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Automated Sensor Tester

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Abstract

The Automated Sensor Tester (AST) is being developed by Sandia National Laboratories for the Department of Energy (DOE) to be a tool to aid in testing exterior intrusion detection sensors in a fixed site security system. This is accomplished by automatically performing a simulated intrusion test of the sensors installed in the Perimeter Intrusion Detection and Assessment System (PIDAS). During the test, a target is moved across the detection zone of the sensor, simulating a human moving through the detection zone. The first phase of this project concentrated on automatically testing the bi-static microwave exterior intrusion detection sensor in one sector of a PIDAS. This sensor was selected because it is commonly used, and the test target has been determined and is presently in use. The goal of the AST project is to provide consistent test results, automatic data logging, easier data reduction and reduced manpower to perform the DOE mandated and frequent intrusion detection sensor tests. The AST will help to determine that the intrusion sensor being tested is functional and has even and adequate detection along its entire detection zone. The AST consists of two vehicles and a data logger. The Mother Vehicle contains the processing and navigation capability and deployed and retrieved the Target Vehicle. The Target Vehicle provided the alarm stimulus. The Alarm Interface / Data Logger was connected to the intrusion sensors alarm signal and recorded the test results. This system will autonomously conduct a series of tests on an entire PIDAS sector. This paper describes the three elements of the AST system and their operation.

Introduction

DOE high security sites have large Perimeter Intrusion Detection and Assessment Systems (PIDAS). The PIDAS can have 30 or more intrusion sectors that are 80 to

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100 meters in length. The intrusion sectors contain intrusion detection sensors that must be frequently and thoroughly tested, and the results documented to conform to DOE regulations. This requires significant manpower to perform the testing and record the results. Also, because human targets are of varying physical characteristics or the simulated intruder targets are deployed in varying manners, the test results can be inconsistent. The objective of the Automated Sensor Tester (AST) is to provide a tool for maintenance personnel to reduce the manpower required, to reduce the test variability, and to format the test data for easy reduction using standard spreadsheet software and a PC.

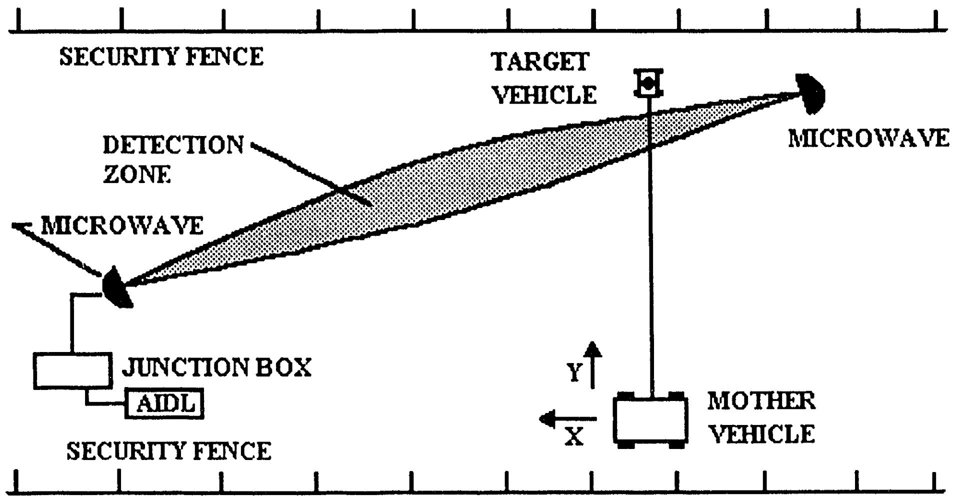

Figure 1. AST in a PIDAS Sector

Figure 1 is a sketch showing the AST system in a PIDAS sector. For simplicity, this sketch only shows a microwave intrusion sensor, a junction box, and the two perimeter fences of the PIDAS. A typical PIDAS would contain more than one intrusion sensor as well as light poles and camera towers that are not shown. There are three main components of the AST: the Mother Vehicle, the Target Vehicle, and the Alarm Interface / Data Logger (AIDL). The Mother Vehicle carries the Target Vehicle in a docking bay until it is in position for a sensor test. After the Mother Vehicle is initialized, it will follow the chain link security fence at a predetermined distance, stop at regular intervals, and send the Target Vehicle across the detection zone of the microwave to cause an intrusion alarm. The test interval is usually every 10 feet, or as entered by the operator. Testing is autonomous after the initial setup.

