ENGINEERING OF INSTRUCTION DELIVERY IN PERFORMANCE ARCHITECTURE

MR. RAYMOND G. FOX
IBM Corporation

ABSTRACT

Performance Architecture is the engineering discipline devoted to organization and specification of the manpower components of a man-machine system over the life cycle of the system. Design of instruction delivery is identified as a key component of this discipline. Instruction delivery is defined as the communication of those elements of information required by the individual/group to successfully operate and maintain the systems. Criteria for engineering instruction delivery in this frame of reference are suggested, and potentials for applying this technology are described. A notation system for instructional units is proposed.

PERFORMANCE ARCHITECTURE

Grayson and Biedenbach describe performance as "What someone does: the tasks, steps, or responses that produce products or outcomes."[1] In a weapon system, the systems performance is the sum of the man-machine function expressed over time, or over a certain number of units of function. This is commonly called system life cycle. The architecture for such a system should specifically accommodate the variables of human performance, in addition to hardware and software considerations of machine function.

However, modern practice still closely resembles the ideas advanced by Frederick W. Taylor, the originator of scientific management, shortly after the turn of the century. Viteles includes in his analysis of Taylor's work as a cardinal precept of "the selection of the best worker for a particular task."[2] As Bugelski points out, Taylor's approach involved selection of men to fit the job, which meant the lack of employment for the unfit. He goes on to say that, aside from the social undesirability of such a practice, "the modern human engineer argues that the job must be modified and fitted to the man.[3] Unfortunately, unless the economic advantages are clear and demonstrable, this has not turned out to be the case. Likewise, this implies that this is an after-the-fact process, rather than one considered at the time of the system's design.

With the advent of the All Volunteer Force in the military services, the positive action equal opportunity programs required for Defense contractors and Public Law 93-112 which now requires industry and government to initiate affirmative action programs for employment of the handicapped,[4] the motivation changes from one of social desirability to that of law and regulation.

In conjunction with this, there is increasing recognition within the Department of Defense that the cost of the man in the weapon system, over its life cycle, is the predominant expense item. The Ginsberg report clearly identifies issues such as the ability to handle varying skill composition, racial mix, and educational levels. Equally important, it places the manpower cost in the Department of Defense's budget at over 50 percent of all items.[5]

Thus, for reasons of cost, as well as systems performance, and force variability in education level and skill mix, it is essential to incorporate performance into the initial design considerations, and engineer overall capability in terms of cumulative interaction of men and machines. Performance Architecture is the term used to describe assembly of the necessary engineering building blocks to do this, as it relates to the performance of the individual in the system.

ENGINEERING OF INSTRUCTION DELIVERY

A principal element in the performance of the individual in the system relates to the method of instruction delivery. Instruction delivery is accomplished not only in the formal schooling process, however, but on the job and during periods of actual maintenance and operation. If reference to a manual is required in order to perform a maintenance action, receipt and comprehension of the information in the manual could be termed instruction delivery. This has two implications. The first is that technical data has commonality to maintenance and operation tasks, as well as training requirements. The second is that if this data is structured into programmed job performance formats, it can be made available on the job in automated or non-automated delivery methods.

However, the notion of engineering the task to the individual implies the individualization of the instruction delivery.

STRUCTURED LEARNING FOR INDIVIDUALIZATION OF INSTRUCTION DELIVERY

Structured learning is a term used to describe the required steps to be undertaken in the analysis of the instruction to be delivered; delivery methods, parameters of presentation, response, and measurement within which it must be achieved. It contemplates a system of presentation and response requiring *learner interaction before advancing beyond* the given frame of instruction to be presented and learned. Learner interaction is required in order to assess learner comprehension. By organizing instruction sequences into individual discrete frames, it is possible to define down to the individual frame of instruction the degree of presentation specificity required and the degree of comprehension desired. It is also possible to assign, by specific presentation frame, the degree of evaluative data needed to give qualitative learner comprehension information. In accordance with this definition of structured learning, systems techniques can be used to structure the presentation sequences, assign the evaluative requirements, determine the learner response needs, and assemble the evaluative data as a result of the learner proceeding through a given sequence of instruction. The actual process of communicating the instruction to the learner is called instruction delivery.

