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A SYSTEMS APPROACH TO AEROSPACE EDUCATION AND TRAINING

by

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All of us are aware that revolutionary processes are at work in education and training. For the first time in modern history the traditional methods of classroom teaching and instruction are being profoundly challenged. This challenge emanates primarily from the work of experimental psychologists and learning theorists, from computer technology and electronic data processing, and from the creation of automated instructional hardware and software.

During the 1950's the initial union of these technologies began to produce experimental and first generation models of auto-instructional devices — indeed, modest by today's standards, but nevertheless sufficient to indicate the trend of the future.

Over the past few years the electronics, publishing, and office machine industries have seriously entered the automated and programmed educational products arena. The impact of the new educational technology is now influencing the entire spectrum of instructional methodology.[1,2] Traditional methods are being called to account and must justify their perpetuation by objective measures of efficiency and cost effectiveness, or give way to instructional methods which do.

From the current perspective it is quite clear that the challenge posed by these new and dynamic teaching devices is neither temporary nor transient. They pose a just claim and deserve a full response by all who are engaged in the business of preparing people to work in the aerospace age. Outside of the formal school system, perhaps no other group stands to profit from these educational advancements as industry, in general, and the aerospace community, in particular.[3,4,5]

In order to understand the character of the new approach to education and training provided by these developments, certain concepts are essential. These concepts are largely derived from the disciplines which have contributed to the creation of the programmed instruction.[6]

First, the product of the program is performance, or in the jargon of the trade, terminal behavior. The terminal behavior to be elicited by the instruction is operationally defined, rigorously quantified, and objectively verifiable. The customer does not, therefore, buy _training_. He buys _performance_. The student or trainee must demonstrate objectively his acquisition of new knowledge or new skills in conformity with specified performance criteria.[7]

Simply stated, this means that a school board must agree that a given level of academic standing encompasses an inventory of behaviors which the student aspiring to that standing must possess. Management must specify precisely in operational language the skills which the trainee must acquire in order to perform the job for which the training is offered. Educational and training standards can no longer be written in terms of descriptive adjectives, learning "outcomes," or course hours.

Second, instruction is programmed in such a manner and in such a sequence as to present the learner with an optimal route or pathway to the attainment of the terminal behavior. The program may be linear (fixed sequence),[8] intrinsic (variable sequence determined by the response of the learner),[9] or combinations thereof. The individual increments of instruction are referred to as "frames."[10]

Third, the program by which terminal performance is assured is viewed and compiled as an instructional system. Teaching media are employed within the system as they contribute most efficiently to the learning process. Each component is selected, structured, sequenced, and validated as an integral part of the total system.[11] The magnitude of the system is defined by the scope of the instructional objective, the population to be instructed, and the amount of time and money available. An instructional system may be an entire high school or college curriculum, or it may be a training program for bank tellers.

Fourth, programmed instruction requires the active participation of the student in the learning process. His response to an increment of instruction generates an immediate knowledge of the correctness or the error of the response and advances the material to the next instructional element. Since student response is an integral feature of the system, progress is paced to the individual student as he demonstrates his ability to profit from the instruction.

These features characterize the systems approach to education and training regardless of the scope or magnitude of the system and differentiate programmed instruction from other teaching methods.[12,13,14]

Traditional or classical courses of instruction depend primarily upon the lecture method, the classroom, and a formal course length. It is assumed that, as information is dispensed, its passive assimulation by the student is somehow assured. Course length is presumed to be positively correlated with progress. Individual differences between and among students are obscured by the concept of the average or even the typical performer. Occasionally, a brief sample of paper and pencil behavior is taken, and from this sample an extrapolation to other forms of behavior is made. None of these presumptions nor assumptions are technically satisfying, nor are they analytically defensible.

By way of contrast, programmed instructional systems permit the customer to buy a guaranteed level of performance for a specified number of students in a specified time at a specified cost. Each step in the formulation of the system is analytically valid and straightforward. All variables are quantifiable and statistically manipulable. The system in operation generates a step by step measure of

student progress toward the attainment of the terminal behavior criterion - the performance for which the instructional system was created.

Lest claims for the systems approach to education and training be regarded as extreme and theoretical, one must freely admit that programs as extensive as those to be proposed in this paper do not presently exist. The real bottleneck is the cost and difficulty of developing programmed instructional materials as extensive as are required by this approach. Subject matter content, properly sequenced and experimentally validated, takes both time and money. The inventory of software available under this concept is constantly growing and becoming commercially available, especially in those areas of greatest demand and suitability.[15]

The present state of the art does provide the analytical framework, the methodology, the data handling capability, and the sophisticated instructional hardware implied by the system. The near time period can provide the chronological frame in which complete and extensive instructional systems may come into being.

