LOW COST PERSONAL COMPUTER
RIFLE MARKSMANSHIP EXPERT TRAINER (MET)

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ABSTRACT

The Naval Training Systems Center has developed a low cost marksmanship expert trainer, MET, that allows low cost marksmanship training without an instructor, real weapon or rifle range. The system is safe and does not use costly ammunition. As part of this program, a special long range light pen was developed. The U. S. Navy is currently contemplating the use of this system to teach marksmanship in the Navy's Recruit Training Centers. Teaching marksmanship has required live rounds, special ranges, and a large number of instructors. At present, Navy investment in real estate in close proximity to recruit training centers to construct rifle ranges would be difficult. Also, a large number of experienced instructors would be needed and the high cost of live rounds will add greatly to the Navy's training budget. This paper describes the MET system and the technology applied to this new rifle marksmanship training device. An expert system has been developed to alleviate both the cost and shortage of instructors. The expert trainer is controlled by a personal computer, the Zenith 248. The MET collects real-time shooter performance data or facts, and then executes rules that analyze the trainee performance. Trainee feedback is provided on the computer monitor and by a computer generated voice. The feedback describes the source of shooting errors including improper sight picture, poor shooting position, incorrect trigger squeeze, and incorrect breath control. Through detailed guidance, the novice is able to transition to marksman.

INTRODUCTION

To defend Naval bases and ships against increased security threats, it is imperative that sailors be trained in the basics of marksmanship. In order to teach marksmanship with live rounds, special ranges, weapons, and instructors are required. To do this, the costs and resources requirements are prohibitive. In the case of recruit training, providing such a capability requires substantial resources. The Navy lacks the real estate in proximity to recruit training centers to construct rifle ranges and the shortage of experienced instructors, the high costs of operating ranges and the attendant safety considerations compound the difficulties. The development of a new low-cost transportable training device configured as an expert system for rifle marksmanship training will increase the Navy's capability for providing this instruction.

The MET instructs rifle marksmanship without an instructor, real weapon or rifle range. The expert system is controlled by an inexpensive personal computer, the Zenith 248. This PC is the standard Navy computer and is available through the supply system. The MET system consists of the following components: long range light pen, Zenith 248, color monitor, computer speech board, analog and digital I/O board, and force sensing resistors. MET systems will be networked so that an instructor can provide special help if deemed necessary by the expert system. Networking will permit one instructor to handle as many as eight students.

The MET is based on the four fundamentals of shooting: (1) assume a steady position, (2) put the front sight post on the target, (3) stop breathing and, (4) squeeze the trigger. Sensors attached to the trainee and the weapon measure all of these parameters.

A long range light pen is attached to the M-14 rifle and targets are displayed on the Zenith 248 monitor. The light pen is utilized to determine hits on the target and tracking steadiness. A breath sensor is placed around the trainees diaphragm to determine if he held his breath prior to firing the weapon. A force sensing resistor is utilized on the trigger to determine how the trainee squeezed the trigger.

The trainee can select via a menu, controlled by pointing the weapon at the monitor, which target or training scenario he desires. Feedback is provided by computer generated voice and monitor graphics. Bang and recoil of the weapon are also simulated.

The instructor station will allow the instructor to view the progress of up to eight students. MET will inform the instructor of any student needing special instruction. A photograph of the system is shown in Figure 1.

MET EXPERT SYSTEM PARAMETERS

MET uses the following light pen and sensor derived data to coach the student using the computer generated voice and monitor graphics:

Shot Location - X and Y light pen coordinates
(X = 0 to 639)
(Y = 0 to 199)

Tracking Data - X and Y light pen coordinate data recorded at a 60 Hz rate. A circular buffer of 30 coordinate locations in X and Y is constantly updated prior to trigger pull. These data represent one half second of tracking data prior to trigger pull, and is a function of steadiness.

Trigger Sensor Data - Data from a force sensing resistor is converted and stored in a circular buffer at 60Hz. Data representing one quarter second before trigger pull is analyzed to determine force vs time characteristics. This allows determination of proper or improper trigger squeeze.

Breath Sensor Data - Data from a strain gauge located on a breath sensor belt is converted and stored in a circular buffer at 60 Hz. These data represent breath data one second prior to trigger pull and are utilized to determine if the shooter was inhaling or exhaling at the time of trigger pull.