INSTRUCTION DELIVERY SYSTEMS DESIGN MODELS

Training, maintenance, and operation tasks are application specific. In order to approach the design of specific systems on a structured basis and recognize the variances that are application specific, design models need to be utilized which will provide transfer capability and commonality of use.

Klemmer described such a structured *approach which is hierarchical and task-*oriented.[6] It is a method for top-down identification of training/performance requirements, in connection with the tasks to be performed. This outline is susceptible to machine-driven management control systems, and when instruction delivery units have been developed, tested and validated, an audit trail can be established back to the requirement.

DEFINING INSTRUCTION UNITS

In order to accomplish the above task, it is readily perceived that a unit measure is needed within which to define the presentation/evaluation requirements for the structure.

A key element of the structure, in order to facilitate engineering analysis and delivery system design, is the composition of the unit of instruction, delineated by presentation frames, queries, branches, and supplementary presentation/response information required. This unit needs to be defined in relation to varying modes of delivery.

Atkinson describes a progress rate in terms of mainline problems which is suggestive of 50 presentations per hour as a reasonable criterion.[7] Rhode (et al) outlines an hour of instruction for a teaching machine with *branching to consist of 50 mainline presenta*tions (frames), 35 with questions. For 20 frames, an incorrect answer will trigger a 3-way branch, each with three remediation frames. For 15 frames, an incorrect answer will cause a branch with three remediation frames.[8]

Figure 1 outlines a notation for a unit of instruction which conforms to the foregoing.

It will be observed that in maintenance tasks and fault isolation routines, the function of instruction delivery, branching and feedback occurs. Figure 2 is an illustration of a sample adjustment procedure, which is a group of instruction delivery and response (or feedback) incidents relating to actions performed, and sample logic branches contingent upon the condition found. One observation is that the structure of the maintenance check procedure can be organized to correspond to the structure of the delivery unit. A second observation is that it may be feasible to organize work tasks into a structure that is uniform in hierarchy, number of presentations, response action, or branch options, and which can relate to training, operations instruction delivery and skill elements as defined in a job description.

INCORPORATING DESIGN OF INSTRUCTION DELIVERY IN PERFORMANCE ARCHITECTURE

From an engineering design point of view *in utilizing this concept, a number of poten*tials open up which may permit:

a. Ability to establish degrees of complexity in materials of maintenance/instruction

b. Ability to make a priori decisions in maintenance/operations systems design

c. Ability to establish criteria and evaluate performance for specific maintenance actions