In order to perform the autonomous testing the Mother Vehicle must be able to: follow the fence, know its initial location, determine distance **along** the sector (X coordinate in figure 1), launch and retrieve the Target Vehicle, and determine the location of the Target Vehicle **across** the sector (Y coordinate in figure 1). Additionally, the Mother Vehicle must communicate to the AIDL and the AIDL must record the test data in a user friendly format. This paper will address the operational concept of the AST, and will describe the design and operation of the main components of the AST.

Operational Concept

The AST system was developed to autonomously test the microwave intrusion detection sensor in a single sector of a PIDAS. The operator must first position the Mother Vehicle in the PIDAS where the testing is to begin, and then connect the AIDL to the alarm signal of the sensor being tested. The menu option "test" is then selected from the menu, and various information is entered as directed by the prompts on the display of the Mother Vehicle. Figure 2 is an example of the screen prompts and operator responses. Upon entry of the final menu information, the AST system will autonomously test the entire PIDAS sector and record the results in a spreadsheet compatible format on a 3 1/2 inch floppy disk.

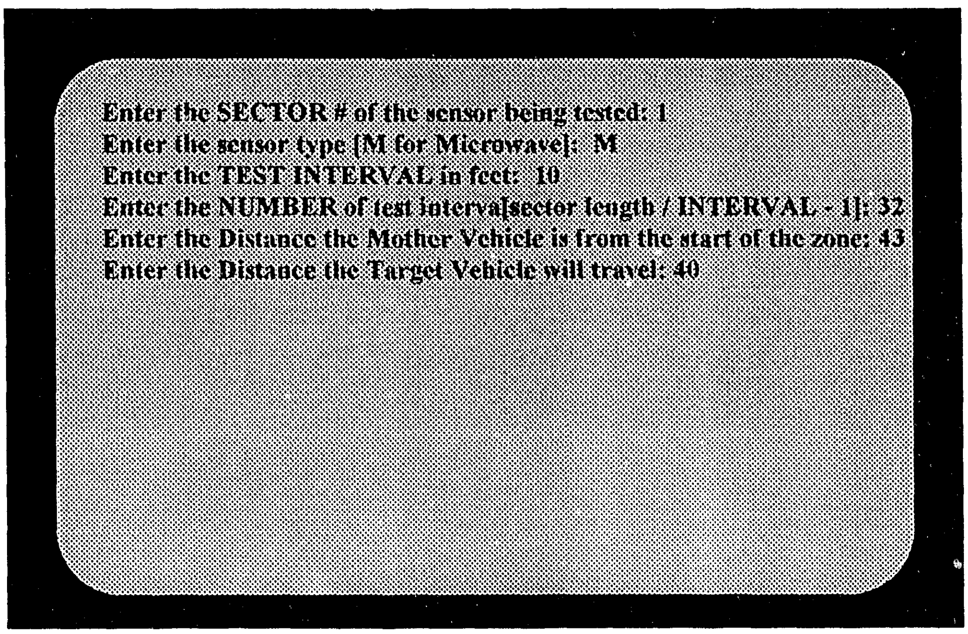

Figure 2. Screen Display

The Mother Vehicle carries and deploys the much smaller Target Vehicle (see Figure 3). An aluminum sphere mounted on the Target Vehicle presents the cor ˋct target signal to the bi-static microwave intrusion detection sensor. The Target Vehicle contains only a small motor and batteries inside the aluminum sphere that enable it to propel itself to the other side of the perimeter, unwinding a tow line from a reel on the Mother Vehicle. The Mother Vehicle keeps track of the Target Vehicle position both along the zone (X coordinate in Figure 1) and across the zone (Y coordinate in Figure 1).