Using the above light pen and sensor data, mathematical functions are calculated for use by the expert system, to analyze shooter data and provide feedback to the trainee using a computer generated voice or graphics on the monitor.

Presently, the trainee fires ten (10) shots which is a minimum significant statistical sample. Using the data discussed above, the following functions are calculated.

Shot Location Data (10 Shots)

    X (mean), Y (mean)
    X (standard deviation), Y (standard deviation)
    Diameter of shot group

Tracking Data (30 readings - 0.5 seconds prior to trigger pull)

    X track (standard deviation)
    Y track (standard deviation)

    Mean X track (standard deviation) for 10 shots
    Mean Y track (standard deviation) for 10 shots

Trigger Sensor Data (10 shots)

    Mean and standard deviation of trigger measurement for 10 shots

Breath Sensor Data (10 shots)

    Difference in breath sensor output over a one second period prior to trigger pull

Other sensors i.e., rifle butt pressure sensor will be added later to enhance the expert system, if deemed necessary.

Using the above data, the MET expert system generates the appropriate feedback to the trainee. Figure 2 is the MET decision flow chart for the expert system. Much of the knowledge base used to formulate the expert system was derived from a PMTRADE sponsored project that developed an artificial intelligence test bed.

MET SYSTEM CONFIGURATION

The MET system consists of the following components: (Figure 3)

    Long Range Light Pen - NTSC Design
    Zenith Data System ZVM-1380 EGA-RGB Color Monitor
    Zenith ZWX-248-62 Microcomputer and Inteface boards:

        MetraByte DASH-08 A/D Converter Board
        FTG PXL-350 Hi-Res Light Pen Board
        Antex VP-600 Computer Voice Board

    Sound System and Head Set
    Breath Sensor-NTSC Design
    Trigger Jerk Sensor-NTSC Design
    Recoil Simulator-NTSC Design

Targets are displayed on the color monitor. A long range light pen is attached to the rifle barrel and is used to determine where the student is sighted on the screen as well as rifle movements prior to firing the weapon. The light pen senses light emitted from a small point on the monitor as the point is scanned across the face of the monitor to create the target display. The light pen has an optical system that limits the amount of the screen viewed to a very small area. When the computer scanned dot is sensed by the light pen optical detector, it sends a pulse to the Zenith computer telling it to read the values of X and Y counters. The counters are controlled by the horizontal and vertical sync from the monitor. The value of the counters are used to determine the lightpen's location at a 60 Hertz rate.

The light pen functions at ranges up to 20 feet from the computer monitor screen, which displays the target and or computer feedback data. The light pen determines where the round would impact on the target and how the trainee is tracking the target, with the simulated weapon.

The light pen uses a small two lens element optical telescope to limit the field of view of the light pen. A photodiode detector with an eye-response optical filter is used to detect the scanned light spot. A transimpedance amplifier converts the light pen current to a voltage that is then amplified. Several electronic filters are used to eliminate power ripple and interfering light sources. The filter has a cut in frequency of 14 KHz. The amplified signal is threshold detected using a voltage comparator. The voltage comparator output pulse is sent to the PXL-350 Hi-Res Light Pen Board. When the light pen detects light from the target monitor, it sets a video latch which freezes the counters. After the Zenith software reads the counters, it clears the video latch and re-enables the X-axis and Y-axis counters. The counters determine the X and Y location the light pen is pointing on the target monitor screen. A separate 12-bit counter is used for both the X and Y coordinates. The X - axis counter is clocked with a 30 Mhz signal that provides single pixel resolution on the monitor screen. The X-axis counter is reset to 0 by horizontal sync pulses, (horizontal retrace). The Y-axis counter counts horizontal sync pulses, which is equivalent to counting the number of lines. The Y-axis counters are reset to 0 on vertical sync pulses (vertical retrace). When light is detected by the light pen, the counter gates interrupt the clock and reset signals to the X and Y counters. This freezes the counter state when the video latch is set, by the light pen. The counters are frozen with the X and Y coordinate data until the system reads the counters and clears the video latch. Figure 4 is a block diagram of the light pen and light pen board. Figure 5 is a photograph of the light pen.

The Zenith 248 personal computer was chosen because it is a Navy/DoD standard computer and is available in the supply system. The Zenith utilizes an Intel 80286 microprocessor and is IBM PC/AT compatible. The operating system is MS-DOS V3.2.

