated with each step in the event analysis is an assigned probability that the student will select self diagnosis. The minimum and maximum times that the student will spend on each task is predicted as well as the probability that the student will perform in an unsafe manner, or that the student will request assistance from the instructor. The next columns depict the minimum and maximum times for those tasks in which the student and the instructor are interacting, and lists the probabilities of unsafe performance for the students requesting additional assistance. The times listed, as well as the probabilities of this case, are of course theoretical and have no real basis other than illustrative. The general purpose simulation system logic is shown in Figure 83. The student enters the simulator and performs the various steps of the event analysis. Upon completion of all steps the program ends, but until then, he continues through the progressive steps in the system. If the student selects self diagnosis, a problem description, a demonstration, a playback or student practice is allowed. If he does not select self diagnosis, he continues the task associated with the particular step and operates within the probability that his performance will be unsafe or that he requests instructor assistance. If either of these conditions occur, he consults with the instructor until such a time as he feels that he can complete the task by himself. If the student does request assistance from the instructor, the instructor and the student work through the task together. This cycle is repeated until all tasks have been completed individually by the student.

The General Purpose Simulation System has the capability of determining the equipment loadings, differential student skill levels and also to provide increased flexibility for examination of alternate configurations.

The General Purpose Simulation System results will differ considerably based upon the assumptions that are made and the mode of system operation. Because of this, it is reasonable to assume that the manual mode of instructor loading will present the greatest instructor loading condition.

Inspection of Table 2 shows typical instructor loading where the manual mode is being employed. In this manual mode, certain assumptions are made. They are one, that the students began the task at the same time, two, the students progress was a function of random distribution, three, after each unrecoverable situation where the logic determined that the performance of the student was unsafe, the student consulted with the instructor before continuing and, four, several students requested additional assistance during the problem segments. On the left, the instructor student ratios are presented. Associated with each ratio is the discrete instructor loading, the probability loading and the resultant available instructor's time. Associated with this table is Figure 84, which are the student delay times. The delay per time per student for the 1 to 3 ratio and the 1 to 4 instructor to student ratio, as shown in Figure 84, illustrates a poor utilization of training time and equipment, due to instructor overload. For the 1 to 2 instructor student ratio, each student may experience delays totalling 10.5 minutes during a two hour session, because the instructor would be assisting the other students.

As the student gains proficiency in the system being simulated, it follows that the automatic mode may be employed. In this mode, the computer takes over many of the instructor tasks which thereby frees the instructor from much of the overloading he would experience in the manual modes. In the automatic mode, the student would not request additional instruction as often as in the manual mode due to the utilization of automated instructional messages, performance playback, and demonstration capabilities of the system. If the system permits student self diagnosis and if it is assumed that the student's request for additional instruction would occur less often, it follows that the total instructor loading would decrease.

GPSS AVERAGE INSTRUCTOR LOADING
RESULTS FOR PROBLEM 4 - MANUAL MODE

INSTRUCTOR/ STUDENT RATIOS	DISCRETE INSTRUCTOR LOADING (%)	PROBABILITY INSTRUCTOR LOADING (%)	AVAILABLE INSTRUCTOR TIME (%)
1/1	10.4	12.7	76.9
1/2	20.8	22.9	56.3
1/3	31.2	36.2	32.6
1/4	41.6	45.3	13.1

Table 2.

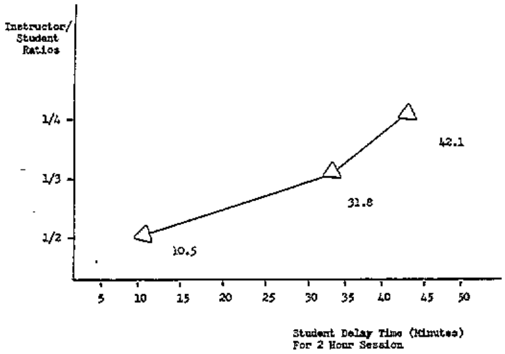

Figure 84.

Utilization of the general purpose simulation system will reveal the optimum student to instructor ratio based upon objective analysis of the program's output.

As automated instruction becomes more and more desirable, automated functions such as adaptive training, student feedback and guidance, permanent recording of results, monitoring of procedural actions, instructor feedback, automatic demonstrations and malfunction insertion reduce the instructor's burden and make it possible for increasing the number of students per instructor. Arriving at the effective student/instructor ratio has previously been accomplished by a very inexact methodology, primarily trial and error during operational evaluation of a training system.

The existance of the General Purpose Simulation System happily has made this costly procedure unnecessary and outmoded. It is now possible to simulate a training system with the General Purpose Simulation System and exercise the parameters which influence the actual system to the degree that valid and reliable results are obtained which can determine the optimum number of students that may be supervised by a single instructor.