IN-PLANT FORMATIVE EVALUATION OF
TRAINING DEVICE INSTRUCTIONAL SUBSYSTEMS

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ABSTRACT

Current training device evaluations performed in-plant do not adequately address instructional subsystem issues. Instead, these tests focus primarily on engineering topics. Formative evaluation is a method which allows training device designers and users to determine instructional subsystem problems before the device is shipped. It also provides opportunities to make improvements. This paper defines training device formative evaluation, describes its purposes and techniques, and points out possible obstacles to its conduct. The paper concludes with an example of formative evaluation which was performed on the M1 Tank Institutional Conduct of Fire Trainer.

INTRODUCTION

The Need for Formative Evaluation

The military spends large amounts of its training device budget on tests of various kinds. Engineering and acceptance tests are performed both before and after a device leaves the factory. While these tests are very important from an engineering standpoint, they give the developers little idea about the potential instructional effectiveness of the device. This paper describes a technique for improving instructional effectiveness while the device is still in the factory. Such tests improve the probability that an effective total training system will be developed. This "formative evaluation" is crucial if the device is to arrive at the school ready to train.

Formative evaluation should be viewed as only one part of a total set of evaluations (instructional and engineering) which should be conducted both before and after the device arrives at the school. These tests include Development Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E). The first test is designed specifically as an engineering test with no concern for instructional questions. The Operational Test and Evaluation is designed to assess the operational suitability and estimate the potential training capability of the device in its operational environment. Typically, these estimates are made using instructors but not trainees. The OT&E often does not rigorously examine instructional issues and materials. Rarely will these tests reveal instructional problems before the device leaves the plant. Experience has shown that altering the instructional courseware of a device after it has been fielded is both difficult and inefficient. Moreover, school staff and trainees become frustrated when the device performs poorly. The negative attitudes thus generated may never be overcome, even if the instructional subsystem is eventually "fixed".

Definition of Formative Evaluation

The concept of formative evaluation has been recognized as being valuable in the field of education for a number of years (1,2). Dick (3) defines formative evaluation as, "a process of systematically trying out instructional materials with learners in order to gather information and data which will be used to revise the materials" (p. 311). The implication of the term "formative" is that the evaluation process occurs while the materials are still being developed.

In order to allow the formative evaluation process to accomplish its goal, it is important to keep the process relatively informal. The evaluators develops a test plan and methods, as would be the case for any kind of test, but they are far more willing to depart from that plan if more information about the instructional effectiveness of the instructional subsystem can be gained.

> Formative evaluation is not meant to be generalizable in nature but rather to be of direct and immediate assistance to those who have to make crucial decisions in a given situation. Formative evaluation is not evaluation intended to determine for all time the worth or value of the project being developed. The working meaning of the term formative evaluation may differ from setting to setting, from user to user. Similarly, the strategies and techniques used under the rubric formative evaluation may vary widely, due in some measure to differences in the development process being used. (p. 7) (4)

Some of the major goals of a formative evaluation are to examine the instructional subsystem in light of:

> Learner characteristics - Do the instructional strategies in the subsystem

accommodate the learner characteristics of the target population?

Instructional goals and objectives - Are the goals and objectives of the subsystem congruent with the goals prescribed by the device's front-end analysis documents (e.g., concept formulation, military characteristics, etc.)? Are the goals and objectives still valid and worth achieving?

Knowledge and skills - Does the instructional subsystem allow the necessary knowledge and skills to be taught?

Instructional strategy - Is the instructional strategy used in the subsystem sound and effective? Are the instructional scenarios sound?

Instructor guidance - Does the subsystem provide sufficent help and direction to the instructor?

Other formative evaluation goals can be added as needed and the method by which the goals are achieved will vary depending upon the situation.

Formative evaluation is not summative evaluation. Summative evaluation uses empirical data from fielded devices to compare the merits of two or more alternative instructional products or systems. An example of a summative evaluation is a Training Effectiveness Evaluation (TEE), which empirically compares two or more different training approaches for accomplishing the same goal (e.g., a full mission simulator versus a part-task trainer). One result of the TEE is usually a value judgement about which training device is most effective.

