AUTOMATED GCA-FINAL APPROACH TRAINING

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Recognizing that recent results from training research and development programs as well as from advanced digital technology could contribute to the solution of training problems, the NAVTRADEVCEN in 1969 initiated a program to test the feasibility of implementing some of these advances.

As part of this effort, LOGICON, INC. analyzed the feasibility of automating portions of weapon system trainers (WST) and prepared some design guides to illustrate implementation on selected flight profile segments. The F-4 trainer was chosen as a sample case. The initial effort involved a survey of typical trainers in operational use. This review of on-going training utilizing WST's concluded that in large:

- WST's were being used primarily for cockpit orientation and procedures training.
- There was a lack of a well-defined approach for utilizing WST's.
- There was a lack of performance criteria and measurement.
- The instructor's role was not well-defined and their approach to training varied widely, especially in student evaluation.

The study indicated that the major technical problems in automated training involve:

- The development of computer programs to evaluate student performance and restructure the training course in real-time.
- The implementation of computer control of all training steps and functions.

The next effort undertaken, by LOGICON, INC. was to demonstrate technical feasibility, the problem being stated as one of implementing sufficient automated weapon system training to demonstrate technical feasibility in terms of computer programs and crew station development, within realistic and practical constraints.

The initial task involving a review of feasible simulators for the test, resulted in the selection of the Training Device Computing System (TRADEC System) at the Naval Training Device Center. This system, which was designed for Research and Development efforts, has the flexibility required for experimental tasks, and most importantly, could be modified and scheduled relatively easily.

Once the TRADEC System had been selected, the training task was bounded in scope and content. The TRADEC System includes a simulated single seat fighter type aircraft. The F-4 aerodynamic equations are utilized. Figure 1, is a block diagram of the major subsystems. The ones of particular interest include the motion system and the COGNITRONICS speechmaker. The latter device assembles a fixed vocabulary into phrases and sentences under computer control. The motion system is driven by the F-4 program contained in the computer. Thus, the TRADEC System constrained the training task to a basic fighter aircraft task with oral command capability. Instrument flight would be required since visual projection equipment is not installed.

A review of the flight segments analyzed in the earlier LOGICON study clearly indicated that the Ground Controlled Approach (GCA) was the most logical task to employ since:

- The task requires an elementary cockpit; i.e., no navigation or flight director system.
- The task is performed under instrument flight conditions.
- The task is a common operational task of fighter aircraft and is of relatively short duration.

The COGNITRONICS Multiplex Speechmaker provided the solution to the GCA voice command input requirement.

Emergency procedures, compatible with the GCA, were selected for additional demonstration tasks. A review of F-4 aircraft emergencies resulted in the selection of two: (1) single engine failure; and, (2) communication failure as feasible for implementation and compatible with the GCA task.

Potential student populations were reviewed. The requirements for a reasonable testing period and meaningful results for weapon system training for operational application dictated the use of qualified military pilots as the primary group.

An analysis of the GCA task was conducted to identify the performance criteria, performance measures, task structure, typical operational environment, and task difficulty factors. For example, standard terminology was collected and tapes of actual F-4 GCA's were recorded and reviewed. Handbooks on the F-4 and GCA Systems, including the SPN-35 and SPN-42 systems, were studied.

The complete GCA includes both a vectoring mode (Airport Surveillance Radar (ASR)) and a precision approach mode (Precision Approach Radar (PAR)). It soon became clear that the vector mode, although not technically difficult to mechanize, would involve extensive modification to the F-4 software. Therefore, the final approach phase, PAR, was isolated for the flight task.