The display is a ZVM-1380 RGB color monitor and is EGA compatible.

A MetraByte 8 channel high speed A/D converter is used to collect data from the breath sensor and trigger jerk sensor. It is also utilized to control the recoil simulator. The A/D has 12 bit resolution.

A force sensing resistor (FSR) is attached to the trigger to measure if the trainee is squeezing or jerking the trigger. The FSR is a new type of thick film electronic component. The resistivity across the device drops in a non-linear fashion as the applied force, perpendicular to the sensor, is increased. The FSR consists of two parts sandwiched together. The first part is a special conductive polymer. The second part is a conductive finger arrangement. The two parts are formed by silk-screening the appropriate materials onto mylar sheets of various thickness, size, and shape.

A very small Shunt-Mode style FSR was constructed on a 5 mil mylar and placed on the surface of the trigger. A non-linear amplifier utilizing the characteristics of an ordinary diode was used to linearize the sensor such that useful analog data could be obtained. The signal was then conditioned for input to the A/D converter.

A breath sensor is strapped around the trainees chest to determine if he has frozen his breath, prior to firing the weapon. Two strain gauges are used in a bridge configuration to double the overall sensitivity. The sensors are mounted on a flexible material that will flex according to the trainees breathing pattern. The very small electrical signal, generated from the bridge arrangement, is then amplified by a Differential Instrumentation amplifier. The signal is further filtered and conditioned for input to the A/D converter.

Recoil is simulated by pulling the weapon from the rear with a flexible cable. The recoil simulator consists of an electric motor, electromagnetic clutch, and flywheel. When the rifle is fired, the clutch is energized for milliseconds engaging the flywheel pulling the cable which is attached to the top of the rifle butt plate. The recoil device will accommodate any firing position.

The trainee wears a head set that is used to both simulate the weapon firing report and provide computer voice feedback. The feedback is individualized based on the trainees progress. Various messages sent to the trainee are shown in Figure 2. Future vocabulary words can easily be added to the trainer.

CONCLUSIONS

The laboratory marksmanship expert trainer has been fabricated and demonstrated with good success. At present, a prototype system is configured with one instructor station and three trainee stations. This system will undergo evaluation testing in August at the Naval Training Systems Center in Orlando, Florida and the results will be reviewed at the conference.

The initial system has been very reliable and all components are low in cost. Using expert systems principles, a trainee can be taught to shoot without a range or live rounds and use a minimum of instructor time.

This application of expert systems is unique in that it uses sensors on a weapon as well as a trainee to teach a psycho-motor skill. Its effectiveness should stimulate the application of expert systems to other psycho-motor training needs.

ABOUT THE AUTHORS

Mr. Albert H. Marshall is a Team Leader/ Physicist at the Naval Training Systems Center. He has specialized in developing weapon fire simulator using lasers, electro-optics and microprocessors. He holds twenty one U.S. patents. He has Master's Degrees in both physics and electronics engineering from Brown University and the University of Central Florida.

Mr. Edward J. Purvis is an Electronics Engineer at the Naval Training Systems Center. He has specialized in developing weapon fire simulators using electro-optics, microprocessors, video processors, and graphics. He has a Masters Degree in Digital Electronics from the University of Central Florida.

Mr. Ronald S. Wolff is an Electronics Engineer at the Naval Training Systems Center. He has specialized in developing weapon fire simulators. He has worked with electro-optics and interfacing various non-linear sensors to microprocessors. Mr. Wolff graduated from the University of Central Florida in 1985. He is currently pursuing his Master's Degree in electronics engineering at the University of Central Florida.