Formative evaluation is also not a form of human factors evaluation. To begin troubleshooting the instructional subsystem, the evaluator does not need mock-ups of the equipment as would be the case in a human factors evaluation. The main purpose is to find instructional, not ergonomics, problems. Although the main purpose is not human factors evaluation, one can expect the formative evaluation to turn up problems of a human factors nature. This occurs because the latter stages of formative evaluation will require trainee and instructor interaction with the instructional subsystem as it is delivered by the hardware/ software subsystems. In fact, it is quite possible that a formative evaluation will reveal human factors problems which even a formal human factors evaluation may not discover.

METHODOLOGICAL CONSIDERATIONS

Traditional formative evaluation performed with paper and pencil instruction in the classroom consists of three phases: one-on-one individual trials, small group trials and a field test (3). In the Department of Defense literature on Instructional Systems Development (ISD), these activities are classed under the title of Validate Instruction Block III.5(6). The methods suggested here are a modification of this approach to conform to special conditions presented by

development of automated instructional subsystems in training devices.

The trainees must be made to understand that it is they who are evaluating the instruction. They are not the objects of the evaluation.

Individual Trials

In individual trials, the instructional designer exposes the instructional materials to two or three representative trainees (or trainee teams, if the team is the unit being trained) for the first time. The purpose is to identify any major flaws in the instructional approach or materials.

Rough drafts of the instructional materials are used. In the case of instructional subsystems in major trainers, this must be done well before the hardware and software delivery systems are developed. Tutorials with instructional frames and defined responses can be modeled on paper. For dynamic scenarios, the development of rough drafts of instructional materials is more difficult. Storyboards, flowcharts, sequential illustrations, written scripts, or simplified table-top computer versions might be useful. A special problem is presented by individual trials evaluation of team training. Operational sequence diagrams may be helpful in representing the instruction to trainees (7).

Typically, it is recommended that as a minimum, an average, above average, and below average trainee be studied to determine the differential impact of the materials by ability. During the individual trials, the instructional designer guides the trainee through the instructional materials and simultaneously interviews the trainee. The purpose is to detect any points in the instruction where the trainee has difficulty performing as expected. The most valuable information may come from noting errors in trainees' responses and seeking the trainees' comments. Questions which help to stimulate this type of critique are:

1. What was your reasoning that led you to the (erroneous) response you made?

2. Do you notice anything about this material that is confusing or difficult to understand?

3. Can you make any suggestions about how to clear up the problem?

4. What parts of this instruction work well for you? Why?

In addition to trainee responses to probe questions, spontaneous comments of the trainee and the observations of the instructional designer can identify instructional problems.

The ISD process calls for the evaluation of learning with pre- and post-tests during this stage. Because of difficulties in rough representation of dynamic materials without an advanced stage of hardware and software development, the level of learning expected may not be as great as from the final system. When performance testing is embedded in the trainer, automatic measurements may not be available for the evaluation. The performance measurement system of the final instructional

subsystem can be mocked up for FE. In tactical scenarios and procedures training, talking through a trainee's response to a static stimulus material may be useful as a first attempt to measure learning.

Small Group Evaluation

After revisions to the instructional plan have been made, following individual trials, the instructional materials should be prepared in a more finished form and exposed to a representative group of trainees. This will probably occur fairly late in system development, since it is desirable at this time to have at least a rough version of the instructional subsystem mounted in prototype hardware. The delivery of instruction may be done by either experienced contract personnel who are familiar with the system, or by instructors typical of those who will actually use the device at its future site. Use of typical instructors is highly preferred. If Department of Defense instructors are used to deliver training, valuable information can be gained regarding the functionality of the device from the point of view of the instructor. Training sites will also be primed to consider how this device will fit into existing instruction, and begin modifications for integration of the device before its arrival. It is crucial that the Subject Matter Experts (i.e., instructors) be brought into the plant for this evaluation, if at all possible.

Frequently only one prototype device is available for the group trials. In addition, the time frame in the production schedule during which significant changes in the instructional subsystem can be made is typically very short. This means that it may be practicable to expose only a few learners to the device during small group trials, thus allowing no statistical evaluations of achievement of learning objectives. Nevertheless, this step is probably one of the most important in successful development of an instructional subsystem. Even a few trainees and instructors can demonstrate typical difficulties which will be experienced in using the system. They can identify serious problems in design of the delivery system, needs for concurrent or complementary instruction and other important deficiencies of the proposed system.

