EFFECTIVE LOW-COST SIMULATION

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In developing weapon system simulators, it has become common practice to strive for as high fidelity as possible. Generally the simulator is indistinguishable from the real thing, both in general appearance and in the necessary task cues. But sometimes we question seriously whether high fidelity is really critical for effective training. We pay for fidelity not only with money, but with development time and personnel to maintain and operate the system.

We actually know a great deal about what cues are critical for effective training through the technology of task analysis. Mere mockups proved to be extremely effective in several training experiments (1, 2, 3, 4, 5, 6, 7, 8, and 9). We know that mockups, and low-fidelity trainers generally, are especially effective for learning procedures and for early stages of other skills.

Today I am going to discuss development of a low-cost trainer for the tactical control officer (TCO) in the Hawk missile system, and the various techniques and materials we developed to use with it. This is a rather complex decision-making task, and it seemed doubtful whether a simple trainer would still be effective with a task this complex. I also want to discuss some other practical considerations in using such a trainer, compared with a high-fidelity trainer which it was designed to supplement.

After the Army's basic officer course, C-20, there is a specialized segment for training those who will become TCO's for Hawk Batteries. We developed the trainer in coordination with a systems-engineering effort for revising that course. For those who are not familiar with Hawk, here is the system. (Figure 1. Hawk System.) There are two radars for acquiring the target: the PAR, a conventional radar, and the CWAR, which uses the Doppler principle to pick up very low altitude targets. This can be confusing because the two radars give different kinds of tactical information which are combined on one radar display screen. Here is the Battery Control Central (BCC) where the TCO and his subordinates control the system. Then there are two identical firing sections with tracking radars, missiles and launchers.

For the TCO course there are three copies of a high-fidelity simulator for use with the Hawk system, the AN/TPQ-21, but various practical considerations limit the usefulness of this device. It was designed to train a whole Hawk team, so someone must man the other stations. The simulator provides electrical inputs to a tactical BCC. From the real system it also