Mr. Robert T. McCormack is an Electronics Engineer at the Naval Training Systems Center. Specializing in weapon fire simulators, he has worked on computer program development and sensor interface to microcomputer/microprocessors. Mr. McCormack graduated in 1985 from the University of Central Florida, where he is currently pursuing his Master's Degree in Digital Electronics Engineering.
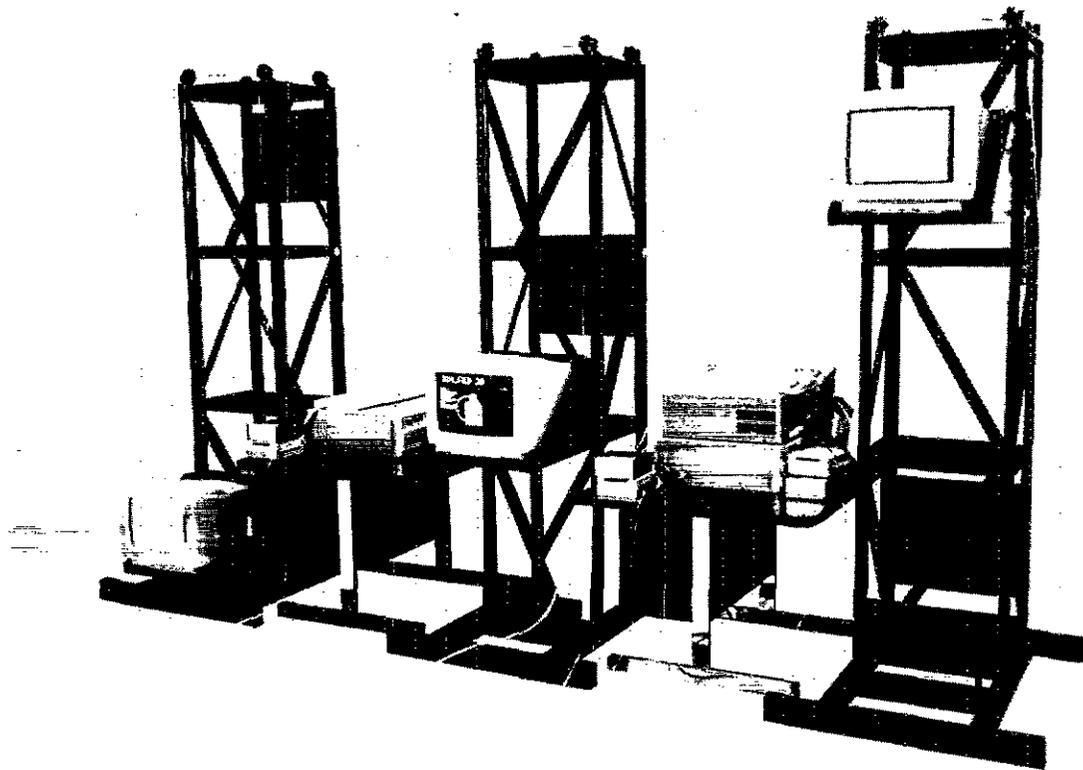
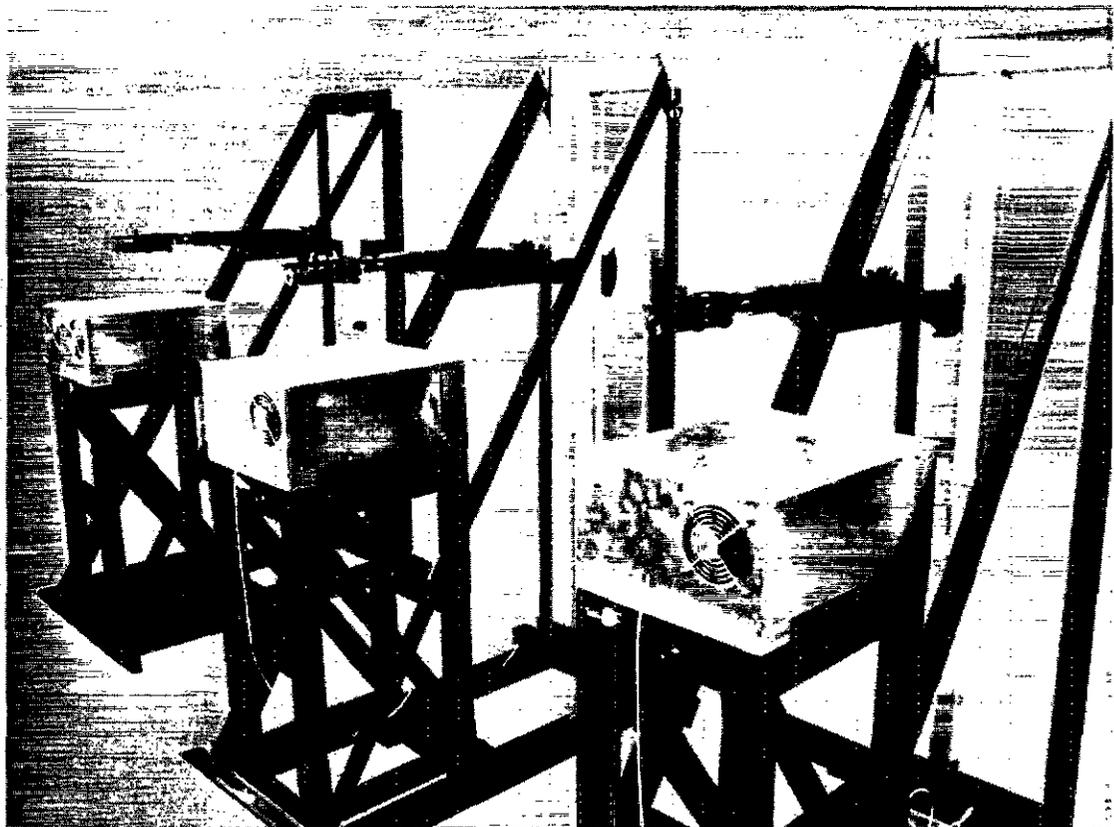Figure 1A. System (Three (03) Target Monitors and Computer Systems)