Outside the areas of formal school systems and industrial training, perhaps no greater potential exists for the application of the new instructional methodology than that provided by the training requirements of complex aerospace systems. Despite occasional and widely heralded references to programmed instructional techniques by the Department of Defense and by NASA, technical training in support of new weapon and space systems is largely conducted in the conventional manner. Training concepts still embody technical courses built around the classroom, the lecture, fragmented subject matter, and course length measured in hours. In compliance with contractual specifications the aerospace contractor provides the initial training, and the customer seeks to replicate the training in his own facilities. So called "training aids" are fabricated and produced as adjuncts to the classroom process. Textual and reference materials are written and printed as collateral to the classroom exercise - all in the faith that each contributes to the learning process in some unknown quantity.

The fundamental question is not whether by these means an aerospace system can be operated and maintained, but rather are these means the most efficient and cost effective avenues to assure appropriate human performance. When the performance criterion is defined and specified, the literature on instructional methods clearly affirms the superiority of programmed instructional technology both in quantity (training time) and quality (training efficiency).

From the contractor point of view the undesirability of the present procedure is quite apparent. Except for the initial training on a new weapon or space system neither the quantity nor quality of supportive training is under the purview of the contractor. Through the medium of customer services or technical representation he seeks to influence customer training but does not directly supervise nor accredit the training provided. In consequence,

he is denied the monitorship of the critical aspects of customer performance as well as the benefits of feedback relating to either deficiencies in training or in product design.

With the growing emphasis upon contractual maintainability and reliability guarantees and the monetary penalties associated therewith, the means for some form of quality control over customer training is becoming necessary. The human error problem as associated with systems reliability cannot be ignored. The magnitude of this error has been estimated from 38 to 50 per cent for missile launch systems.[16,17] In terms of maintainability the reduction of a single maintenance man-hour per flight hour accounts for a cost reduction of between 15 to 19 million dollars over the ten-year life cycle of two current aircraft systems.[18] Costs directly attributable to the human performance variable must be subjected to the same rigorous analysis and control as any other contributing variable.

It is, therefore, proposed that the contractor be assigned responsibility for the creation not only of the initial training on his system, but also for the development of the complete instructional system as a constituent of the weapon system itself. Such a training system could be developed concurrently with the prime system and conform to the skill requirements generated by it. The data resources of the prime system thereby become directly available to the educational technologists to be employed in the instructional process as appropriate.

Since both the hardware and software elements of the instructional system are included in the contractual training package, the contractor must eventually determine what portion or portions of the system are within his capability to produce. The state of the art in instructional hardware is such that the contractor will in all likelihood find it mandatory to rely on the equipment manufacturers already in the market. The software requirement may at the beginning be satisfied to some extent under subcontract, but in time offers an attractive in-house capability to be developed and controlled. Special advantages accrue to the contractor who is able to program the instructional materials pertinent to the weapons which he produces.[19]

The software (or programming) component of the instructional system provides the vehicle by which essential control may be exercised over customer training without direct intrusion. A program once compiled and standardized introduces a measure of uniformity which may not be altered without full justification and awareness of the consequences. Frequently such changes may be beyond the capabilities of on-site personnel and serve further to require appropriate review before program modification may be accomplished.

At the same time mutual benefits are gained by the customer in that he is assured of current, competent instruction specifically formulated to guarantee performance products consistent with his needs. He is provided a complete instructional package without the stress and strain of the conventional approach. Subsidiary benefits to the customer include:

a. Control over the instructional system, as is currently exercised over other subsystems, is maintained.

b. Fixed price training programs are possible.

c. Duplicative, unnecessary and competing instructional materials are eliminated.

d. Student performance records generated by the instructional system are readily accessible.

In order to demonstrate the feasibility of such an instructional system as has been discussed in the foregoing, the theoretical integration of this methodology into the current Air Force research, development and procurement cycle has been chosen.

Under the Air Force management concept as described in the AFSC 375 series of management manuals, all training elements identified with the development of a particular weapons system are subsumed under the so called "Personnel Subsystem." The components of this subsystem, and their relationship to each other are shown in Figure 1. One can readily detect that the Personnel Subsystem embraces virtually every aspect of man's interface with the hardware system. Beginning with Human Engineering and Life Support considerations in product design, the subsystem includes Qualitative Personnel Requirements Information, Procurement of Training Equipment and Technical Publications, and Personnel Subsystem Testing and Evaluation. While each of these Personnel Subsystem elements shares a dependency upon the others, the "training package" derives from the Qualitative Information (QQPRI). This information prescribes the forecasted personnel requirements of the system-in-being, in terms of numbers, specialty codes, and skill levels.