BATTERY CONTROL CENTRAL
Role of Personnel in Tactical Control

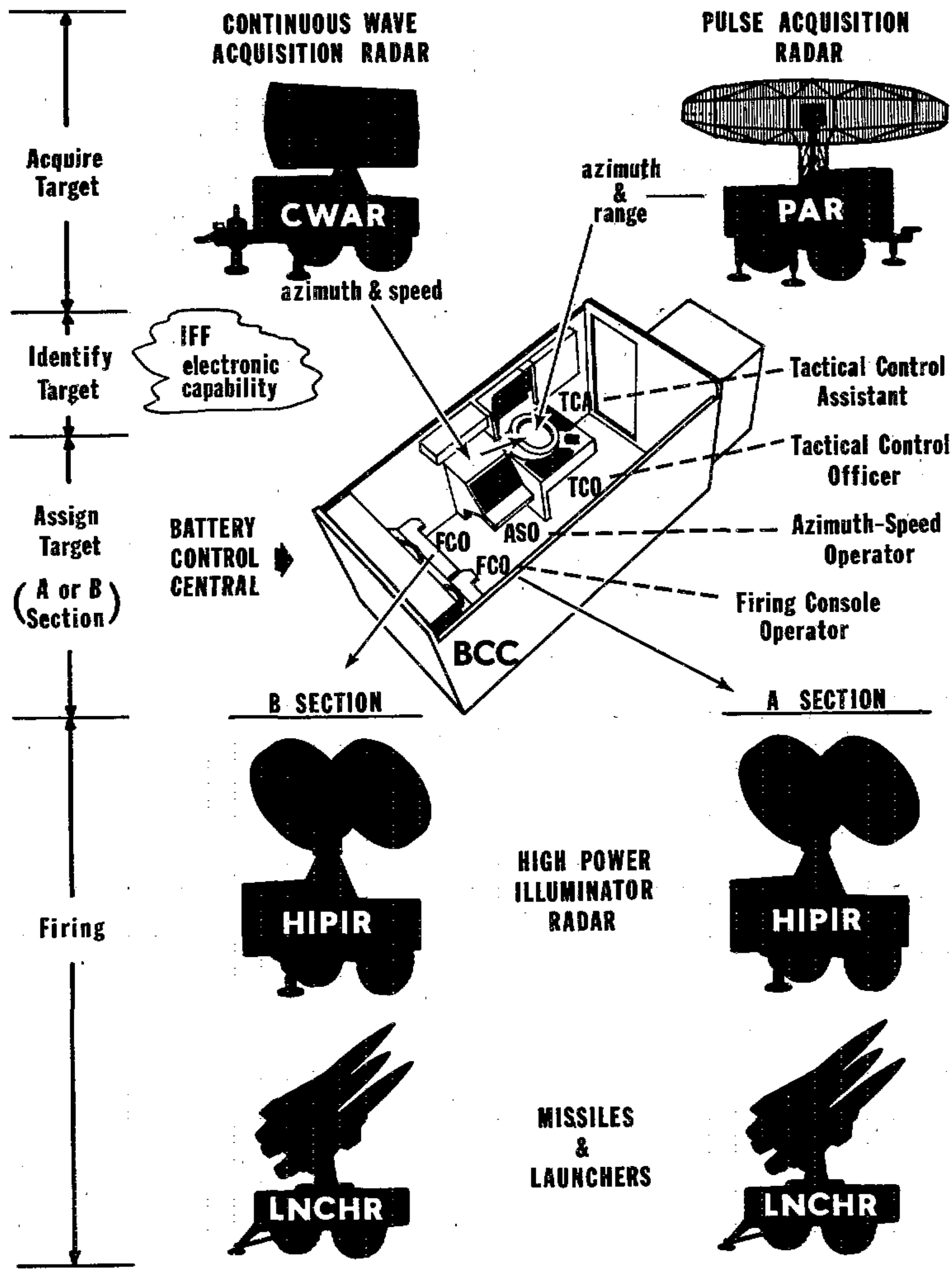

Figure 1. Hawk System

uses the PAR, two HIPIR, and two or three generators. Consequently, it takes about seven men, at a minimum, to keep the training system going; to provide hands-on training for just one TCO position. And it takes three or four men a couple of hours on the previous night shift to check out the system and make adjustments. The simulator itself costs about $400,000, but with the tactical hardware items, there is well over a million dollars tied up in a training exercise. And with this complexity, there is considerable training time lost because something is not working properly.

The typical officer-student is lucky to get 4 hours hands-on practice as a TCO by the end of his training. I have talked to graduates from past classes who got less than an hour. The simulator is used for other parts of the course, for demonstrations and training on other positions, but right now I am concerned with the TCO skills.

In developing the low-cost trainer we decided to include much more than a simple mockup. Task analysis revealed that there simply were too many indicator lights, controls, and interactions to ask the man to learn these from a book exercise. There are 26 switches and pushbuttons controlling 31 indicator lights and a buzzer, plus duplicates for another firing section. Sometimes the TCO turns them on or off, sometimes they are controlled from ADCP or from another station, and sometimes they are turned on from one place and off from another. Often a light can be switched by either of two controls. For anyone doing this kind of analysis, I would suggest making a matrix table with all the controls listed along one margin and all indicators along the other; then, write "on" or "off," or whatever is appropriate, whenever there is an effect in the system.

The low-cost trainer looked like this (Figure 2). It was designed to be entirely self-instructional and self-paced, without prerequisites, when used with the associated training aids and materials. The panels were full-sized photos using high-contrast (orthographic) film, protected with plexiglas, and illuminated from the rear. Controls were provided only where they were needed in the exercises, and they affected the indicator lights appropriately (Figure 3, Video). The video display was plexiglas; the constant features, such as range rings, were etched onto the back surface. For each problem, radar return was simulated by a piece of paper slipped behind the plexiglas. The SIF return and CW cursor occur only at particular points in a problem; they were put on the back of the paper so that they would appear only when the paper was back lighted. The repeat-back marks were represented by rods mounted like the hands of a clock; the student would move them manually over the target, and then slide the range strobe marks out to the target. The nomenclature was printed right on these elements so that the student can learn these terms as he practices.