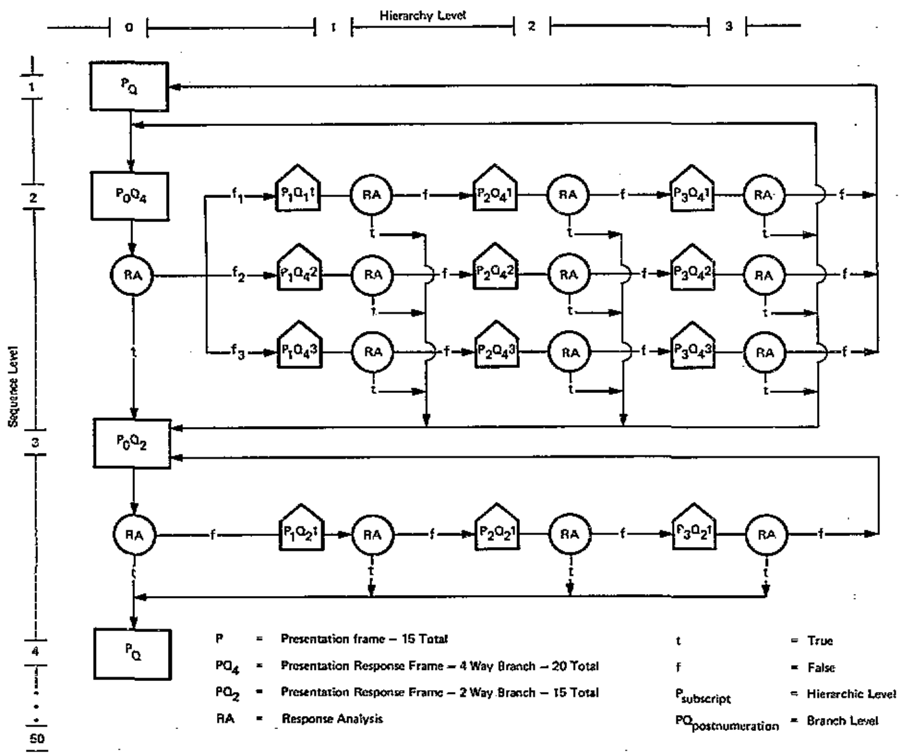

Figure 1. Sample Instruction Unit Format and Notation

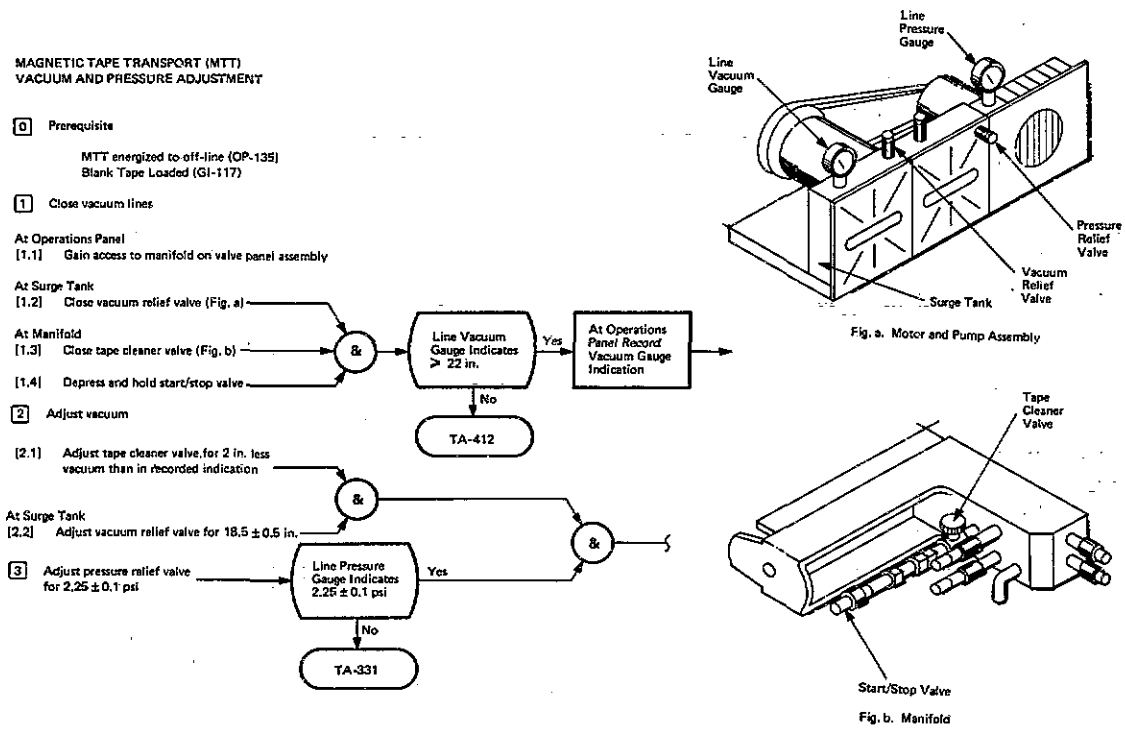

Figure 2. Sample Adjustment Procedure

d. Ability to make complexity projections and comparisons for systems of greatly differing technologies

e. Ability to explore optimum instruction/performance algorithms for varying individuals and groups

f. Ability to establish baseline data for performance and instruction measurement, management, and modeling

g. Ability to specify delivery systems engineering to the optimum delivery unit design.

Accomplishment of the foregoing will directly bear on our ability to achieve the objective Rouse stated: "When designing any system that will employ a human operator or decision maker (DM), it is necessary to predict how well the human can perform the task in question."[9]

POTENTIAL FOR PERFORMANCE MANAGEMENT AS A FUNCTION OF ENGINEERING INSTRUCTION DELIVERY

By being able to describe, deliver, and measure a unit of instruction on a uniform basis, it is possible to identify the unit of instruction with the required performance. It is also possible to link the unit of instruction with parameters of time for accomplishment of the unit of instruction.