It is important to note that this information in order to be accurate must be the product of detailed task and sub-task analysis. Under the procedures prescribed by AFSCM 375-5 these analyses are derived from system engineering data in the form of requirement allocation sheets, maintenance loading analysis, personnel utilization sheets, etc. New and unique skills are, of course, singled out for detailed time line descriptions.

Presently, the product of this analysis is expressed in QQPRI data items as Air Force Specialty Codes (AFSC's), Proficiency Levels, Unit Manning Documents (UMD's), and Organizational Charts. While it is admittedly necessary to ultimately express these data in Air Force language, as the antecedent of an instructional system it is likewise readily possible to express the analytic product behaviorally, i.e., in terminal performance requirements. Once expressed as such they may be collectively allocated, as are tasks presently, in the language of the Air Force. The net gain is that the qualitative deficiencies in AF specialty code descriptions and job training standards are now replaced by specific performance requirements derived from task analyses and expressed in behavioral terms. In point of fact this information is more truly "Qualitative and Quantitative" Personnel Requirements Information than that currently bearing the

title and establishes a valid basis for planning training programs.

As with QQPRI, continual refinement of these analytic products must be carried out until both the Air Force and the contractor are satisfied that they indeed define the terminal skills essential to the efficient operation and maintenance of the weapon or space system. Under the Personnel Subsystem concept this validation is ordinarily terminated during the Personnel Subsystem Test and Evaluation phase.

The Training Concept and the Training Plan currently reflect an interaction between the Air Training Command and the contractor. The Training Concept is drawn up and submitted by Air Training Command, on the basis of information obtained from the contractor, for Air Force approval. It proposes such elements as types of training to be accomplished, training schedules, training management, training facilities and equipment requirements, training logistics, training manpower, fiscal requirements, etc. The Training Plan is submitted by the contractor, in coordination with Air Training Command, and proposes such training as the contractor believes to be required to insure proper operation and maintenance of the complete weapon or space system and all its supportive equipments. Both the concept and the plan embody all the training from whatever source required by the hardware system.

The instructional package proposed in this paper requires a fundamental re-orientation of training philosophy consistent with the technological capabilities of modern teaching media. To be sure, a concept and a plan are appropriate, but of a different sort than is presently acceptable.

As the terminal performance requirements information is generated and as this information becomes mutually acceptable to the customer and to the contractor, the contractor as a concomitant of and concurrent with hardware development evolves a complete instructional system, programmed to produce the performance, the human skill repertoire, specified by those requirements. This program of instruction is created as a totality utilizing the subject matter expertise of those directly involved in the design and development of the hardware. The professional and technical talent essential to the actual programming of the instruction is unique to this form of teaching methodology. The sophistication of the instructional system is dependent upon the skill with which the program is assembled, the teaching media are employed, and the instructional hardware chosen.

Specialists in the various aspects of programmed instruction are increasing in number constantly and are now being trained through the master's and doctoral levels. Their services may be purchased directly or may be contracted.

The really important point to be emphasized is that under the systems approach to training the responsibility for the instructional program is a contract responsibility to be achieved at a stated cost, in a specified time, for a given target population — in this instance uniformed Air Force personnel. Once devised and approved by the Air Force, such a program becomes the

standard teaching form to be modified only as experience and hardware design changes may dictate. With the passage of time contractor capabilities and innovations by the Air Force will greatly enhance the utility of the concept and its application to the technical training task.

The Training Concept and the Training Plan must embrace the realities of the new training philosophy and formalize it by documentary means. Steps in this formalization would appear somewhat as shown in Figure 2.

Training Equipment Planning and the preparation of printed instructional materials become integral components of the learning system and thus lose their present adjunctive role. Justification of these equipments and these materials must stem from their validated contribution to the learning process as demonstrated by the performance or skill acquisitions of the trainees. A little experience with the hard facts of modern educational technology will do much to rid the system of superfluous or unproductive training devices.

Personnel Subsystem Test and Evaluation consumates the validity of all that the Personnel Subsystem includes. The demonstration of the acquired skills in the operation and maintenance of the system-in-being is the pay-off. The building of a learning system under the programmed instruction philosophy requires the extensive testing and retesting of the individual and incremental elements of the program. The analytic and statistical verification of the performance outcomes of the instruction and the error rate criteria commonly in use enforce the refinement of the program to an extent far in excess of that required of conventional teaching methods. It is precisely this verification that inspires such a high confidence in the method and justifies its proposal in the context of this paper.