Figure 2. Low Cost Trainer

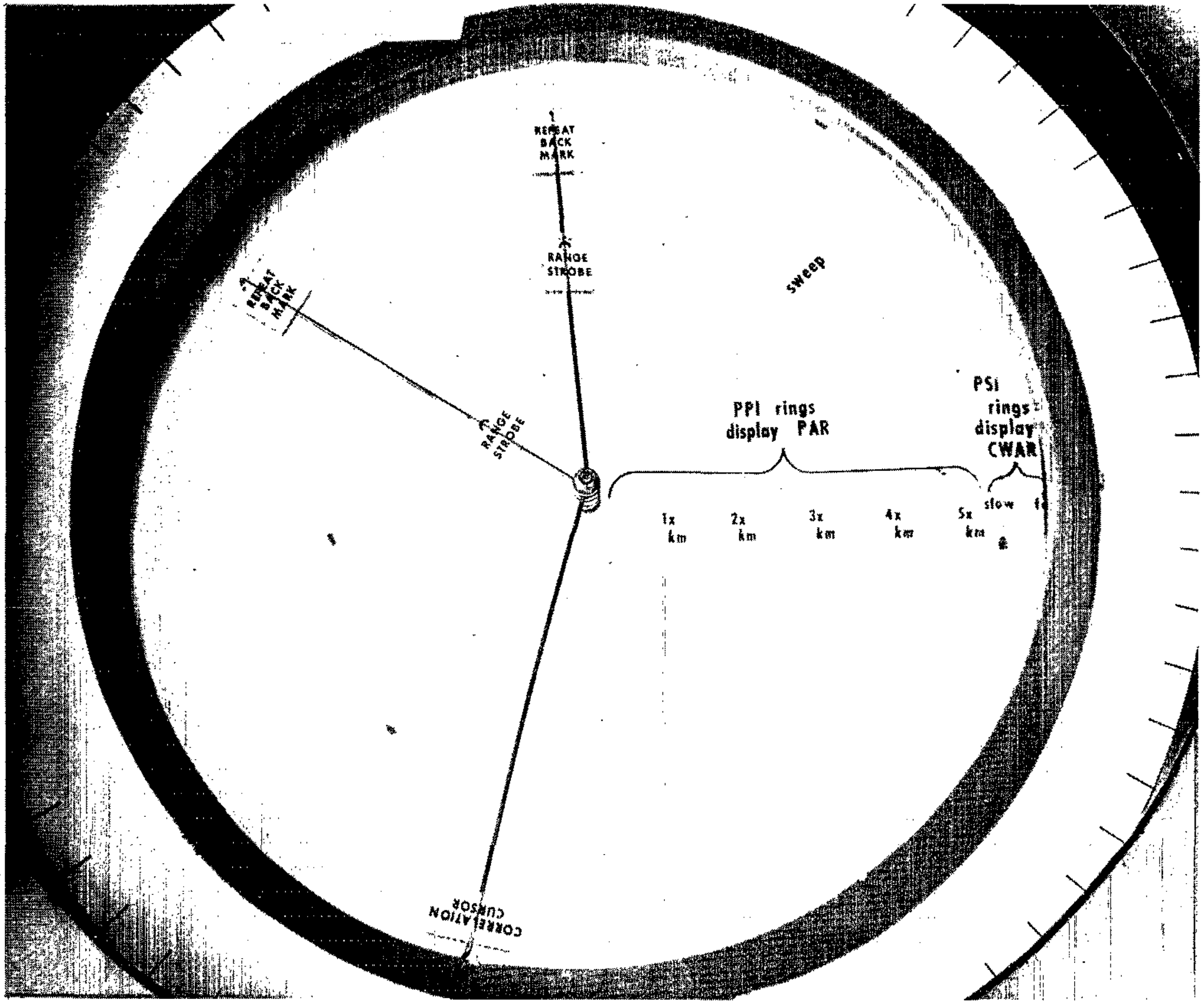

Figure 3. Video

Inputs from other stations were provided from a special panel (Figure 4. Input Panel). Each subpanel provided inputs from one other station, and the controls were put in sequence of use.

Since we assumed no prerequisites, we developed an introduction to Hawk. It was structured around two visual aids like the one I showed earlier. It described the different kinds of radar and the tactical information they gave, and the positions and general duties of the Hawk crew.

To guide the man through the procedures we developed a script in the form of a flow chart (Figure 5a, 5b. Flow Charts). He would start at one of the three points at the top, depending upon whether the operation was under ADCP control, autonomous, or autonomous with the ASO first detecting the target. This was mounted on a board right by the TCO station.

The specifics of each problem were printed on the paper which also had the radar target configuration. Seven problems were developed, representing the various kinds of difficulties the man will face.