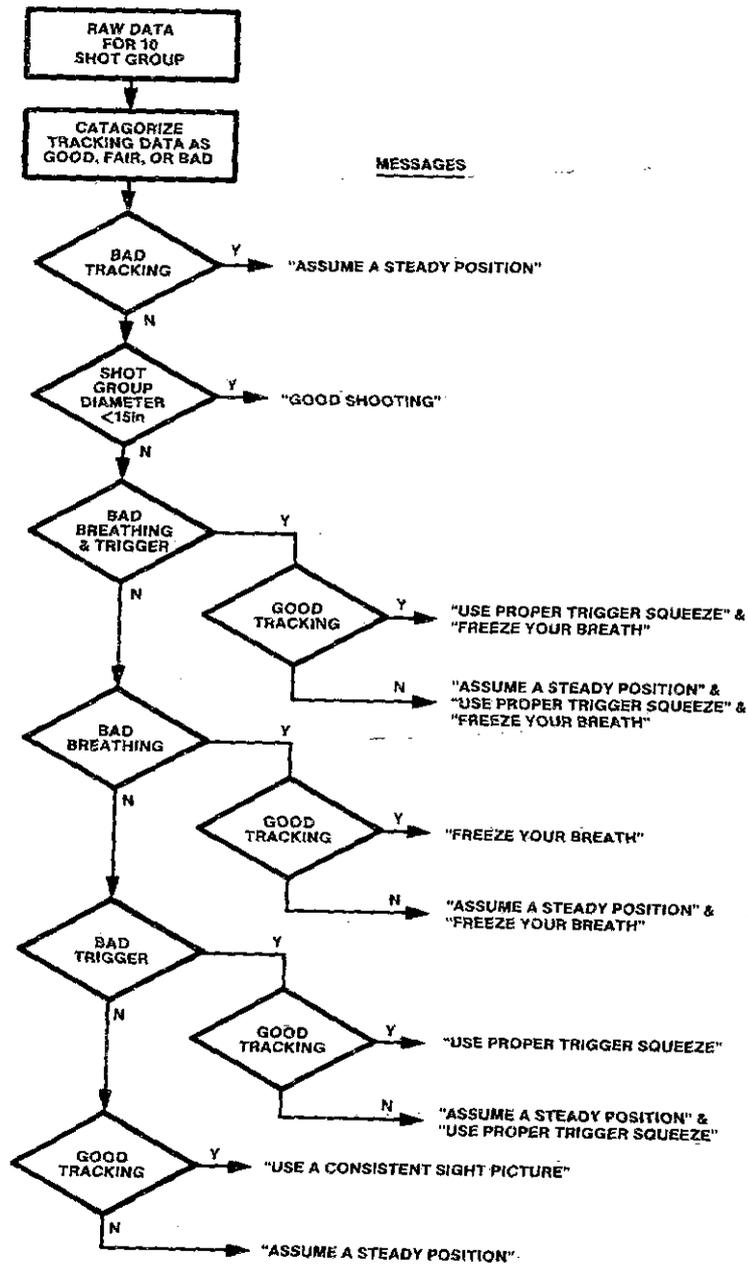Figure 1B. System (Three (03) Weapons and Recoil Devices)