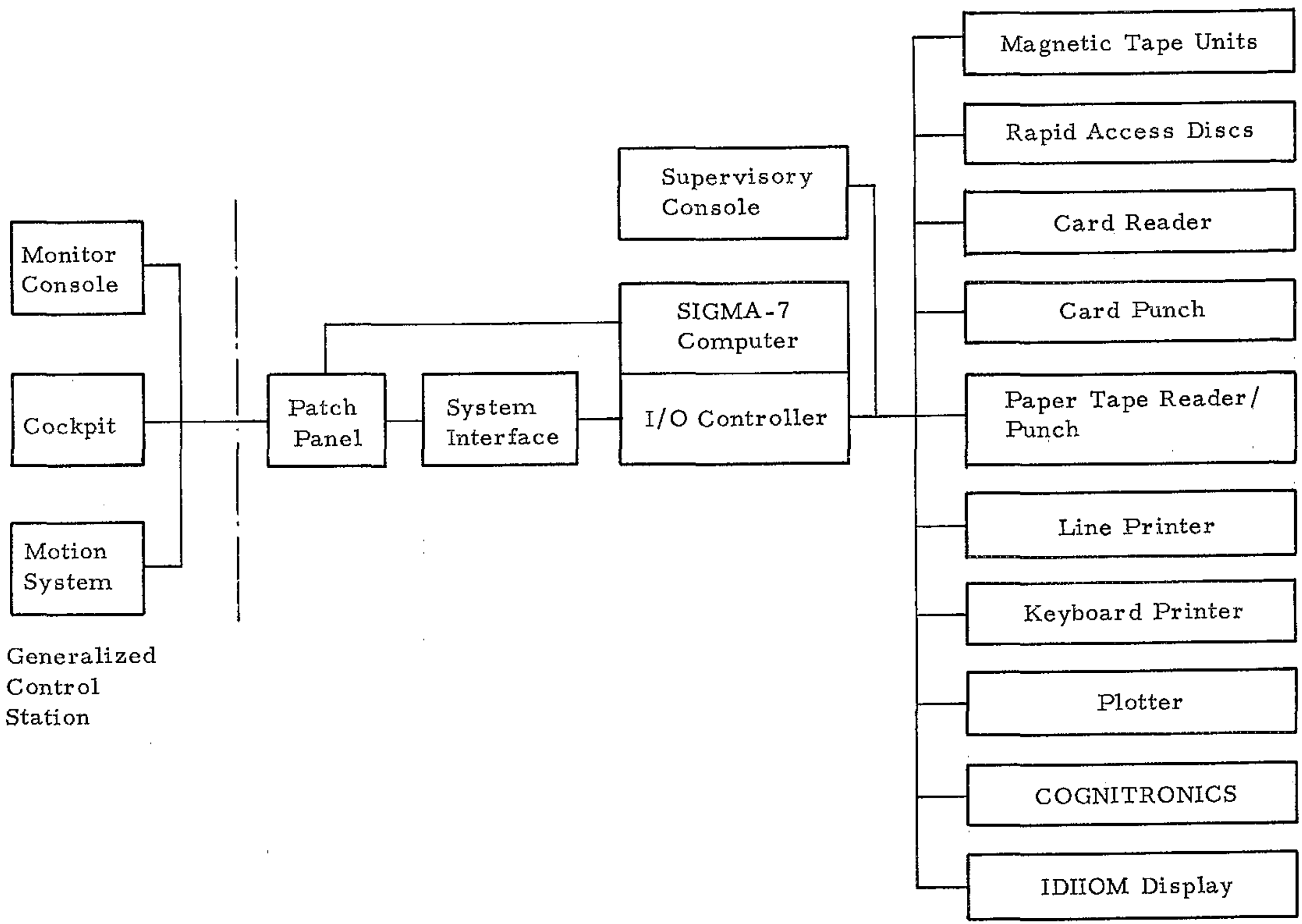

Figure 1. TRADEC System

Functional descriptions provided the foundation for the design and development of the computer program and training program. The end product was a design package which was used to implement the demonstration program. It included:

- A detailed description of the test to be performed to demonstrate the automated training techniques.
- The design and development of the software required for the demonstration.
- Preparation of training schedules, data forms, and student briefing lectures.
- Specification of the required changes to the existing TRADEC hardware/software to properly interface the proposed demonstration program.
- The design of a test plan to adequately check out both the experimental concepts and the program itself.

Three design tasks were conducted. The first involved the development of a sequence of GCA's of increasing difficulty; the second involved design of a system for scheduling the GCA; and the third involved development of a measurement system.