Whatever the 1970 time frame provides by way of technological achievement, one thing is certain. Man will still be the measure of all progress. His capacity to understand, to communicate, and to act in his environment is the crucial and ultimate element in any system. The means by which men and machines are made compatible must keep pace with the surrounding technologies and provide the human skills required by them. The systems approach to education and training seeks to combine the contributions of the learning sciences with those of the physical sciences and to assure that man's response is adequate to the demands imposed upon him.

REFERENCES

1. "The computer as a tutor," Life, Jan. 27, 1967, 62, 68-81

2. "New course for canned teaching," Business Week, July 24, 1965, 67-69

3. Revolution in training: programed instruction in industry. New York: American Management Association, 1962

4. Taylor, H. "Programmed instruction in industry - a review of the literature." Personnel Practice Bulletin, 1964, 20(4), 14-27

5. Ofiesh, Gabriel O. Programed instruction, a guide for management. New York: American Management Association, 1965

6. Fry, E. Teaching machines and programmed instruction. New York: McGraw-Hill, 1963

7. Murphy, John R., and Goldberg, Irving A. "Strategies for using programmed instruction." Harvard Business Review, May 1964, 42, 115-132

8. Skinner, B. F. "Teaching machines." Science, 1958, 128, 969-977

9. Crowder, N. A. "Automatic tutoring by means of intrinsic programing." In Galanter, E. H. (Ed.) Automatic teaching: the state of the art. New York: Wiley, 1959, 109-116

10. Markle, Susan Meyer Good frames and bad: a grammar of frame writing. New York: Wiley, 1964

11. Presentation by Mr. Richard Shetler, President, General Learning, Inc., at Seminar on Educational Technology sponsored by Aerospace Education Foundation of the Air Force Association, Washington, D. C., September 14-16, 1966

12. Christian, Roger W. "Guides to programed learning." Harvard Business Review, November 1962, 40, 36-38

13. Lumsdaine, A. A. and Glaser, Robert Teaching machines and programmed learning, a source book. Washington: Department of Audiovisual Instruction, National Education Association of the United States, 1960

14. Glaser, Robert Teaching machines and programmed learning, II. Washington: Department of Audiovisual Instruction, National Education Association of the United States, 1965

15. Hendershot, Carl H. Programmed learning: a bibliography of programs and presentation devices. Saginaw, Michigan: Scher Printing Co., 1964

16. Woodcock, W. P., Gilmore, H. L. and Hatterick, G. R. "Human factors engineering in reentry system design." Presented at 1967 Annual Symposium on Reliability, Washington, January 10, 11, and 12, 1967