RAW DATA
FOR 10
SHOT GROUP

CATAGORIZE
TRACKING DATA AS
GOOD, FAIR, OR BAD

MESSAGES

BAD
TRACKING — Y → "ASSUME A STEADY POSITION"

N

SHOT
GROUP
DIAMETER
<15in — Y → "GOOD SHOOTING"

N

BAD
BREATHING
& TRIGGER — Y

N

GOOD
TRACKING — Y → "USE PROPER TRIGGER SQUEEZE" &
"FREEZE YOUR BREATH"

N → "ASSUME A STEADY POSITION" &
"USE PROPER TRIGGER SQUEEZE" &
"FREEZE YOUR BREATH"

BAD
BREATHING — Y

N

GOOD
TRACKING — Y → "FREEZE YOUR BREATH"

N → "ASSUME A STEADY POSITION" &
"FREEZE YOUR BREATH"

BAD
TRIGGER — Y

N

GOOD
TRACKING — Y → "USE PROPER TRIGGER SQUEEZE"

N → "ASSUME A STEADY POSITION" &
"USE PROPER TRIGGER SQUEEZE"

GOOD
TRACKING — Y → "USE A CONSISTENT SIGHT PICTURE"

N → "ASSUME A STEADY POSITION"
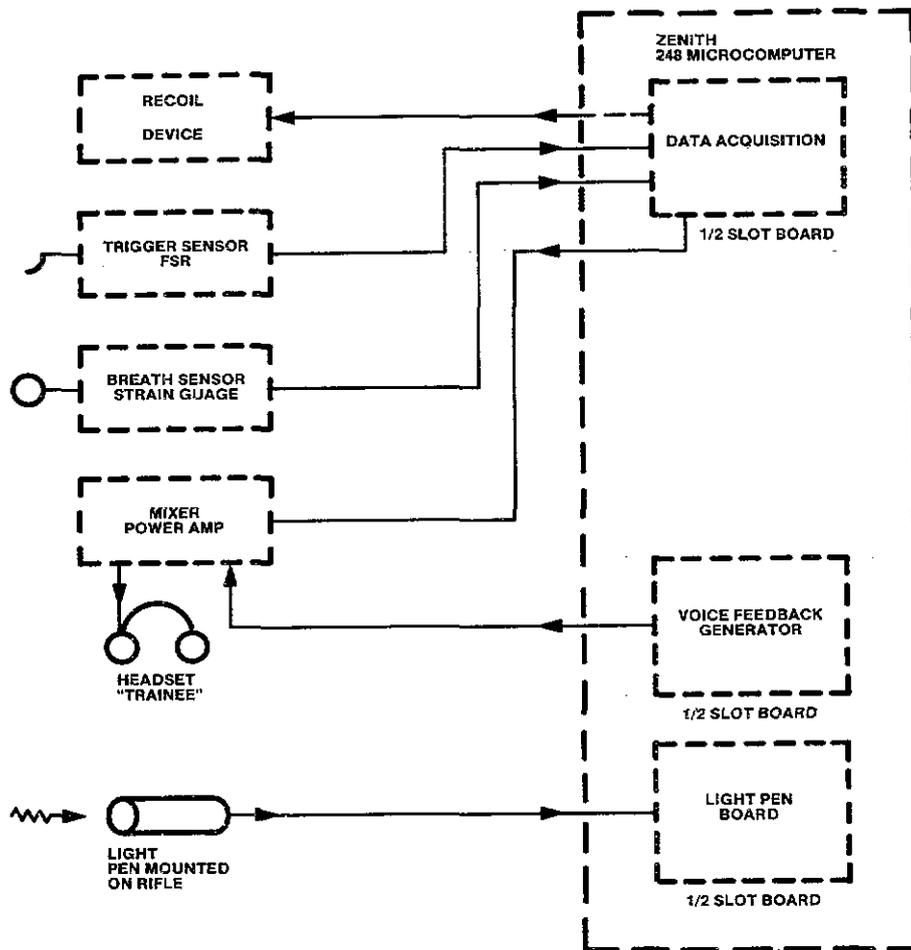
Figure 2. MET Expert System Flow Chart
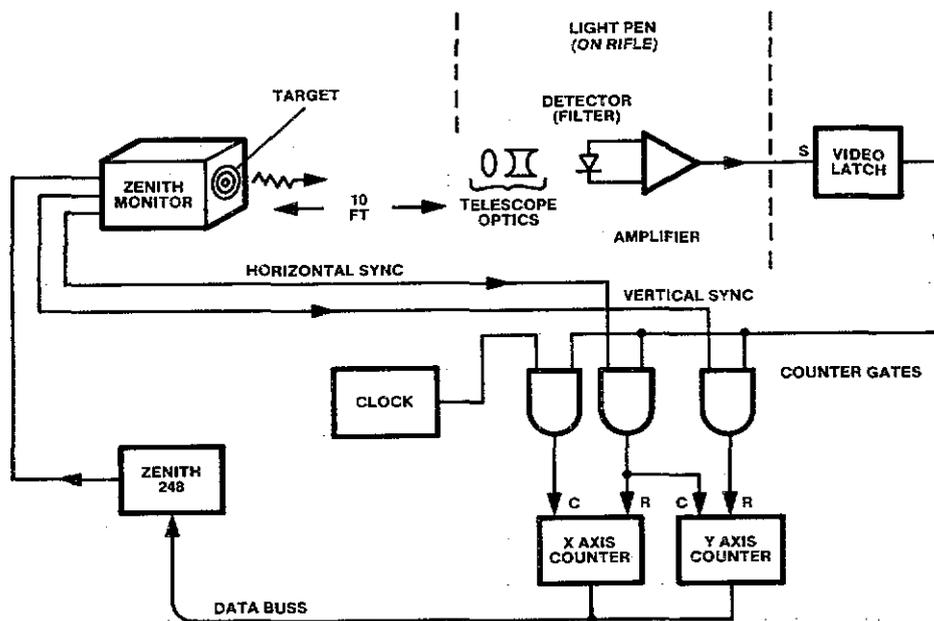
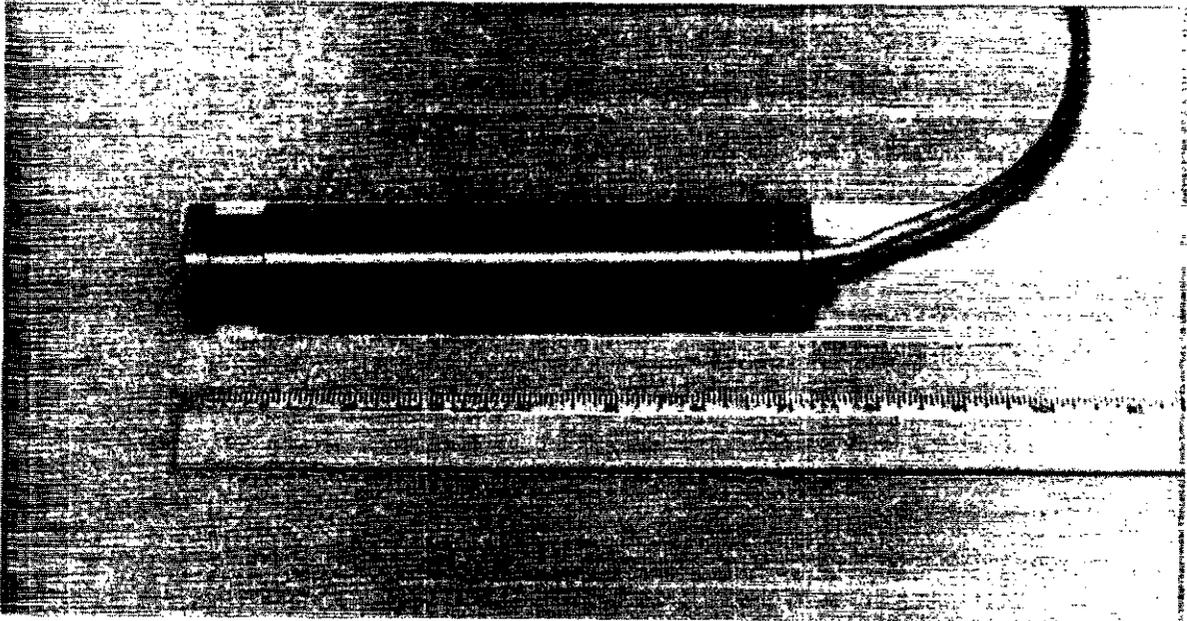Figure 3. MET System Block Diagram

Figure 4. Light Pen and Light Pen Board Block Diagram

Figure 5. Long Range Light Pen