A training course consisting of 38 different runs for GCA training and five for emergency procedures was designed. The analysis of the GCA requirements had produced three major task difficulty factors. These were changes in aircraft weight and drag, atmospheric turbulence, and runway wind conditions. Five conditions and levels for each factor were selected. All reflected F-4 operational capability.

An adaptive logic program was developed to permit the student to complete the course in accordance with his ability. Figure 1 is a flow diagram of the logic developed. The procedure is actually "adaptive-adaptive" since a series of successful runs can accelerate the schedule.

A variety of performance measurements were investigated ranging from control stick displacements and rates to vehicle angles and rates to GCA errors. As discussed earlier, interpretation becomes difficult for all but direct system performance measures. Fortunately, the GCA has very definitive performance requirements. Therefore, measures related to operational performance were feasible. Two separate scores were developed. The first reflected performance during the run. The second reflected offset position relative to the runway at the conclusion of the control phase of the PAR.

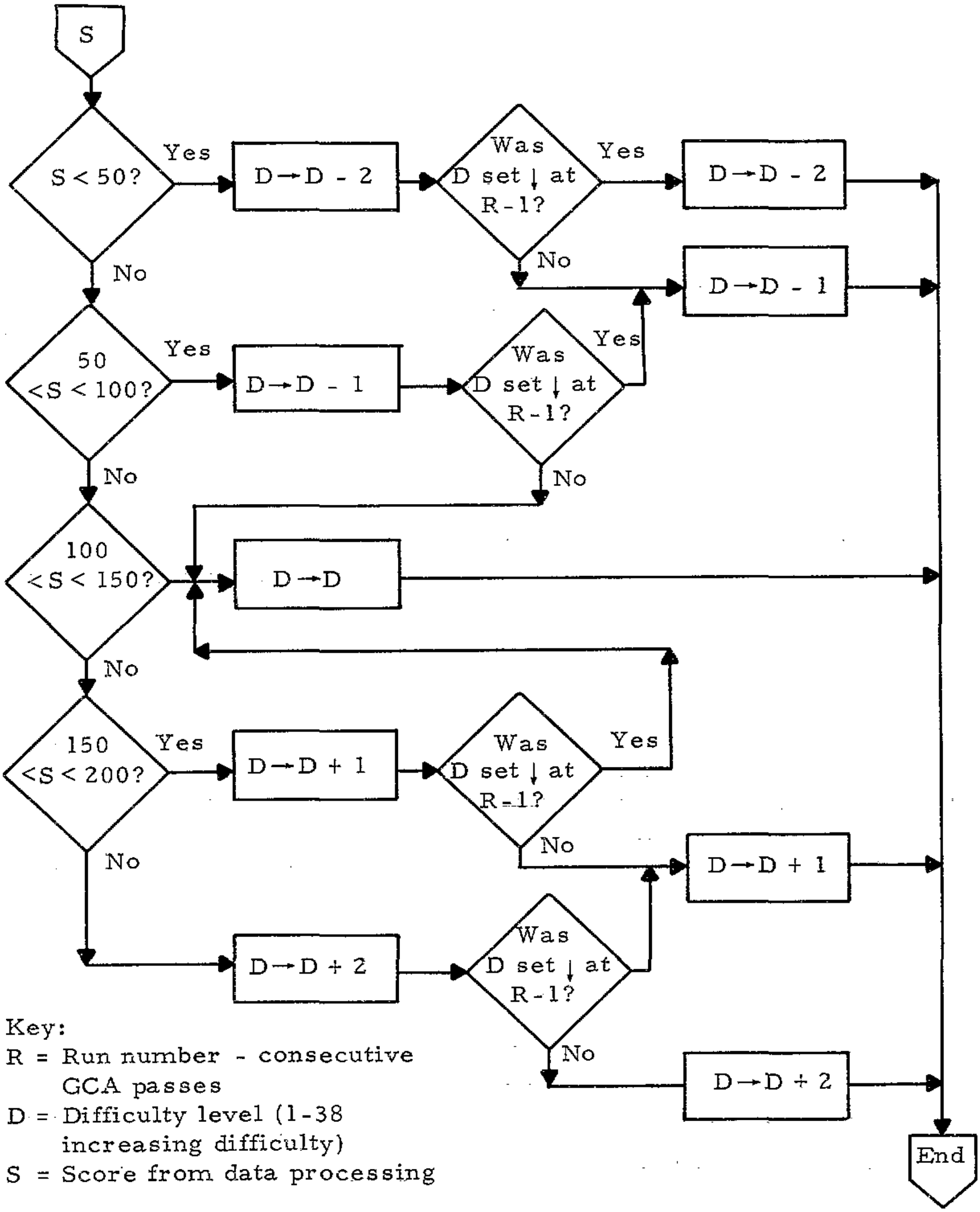

Figure 2. Adaptive Logic Flow Chart

Approach path performance was measured in terms of position error and angle of attack at a one second rate while on final approach. Final performance was measured in terms of actual position with respect to the glide path at the time of passing through final "gate". Five measures were taken:

1. Lateral displacement in feet from the approach course centerline.

2. Vertical displacement in feet from the glide slope centerline.

3. Angle of attack error in units from optimum.

4. Rate of heading change in degrees per second.

5. Rate of angle of attack change in units per second.

These measures resulted in 15 path measures and 5 gate measures. These were combined to provide a single score for input to the adaptive scheduling plan. In effect, a path score was computed for all runs. If successful, a gate score was computed and the path and gate scores were combined for a total run score. If the run terminated in a wave-off or a crash, the path score was adjusted to compensate for the proportion of the run completed.