At this stage, behavioral observations by trained observers may be substituted for the "talk-through" of the individual trials to gain information about how uninterrupted instruction flows. In addition, automated performance measures can be tried out. As a supplement, however, it is still worthwhile to conduct interviews with users after participation to get observations and comments on the functioning of the device and errors demonstrated by trainees and instructors. At this point, collection of measures of user satisfaction are relevant. Finally, simple questions which plague developers without hands-on information can be answered, a prime example of such a question is "How long does it take for a typical trainee to complete the instruction?"

A special form of small group trials is the formative evaluation of team training. It is to be expected that major difficulties in team training may not appear until small group trials,

even though individual trials were conducted. This is related to the fact that two sets of dynamic interactions are required - individual with training device and individual with team. Although rough mock-ups can identify some types of instructional problems, others are likely to appear in this phase of formative evaluation.

At the conclusion of small group trials, and revision of the instructional subsystem according to outcomes of this stage of evaluation, the system should be functioning well. The final stage of evaluation, field trials, is a last chance to fine tune the device.

Field Evaluation

The purpose of the formative evaluation field trial is to demonstrate that the "fixes" identified earlier are effective, and that the system can be used as intended by instructional personnel in the final training setting. The field trial can best be addressed after the device is fielded via the Operational Test and Evaluation.

The field evaluation should be performed in the setting in which the device is to be used with typical trainees and instructors. A rule of thumb is to administer the training to 30 trainees or teams (3). System designers should have a minimal role in conduct of the instruction. Instructors should be able to turn to manuals or other resources which will be continually available and should be able to address learner needs adequately with the system as it stands.

Use in the field will demonstrate whether the system is functioning independently without further contractor support, or whether additional training of instructors, manuals, or other add-ons are required. Integration of the system into the existing curriculum can be examined. Administration of use of the device and records can also be evaluated. Some estimate of normative performance of trainees can be obtained through automated performance measures records, if any can be developed. Additional attitude questionnaires can be administered. This formative field evaluation should be performed while development of the device is still under contract, so that any additional problems identified can be addressed.

POSSIBLE OBSTACLES TO INSTRUCTIONAL SUBSYSTEM FORMATIVE EVALUATION

There are at least four obstacles to training device formative evaluation:

1. It takes additional time in the device development cycle to perform formative evaluation. In development schedules, which are already tight, team members may be tempted to skip the formative evaluation. This can happen even if all were agreed at project start to perform the evaluation. The real problem comes when a formative evaluation reveals instructional system problems which can hold up the project while the problems are resolved. This obstacle can only be overcome by contract requirements which clearly call for the formative evaluation. It usually cannot be done successfully if it is an add-on after the project has started. Therefore, additional funds and

schedule time should be set aside for evaluation in project estimates. Also, the ultimate user should agree to the evaluation since the Ready for Training date may have to be slipped if significant instructional problems are revealed.

2. A formative evaluation will add up-front cost to the device development. Extra hours for preparation and conduct of the evaluation can be reasonably estimated at the time of the project proposal. So too can the resources needed for trainee and instructor time. However, it is very difficult to tell beforehand what extra cost will be added as a result of the revisions which must occur based upon the evaluation findings. An extra amount of project funds should be kept in reserve for such revisions. Although the evaluation will add up-front cost, the overall life-cycle cost should be reduced. The basic premise is that instructional problems discovered and resolved early cost less than those discovered and resolved after the device has been delivered to the school.

3. The project team and management may have concerns about their role in the formative evaluation beyond those discussed above. These concerns are described briefly below along with possible methods for countering them.

a. Formative evaluation could cause the project team extra work. The up-front work may be greater, but the total work over the trainer life-cycle should be less. The delivery of a more effective trainer to the school will eliminate much revision that might be necessary otherwise. Convincing a project team and management to make the job more complex at the start for better results later may be difficult. It is advisable to have both contractor and Government personnel design and conduct the evaluation and interpret the findings.

b. The development team and management could oppose the evaluation for fear that they could be criticized if design problems are identified. The formative evaluation and resultant refinements to the system should be viewed as a natural part of development. The team should realize that the complex nature of instructional subsystem development produces design problems that can only be found through try-out. Managers, sponsors, and users can foster a positive team attitude toward formative evaluation by assuring the team that their performance evaluations will not be negatively affected if design problems are revealed. In fact, the team should be positively reinforced to the extent that a more effective training device is delivered as a result of the evaluation.