We tried out the whole training package with about 20 men, training one or two at a time, making extensive changes in the program as we discovered weaknesses. These men were selected so that they were no better qualified, as a group, than the C-20 students. None had experience with Hawk; we tried to get junior officers, but accepted some enlisted men. The process was very fluid, with probing questions to find the reason for any difficulties they had, and tryouts of revised techniques.

The techniques discovered in the tryouts seem so self-evident, after the fact, that most people probably would accept them without argument. Yet they were not obvious before the tryouts, so it may be worthwhile to mention them briefly for those who might be involved in similar endeavors.

First, we found that students working in pairs performed much better, more more reliably, than students working alone. One student would read the flow chart and make all inputs to the TCO station, while the other checked his reading and performed actions as the TCO. This sharply reduced the chance of skipping some item, which should not surprise anyone. After each problem, the partners exchanged roles. There seemed to be no difference in what the partners learned, whether actually performing TCO duties or supervising performance of the partner.

We also found that we had to simplify the flow chart considerably, leaving many of the nuances for later. For instance, the procedures for changing targets, cease fire and hold fire were put on a separate chart which was introduced after the basic procedures were learned.

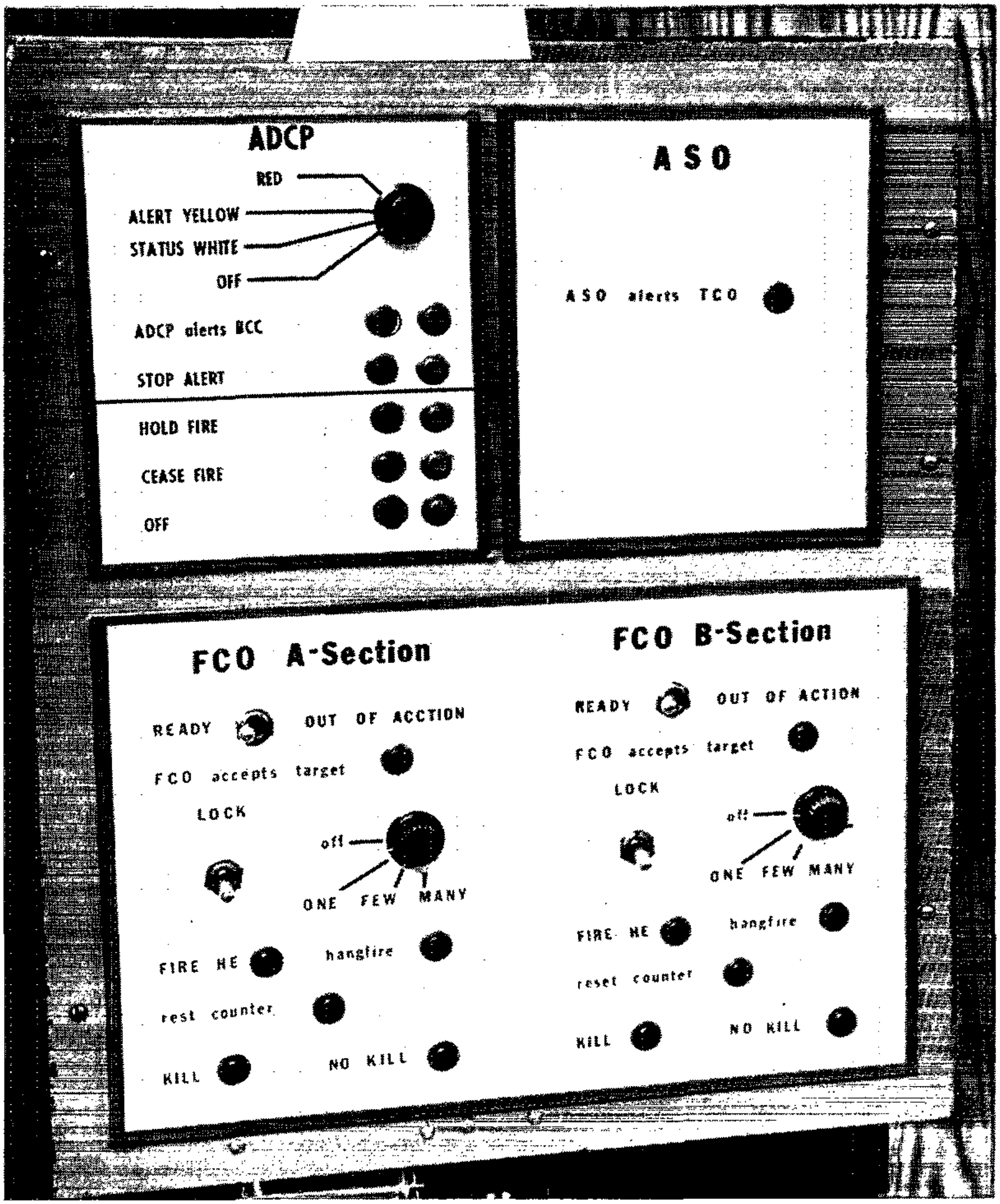

Figure 4. Input Panel

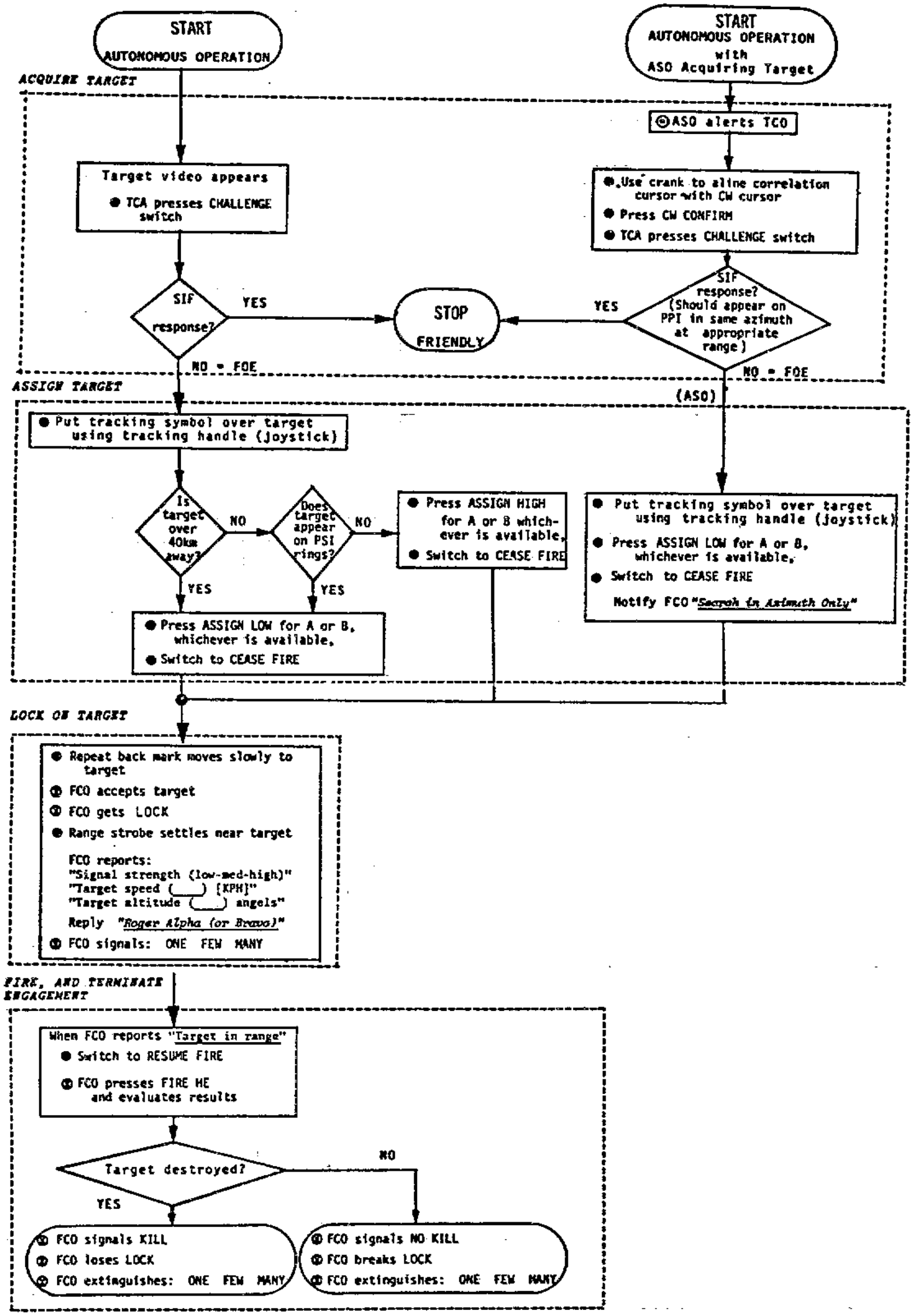

Figure 5a. Flow Chart

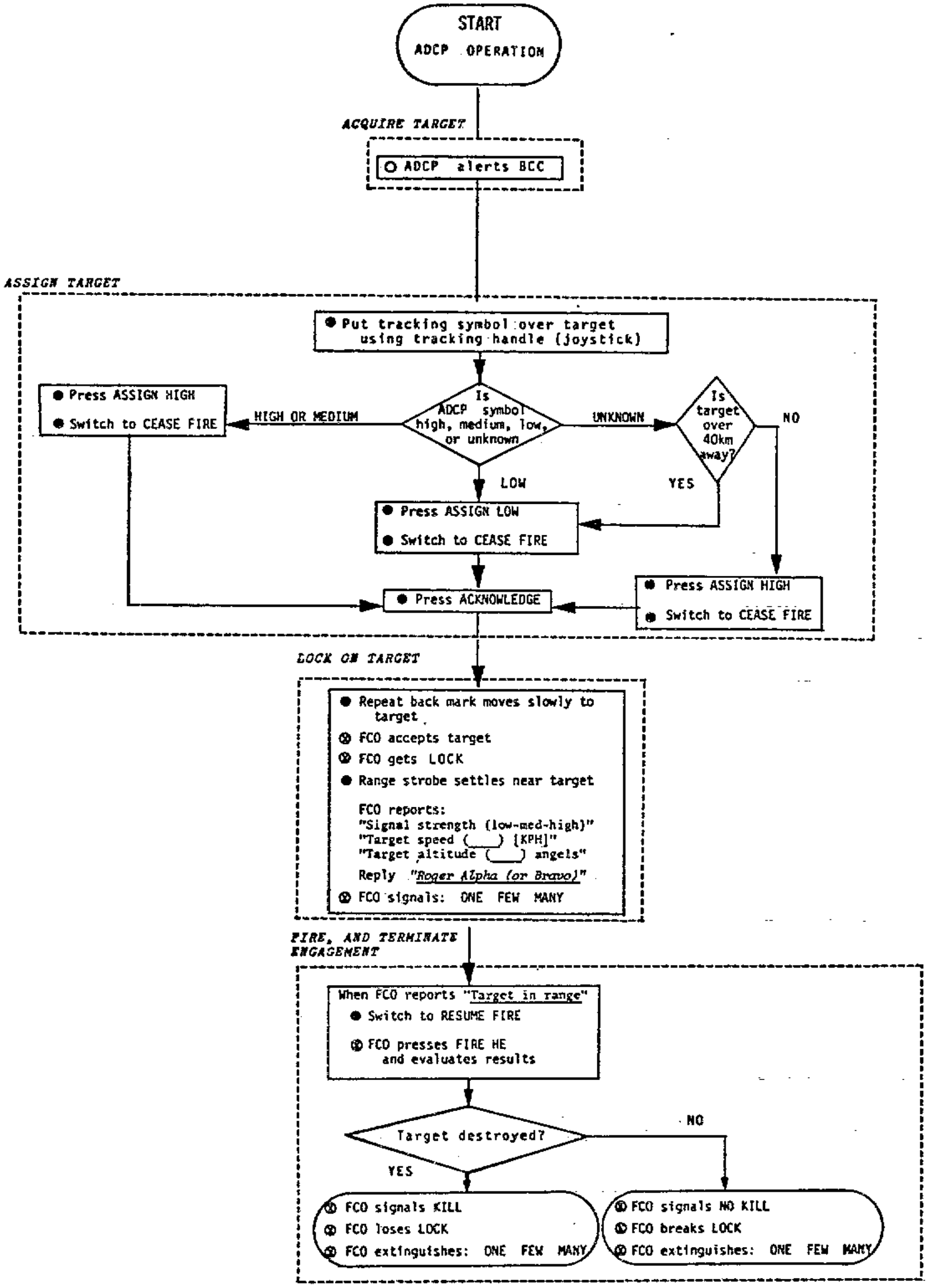

Figure 5b. Flow Chart

Another point: we had to clearly distinguish overt action items in the flow charts, even though such information was implicity in the language used. We did this by putting a big, black dot in front of each item where the TCO had to do some physical act, like pushing a switch or moving a lever. For inputs from other stations we used colored dots, color-coded to the panel on which the action was taken.