17. Stanford Research Institute, Project 399 Final Report, ONR Contract N7ONR-31203, 15 January 1952

18. Unpublished data developed by McDonnell Aircraft Corporation and Vought Aeronautics Division, LTV, Incorporated

19. Shoemaker, H. A. and Holt, H. O. The use of programed instruction in industry, In Glaser, Robert Teaching machines and programmed instruction, II, pages 685-742
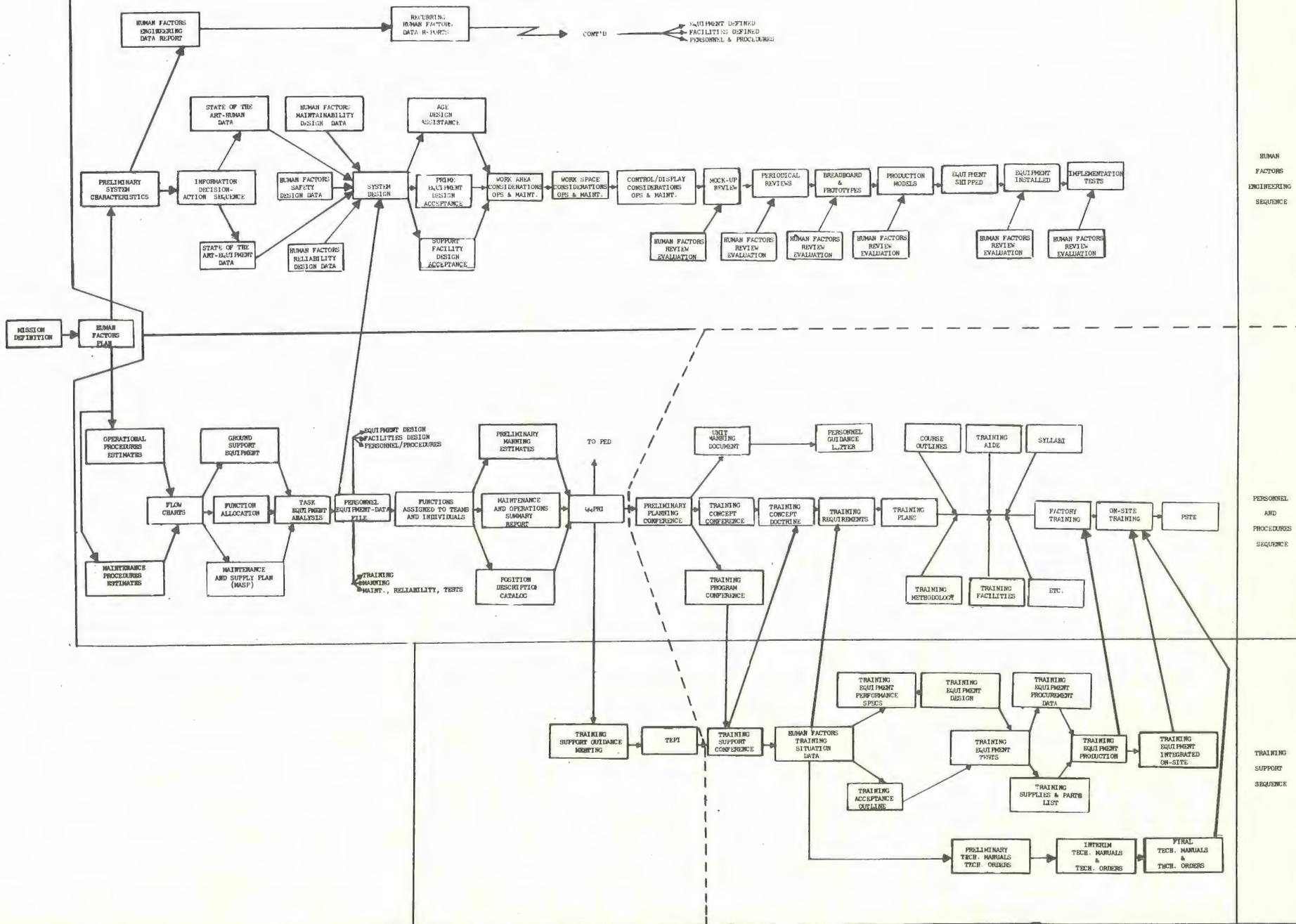
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FINAL TECH. MANUALS & TECH. ORDERS

Figure 1.   PERSONNEL SUBSYSTEM FLOW CHART

	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
	TRAINING SYSTEMS ANALYSIS	TASK ANALYSIS	BEHAVIORAL ANALYSIS	PROGRAM PRODUCTION	PERFORMANCE TESTING	DATA INTERPRETATION AND REVISION
THE CONTRACTOR'S DEVELOPMENT PROCESS	Training System Definition Specification of: —Training requirements —Trainee population —Training schedule —Performance parameters —Training Support requirements	Establishment of training goals through analysis of the tasks to be performed and consultation with user.	Statement of training goals in behavioral terms. Detailed analysis and specification of all skills and information to be imparted to trainees. Establishment of post-training standard for measuring trainee performance.	Physical production of the training materials. Maintenance of liaison between project managers and user to assure conformity with Phase 3 terminal-behavior specifications.	Training materials are tested under field-use conditions to determine the trainee's level of performance as measured by the criterion examination.	Final revision of the materials and preparation of a final version.
DOCUMENT PRESENTED TO CUSTOMER	Technical proposal: —Design concepts —Statement of work	Statement of operational objectives: —Training goals expressed in terms of time, economics, administration, and personnel. —Action statements of training goals with detailed statement of performance requirements.	Terminal-behavior specifications, including precise skills and information to be taught. Criterion examination, i.e., standard against which teaching effectiveness will be measured during performance testing in Phase 5	Draft instructional program.	Performance data are made available to user to confirm the adequacy of material; programing company utilizes them for final refinements.	Final delivery of instructional program and associated hardware.
THE CUSTOMER'S DECISION PROCESS	Accept, modify, or reject proposal.	Review and approval of statement of operational objectives. Agreement that this is the work the programmer should be doing.	Review and approval of both documents above.	No action required of user.	Cooperation in performance testing and acceptance of performance data.	Acceptance and implementation.

Figure 2.   FORMAL DEVELOPMENT OF THE INSTRUCTIONAL SYSTEM