4. The school managers may have fears that formative evaluation will place too great a burden on school resources. After all, it is the school that may be asked to provide instructors and/or trainees for the in-plant evaluations. The school personnel must develop an ownership in the formative evaluation concept before they will commit the resources required and accept the possible delivery delays which might result from the evaluation. These personnel must receive briefings on the evaluation process and its benefits very early in the device development process.

AN EXAMPLE OF FORMATIVE EVALUATION IN INSTRUCTIONAL SUBSYSTEMS

This example describes a formative evaluation performed on the M1 Tank Institutional Conduct of Fire Trainer (ICOFT). The evaluation was requested, and funded, by the Army's Project Manager for Training Devices. The example is meant mainly to illustrate some of the methods, problems and advantages of device based formative evaluation. While the evaluation was called an "Individual Trials Evaluation", it actually contained elements of both Individual Trials and Small Group evaluations. This combination was necessary since an Individual Trial had not been performed early in the instructional subsystem design. The first time the instructional subsystem was exposed to trainee-like subjects was during the evaluation.

Institutional Conduct of Fire Trainer (ICOFT) for the M1 Tank

One ICOFT (see Figure 1) consists of four M1 trainee stations and four Instructor-Operator Stations. Trainee stations simulate M1 gunner and commander positions. Either one or both crewman are presented instruction on procedural and gunnery tasks. The training subsystem provides the cues and responses, monitors/evaluates performance, and manages the trainees' progress through the training program. When only one crewman is undergoing training, a synthetic crewman provides the missing member's actions, voice commands and responses. Instruction, demonstrations, and feedback are provided by a Voice Generating System that leads the trainee through a tutorial, demonstration and practice exercises. Depending on the trainee's progress, he may get a remedial exercise, be advanced, or repeat the present exercise. For a detailed description of the COFT, see (8).

Goals and Objectives of the Formative Evaluation

The purpose of the evaluation was to assess the training effects of the ICOFT training system on a small population of students representing trainees at the Armor Officer Basic (AOB) course and the One Station Unit Training (OSUT) course at the U.S. Army Armor School at Ft. Knox, Kentucky. While hardware/software integration tests and the Prototype Qualification Test were conducted prior to the On-Site User Test (tests of all systems requirements), there was no provision for a preliminary look at the training aspects of the system. All other testing did not answer "does the instruction work?" "Can a representative target audience achieve the learning objective?" Another objective/goal was to identify changes required prior to going into full scale production.

Evaluation Personnel

Sixteen trainees and ten instructors were used to conduct the evaluation over a two week period. It was not possible to obtain students from the Armor School. Therefore, a group of subjects was hired who had characteristics similar to those of the actual trainees. For AOBC, the subjects had at least two years of college and a number were about to join the Army. For OSUT, all were high school graduates, many of whom would soon be joining the Army. None of the subjects had prior experience with a tank. The Instructors/Operators (I/Os) were

noncoms who attended a two-week Instructor/
Operator course immediately prior to the trials.
Only one had any experience with COFT. Both
government and contractor personnel acted as
evaluators. They received training on the pur-
pose of the trials, data collection forms,
scheduling, and responsibilities. Some evaluators
also attended the I/O course.

Data Collection

The data collection effort basically utilized the
following sources:

o Event sequence data.

o Hard copy printouts on the sequence and
occurrence of trainee remediation, I/O
intervention, and use of special instruc-
tional features for trainee remediation
and critique.

o All ICOFT printouts of trainee performance.
The printouts showed exercise Performance
Analysis Records, Shot Pattern data (where
available), Session Summaries and Student
Records.

o Interviews and questionnaire: Prior to
the start of the trials, a Personal
History Questionnaire was administered to
each trainee and I/O to identify entry
level aptitude for the former and level of
proficiency for the latter. Interviews
were conducted with both the trainee and
the I/O at the end of each training ses-
sion to address any problems encountered,
as well as clarity and pace of the Voice
Generation System, difficulty and structure
of the exercises, training results achieved
and the effectiveness of system remedia-
tion. Post test surveys were also con-
ducted for both the I/Os and trainees
related to the overall system effective-
ness, training results achieved and
suggestions for improvement.

o System logs and equipment performance
reports were collected.

o A detailed log of all system activity was
maintained by the Government Evaluator and
the instructor at each training station.
All incidents encountered were recorded in
the system logs and those considered of
sufficient significance to require con-
tractor corrective action were converted
to Equipment Performance Reports (EPRs).
A total of 407 EPRs were generated during
the course of these trials. As mentioned
previously, had an Individual Trials
evaluation been performed on the instruc-
tional subsystem as it was being developed,
the number of EPRs discovered in this
evaluation phase would have been consider-
ably reduced.