The original constraints imposed on software design reflected the requirement for compatibility with the F-4 simulation program, especially in cycle time, and with the TRADEC System capability in general. Since the time remaining in the computation cycle was limited, it became clear that an executive program would be essential and that a modular approach to the program would be optimum. The executive program was required to monitor and control execution of the modules and provide the interface with the existing TRADEC software. Other functions of the executive program included:

- Monitor inputs
- Direct outputs and feedback parameters
- Control communications between modules
- Transmit data between operator and program
- Schedule events
- Establish priorities
- Allocate memory for the modules
- Provide procedures for error recovery
- Provide timing and accounting parameters.

The basic design of the executive program involved a foreground and background mode. The advantages of this design included:

- Program modules were list ordered by execution priority.
- The Executive Routines were independent of the other modules.
- Priority of any Foregound or Background (F/B) program was easily changed by reordering the program lists.
- Active modules could activate or deactivate any other F/B program.
- Inactive modules were easily bypassed.
- New modules were added by simply inserting the program and a one-word linkage to the list.
- Obsolete modules were removed by simply removing the program module and the one-word linkage.
- Modules could be virtually removed by deleting the one-word linkage.
- Foregound modules could be transferred to Background (and vice versa) by interchange of the one-word linkage.

These features are obviously desirable for an advanced program where flexibility is essential. Figure 3 illustrates the basic hardware/software system flow.

A total of 12 Navy and Air Force F-4 pilots were "trained" during the test phase. Additional data on two nonpilots was accomulated for comparison.

All of the 12 F-4 pilots were on operational flight status with an F-4 squadron. The pilots were only available for one day because of operational and training commitments. Therefore, the training plan was a "pilot-demand" schedule in which the pilots flew GCA runs until they were tired or wanted to rest. Two pilots were scheduled per day so that they could alternate flying and resting. Training began about 0900 and continued as late as the pilots were willing to fly or until they completed the course. This procedure resulted in a median number of trials per session of seven.

Five of the 12 pilots completed the GCA course in terms of reaching the most difficult level of the syllabus. The median number of runs for these pilots was 26 as opposed to a median of 30 for the pilots, who did not complete the course, because of time limitations or fatigue.