From a management viewpoint, this permits analysis of units of instruction delivered by specific individual, occupational specialty, or academic program. This implies the inherent ability to objectively assign competency standards and performance criteria suitable for measurement, assignment, promotion, and evaluation. Managers using this technology can follow individual performance, project completion dates, predict failure rates, and assess levels of competence in terms of defined instructional requirements.

It is also possible to link the unit of instruction to basic skill definitions inherent in many professions. Thus, it is possible not only to manage instruction, but to model in very definable units in order to establish predictable outcomes.

By defining the unit of instruction as the discrete module or frame, and relating this to the instructional objective, task proficiency knowledge or occupational specialty skills inventories can be maintained. Changes can be predicted based on an empirical data base constructed of the individual performances on instruction modules. It should be possible to extrapolate from this data requirements for retraining to meet new force skill mixes, in the case of the military services. Cost and time can be related to training of representative populations in specific skills. Tradeoffs can be made, and alternatives can be examined using this learning system's technology concept.

REFERENCES

1. L.P. Grayson and J.M. Biedenbach, Editors, "Individualized Instruction in Engineering *Education*" *American Society for* Engineering Education, 1974, p. 137.

2. Morris S. Vitales, "Industrial Psychology" W.W. Norton and Co., 1932, p. 10.

3. B.R. Bugelski, "The Psychology of Learning Applied to Teaching," Bobbs and Merrill, 1964, pp. 7-8.

4. Public Law 93-112, 93rd Congress HR 8070, September 26, 1973, pp. 35-39.

5. Eli Ginsberg, Chairman, Defense Science Board Task Force Report "Manpower Research and Management in Large Organizations," June 1971. Available from Department of Defense, Office of Director of Defense Research and Engineering, Washington, D.C., 20301.

6. Andrew Klemmer, "Training - An Engineering Process," Proceedings Annual Training *Equipment Center/Industry Conference*, November 1973, pp. 544-552.

7. Richard G. Atkinson, "Computerized Instruction and the Learning Process," American Psychological Association Meeting, September 1967, American Psychologist, April 1968. Volume 23 No. 4, p. 235.

8. W.E. Rhode and P.J. Esseff, C.J. Posin, F.B. Quirk, R. Schulik, "Analysis and Approach to the Development of the Advanced Multi-media Instructional System," Vol. II, p. 649 AFHRL-TR-69-30 available from NTIS, Springfield, Va., 22151.

9. William B. Rouse, "A Model of the Human in a Cognitive Prediction Task," IEEE Transactions on Systems, Man and Cybernetics, Vol SMC-3, September 1973, p. 473.

ABOUT THE AUTHOR

MR. RAYMOND G. FOX is Educational Systems Development Manager of IBM Federal Systems Division. He received his Bachelor's degree in Industrial Engineering at Rensselaer Polytechnic Institute. Mr. Fox joined IBM in 1946 and has held a number of marketing and technical management positions until 1965, when he was appointed to his present position. He is primarily concerned with development of the new and advanced programs for the Federal Government in the areas of instruction delivery systems, education management and evaluation systems, and applied learning systems technology. Mr. Fox serves as Chairman of the Training group of the National Security Industrial Association and was formerly Chairman of the NSIA "Training Methods and Technology" panel. In addition, Mr. Fox served as a technical advisor to the Virginia Advisory Legislative Council on the application of technology for the training of the handicapped, and in 1973 was appointed Consultant for Technology to the Commonwealth of Virginia Council for the Deaf. In 1974 he was appointed chairman of the Council's Committee for Industrial Relations. Mr. Fox is a member of the National Defense Executive Reserve, Office of Preparedness. He is Vice President and a trustee of the Fauquier Educational Foundation which operates the Highland School. He serves as a member of the Secretary of the Navy's Advisory Board on Education and Training, and in 1972 was elected President of the Society for Applied Learning Technology. For his work in guiding the Industry/Government program on "Application of Computers to Training", Mr. Fox was selected as the 1971 recipient of the Edward M. Greer Award, which is given annually by NSIA in recognition of outstanding contributions to the Department of Defense.