Results of ICOFT Formative Evaluation

The formative evaluation revealed the following
problems with the ICOFT instructional subsystem.
All of these problems represented refinements to
the basic training concept and were largely

remedied before the device was approved for
production.

o All exercises took much longer to complete
than planned.

o Tutorials were too general in nature and
did not address specific student needs.
They lasted too long without practice
intervals.

o Scoring, remediation and feedback was not
consistent. Feedback did not agree with
performance measurements. Students were
mediated when no remediation was required.
Other times errors were noted by the I/O,
but were not detected by the scoring
system.

o The instruction given by the voice genera-
tion system was too long, slow and
repetitive.

On the basis of the formative evaluation, it was
recommended that all deficiencies noted, which did
not meet the design specification of the contract,
be corrected prior to the On-Site User Test. It
was suggested that deficiencies/recommendations for
improvement beyond the scope of the existing con-
tract be evaluated and categorized as to critical-
ity by the user and then a joint determination be
made between the user and developer as to which
improvement should be incorporated into the system
given time and money considerations. It was also
recommended that the I/O course be restructured
and validated, and that the instructor's Utiliza-
tion Handbook be updated prior to the On-Site
User Test at Ft. Knox.

Formative Evaluation Lessons Learned from the ICOFT Experience

This formative evaluation, to our knowledge, is
the first formally attempted on a training device.
Since the evaluation design was adapted from
methods which have proven useful with more tradi-
tional instructional delivery techniques, (e.g.,
slide-tapes, computer-assisted instruction, etc.)
we knew that there would be some difficulties.
That proved to be the case. This section will
describe major problems encountered and present
suggestions for future device-based formative
evaluations.

Each subject was given a number of days of class-
room training prior to, and during, the evaluation.
This "complementary" training was intended to
parallel, in brief form, the training they would
have received at the school. The subjects would
thus receive the necessary prerequisite skills
and knowledge. Unfortunately, not enough time
was allowed for this training period and conse-
quently many of the subjects lacked the necessary
prerequisites for some of the exercises in the
ICOFT. This caused the instructors to spend more
time in remediation activities than they might
have normally, and also extended the time required
to complete a given exercise.

Ideally, the formative evaluation should use sub-
jects who have all of the necessary prerequisites
prior to the evaluation. Subjects who come
directly from the school would be best suited for

that purpose. If these trainees cannot be obtained, it is crucial that the prerequisite skills and knowledge be clearly identified so that appropriate complimentary training can be designed. Once this training has been developed, the proper amount of training can be alloted prior to the formative evaluation.

Training and utilization of the instructors proved to be problematic. The brief Instructor/Operator (I/O) course, constructed for the evaluation, did not provide the instructors with a complete understanding of how the device was to be operated. Nor did it give them the proper guidance in how to interface with the trainees. In other words, they were allowed to pursue their own instructional strategies. The consequences of these problems were that the instructors had to continually ask contractor personnel for help in device operations and they spent more time on each exercise than they would normally spend in the school. Finally, the instructors were required to work under a difficult schedule. Working on-and-off from early morning till late at night (5:30 a.m. to midnight) was not unusual.

It is crucial that Instructor/Operators who participate in formative evaluations be given as much training as possible on the device, the instructional subsystem and its instructional strategy. It is useful, to an extent, to test out the future I/O course during the formative evaluation, but only to the degree that the trainee interaction with the instructional subsystem is not hampered. Wherever possible, experienced instructors should be used. Otherwise, the evaluators will have difficulty in determining whether instructional problems are inherent in the subsystem or are caused by undertrained instructors.

It appears in retrospect that more instructors and trainee-like subjects were used than were needed. As a consequence, there were an excessive amount of data collected. This not only increased the cost of the evaluation but also made data analysis difficult because there were more data to interpret.