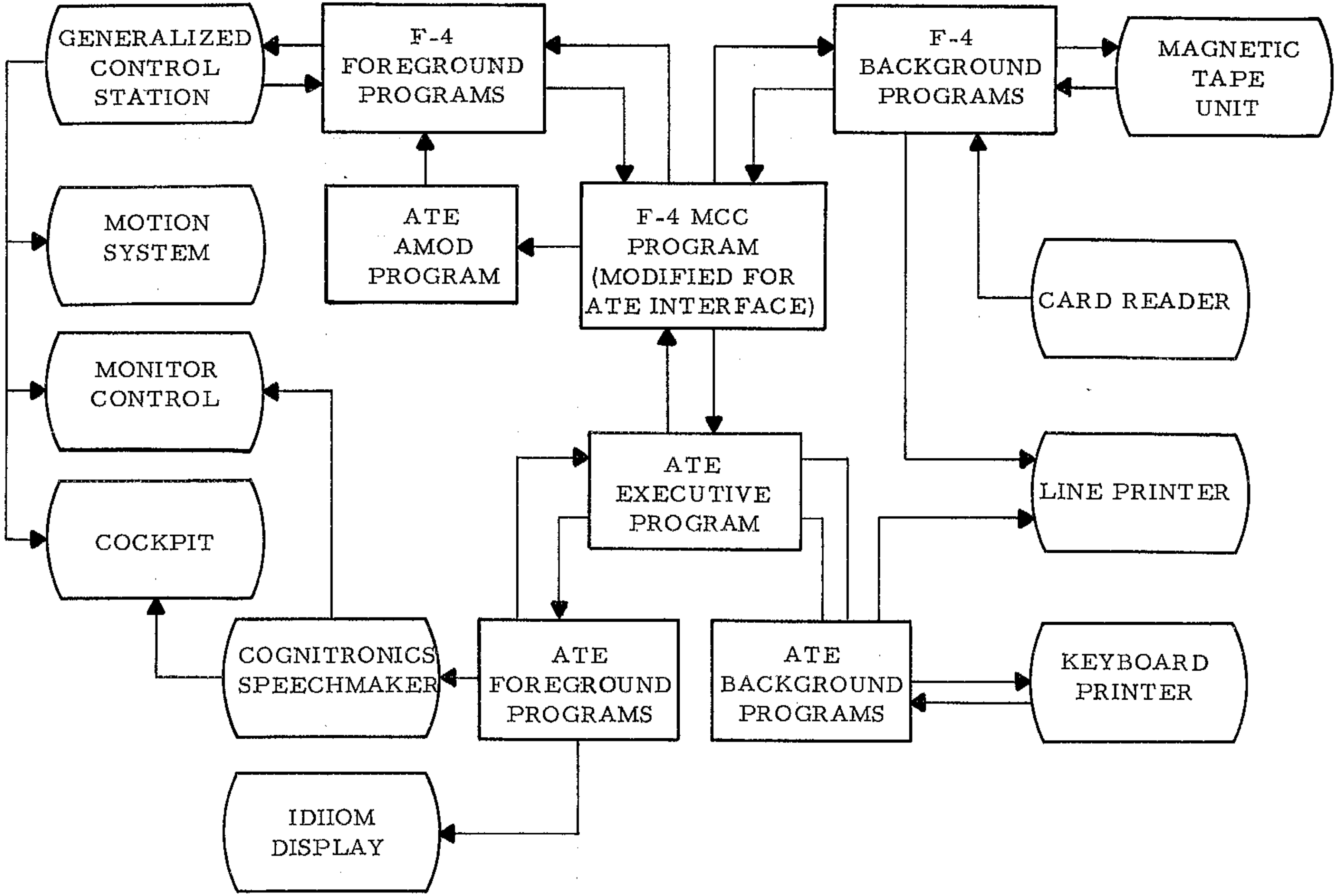

Figure 3. F-4/ATE Basic Hardware/Software Systems

Plots of the progress of each pilot as a function of the run number and difficulty level reached were made. Figure 4 is a sample plot.

It was concluded that the technical feasibility of the concept of automated instruction in a weapons system trainer has been demonstrated and that the state-of-the-art of digital systems and training methodology appears adequate for implementation of automated training.