We found that the introduction with the training aids was essential. I occasionally skipped some point in the introduction, or gave it insufficient emphasis, and then the students would seem unable to deal with the corresponding task elements. For instance, if I did not mention the Doppler principle and how the two acquisition radars gave different tactical information, then the students would be unable to use the radar display, which combined both kinds of information. It seems as though the task is very difficult to learn by rote memory.

At first there seemed to be considerable fumbling and searching while locating the controls, like the tracking handle on the "assign high" pushbutton. The elements were labeled, but it would take time for a man to find the label. We did not want to use a traditional nomenclature drill because such role memorizing is generally inefficient. Instead, we initially demonstrated the first problem exactly as they were to do it. After that there was virtually no hesitation while locating parts.

The men also had difficulty relating the specific problem information to the appropriate place in the flow chart. The problem specifics were printed on the radar display sheet, completely separate from the flow charts. The change was to put a clear acetate pocket right beside the flow chart, and slip a long, narrow sheet of paper with the problem specifics printed right beside the corresponding place in the flow chart. This problem of coordinating several sources of information is very common in learning complex performances.

When the trainer and training package had been refined to the point where students performed well, without much hesitation or fumbling, we tested for transfer to the real BCC. Two men got the introduction, the demonstration, and they practiced the seven representative problems on the trainer. This took about an hour and a quarter, which was typical for the training package. Then they transferred to the real BCC, with inputs from the simulator and the radars; they performed several problems while referring occasionally to their flow charts. They performed with fair dexterity; there was no sign of any difficulty in relating elements of the real BCC to the corresponding items in their earlier training. Two of their comments seemed significant. They noted that all the noise and the darkness would make it very difficult to learn the basic skills. And they noticed how much time was wasted while the problems developed, or when the radar was malfunctioning. It is readily apparent on the trainer that the self-paced problems are greatly compressed in time. For those familiar with Hawk training, the training package seems to be very efficient in developing a rather complex performance.

Eight copies of the device have been produced by Fifth Army Training Aids, following the HumRRO prototype, and they have been installed as a routine part of the TCO course. Unlike the full simulator, they will be introduced early in the course, so that knowledge of these procedures can be used as a conceptual framework for absorbing facts in the classroom. Knowing the procedures should also help the man determine the relevance of information in the course. They will still get experience with the high-fidelity simulator, but now they should be much better prepared to benefit from that experience.

I have tried to show some of the promise in low-cost simulation and some of the techniques needed to make it a practical training tool. Low-cost simulation is not antagonistic to high-fidelity simulation; each has its proper role. I've discussed some of the practical considerations besides dollar cost and fidelity. I've tried to emphasize the importance of programming software for "getting it all together": conceptual background, physical cues and the environment, necessary prompts, and teamwork.

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ABOUT THE AUTHOR

DR. ELMO E. MILLER is Senior Scientist in HumRRO Division No. 5 in Fort Bliss, Texas. His education includes a B.A., magna cum laude, Phi Beta Kappa, 1952; M.A., 1955; PhD, 1958, University of Minnesota. He is affiliated with the American Psychological Association, American Education Research Association, Southwest Psychological Association, and is a Certified Psychologist (Texas).

Dr. Miller served in the Navy as an Aviation Experimental Psychologist from 1956 to 1958, studying various problems in flight training and flight safety. In 1958 to 1959, on the staff of the University of Illinois, he devised a learning taxonomy for the Air Force. From 1959 to 1960 he worked for Link and for Honeywell on various problems in simulation design, joining HumRRO in 1963.

Dr. Miller currently is conducting research on low-cost simulation in practical exercise instruction. He also is developing a coherent technology for simplifying printed instructions, including not only language techniques, but also innovations in illustrations, tables, graphs, and format. In directing other HumRRO projects, Dr. Miller has innovated a wide variety of techniques for "picture-guides" and other media. He has further contributed to task analysis technology with his taxonomies which give generalized approaches for training various practical skills.

Dr. Miller has authored numerous publications in his field, the most recent being "Military Psychology," The Psychomotor Domain Movement Behaviors, Robert N. Singer (Ed.), Lea and Febiger, Philadelphia, 1972.