The formative evaluator must use careful judgment in deciding how many people to use in an evaluation. As a rule, only as much data as is absolutely necessary should be collected. Individual trials should use no more than four or five trainees. Small group evaluations should probably restrict trainees to 10-12 and instructors to two or three. Remember, the formative evaluation is not striving to meet scientific standards of accuracy, validity or reliability. Large sample sizes are not required to point up problems with an instructional subsystem. If properly designed, a minimum amount of evaluation data can lead to major improvements in the subsystem.

ICOFT Conclusion

The Individual Trials Assessment provided much needed insight into how the system would perform its training mission with a representative target audience. It identified a large number of problem areas which have been corrected prior to the On-Site Unit Test at Ft. Knox. Many of the problems would not have been discovered had the formative evaluation not been conducted. Finally, the evaluation confirmed that the ICOFT is a viable training system given updated and mature software.

SUMMARY

Formative evaluation of instructional subsystems in major training devices is essential in achieving effective training. Errors in development of instructional subsystems which invalidate the use of a major training device can be extremely costly. Unless deficiencies in the instructional subsystem are identified during development, they cannot be easily corrected. The instructional subsystem will no doubt be constructed to interface with other important components of the device, and late changes will require unraveling of other work which has already been completed. In addition, a poorly functioning system delivered to the field will develop a poor reputation which may not be remedied by later fixes. Finally, development of effective and usable instructional subsystems is a specialty which is not found or expected in most instructor personnel. Many have no doubt limped along with inferior training approaches because of lack of expertise in identifying deficiencies and recommending corrections to instructional subsystems.

For a number of reasons, formative evaluations are unlikely to be performed unless required contractually, with funds earmarked for that purpose and critical time periods specified for these evaluations. Institutionalization of this practice through publication of formal procedures, development of standard contract clauses and identification of responsible agencies is required.

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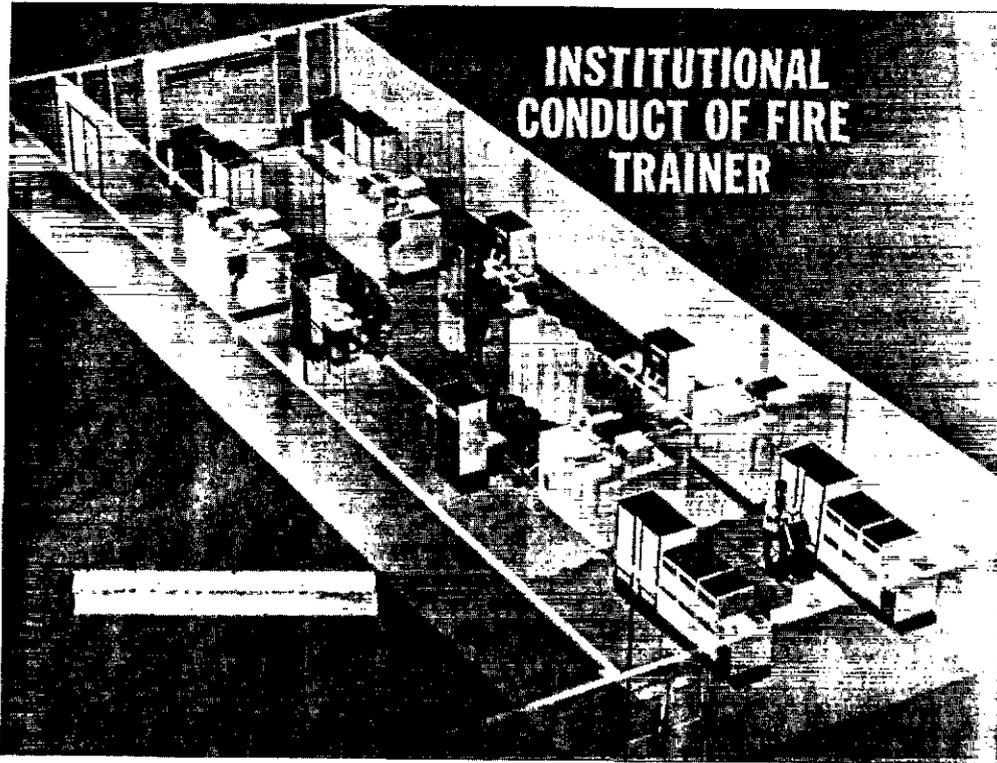
FIGURE 1

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