Based on the limited nature of the tests concluded, the following additional conclusions are suggested:

- Automated flight training is acceptable to pilots.
- Adaptive training techniques can be implemented and appear effective and acceptable by the students.
- Voice generation techniques are adequate for simulation purposes.
- Pragmatic solutions to student performance measurement are feasible and prove useful for training control. Total system performance criteria, however, must still be established and measured.

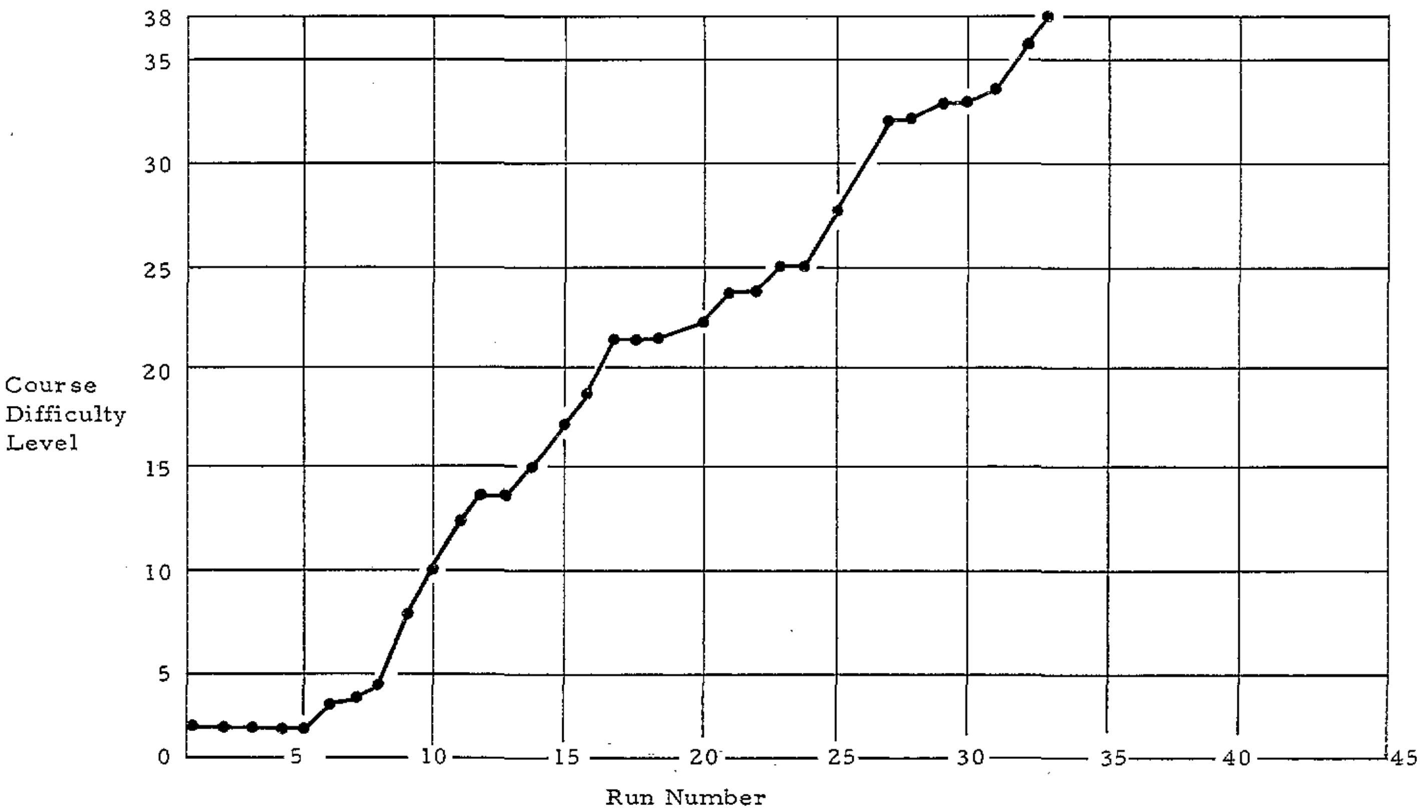

Figure 4. Sample Pilot Data