The Mother Vehicle conducts each test by lowering the Target Vehicle ramp, sending a "test start" message via an RF modem to the AIDL, releasing the Target Vehicle, and then continually sending Target Vehicle coordinate information to the AIDL until the Target Vehicle has been deployed to the programmed distance. Upon Receipt of the "test start" message, the AIDL will monitor the alarm signal lines for an alarm level. When an alarm is detected, the next set of Target Vehicle coordinates will be recorded along with the number of the test. The Target Vehicle drags a tow line as it traverses the PIDAS sector. When the line is unwound to the programmed length, the Mother Vehicle will lock the reel. This action pulls a spring switch on the Target Vehicle and turns off its motor. The Mother Vehicle sends a "test stop" message to the AIDL. The AIDL stops monitoring the alarm lines and records a miss for that test number if no alarm was detected between the "test start" message and the "test stop" message. The Mother Vehicle then reels in the Target Vehicle, raises the ramp, and the Target Vehicle batteries are recharged while the Mother Vehicle proceeds to the next test location. This sequence is repeated until the entire sensor detection zone is tested at the selected interval.

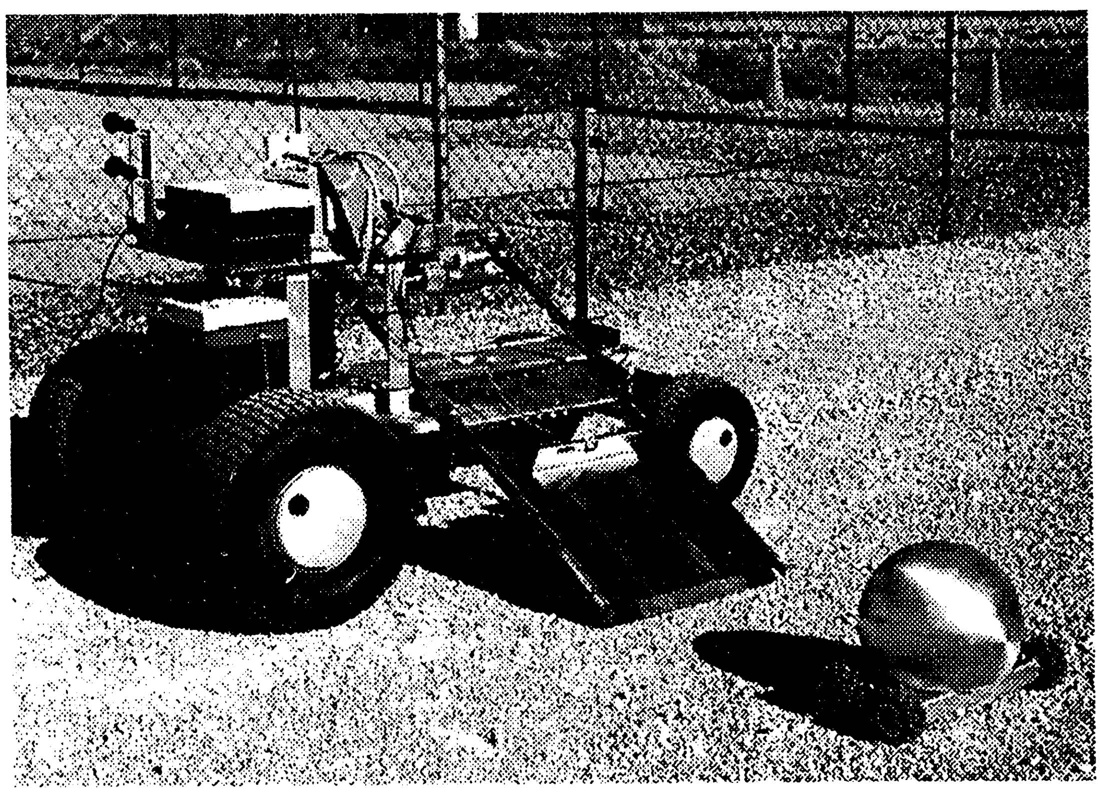

Figure 3. Mother Vehicle, Ramp down, Target Vehicle Deployed

<u>Mother Vehicle</u>

A Sears garden tractor was selected as the chassis for the Mother Vehicle for several reasons. The major reason was because it had four wheel steering. The platform was very maneuverable; it could turn in a 12 inch radius. It was also light weight, and it had wide tires that would prevent it from sinking in the loose gravel of the PIDAS.

Lastly, it was narrow and would fit through the access gates to the PIDAS. The chassis was stripped and batteries, an electric motor, actuators, sensors, and a STD Bus computer system were installed. Figure 3 is a picture of the Mother Vehicle with the ramp down and the Target Vehicle deployed. The Mother Vehicle has an ultrasonic ranging system that was used to maintain a fixed distance from the fence, and to keep the vehicle parallel to the fence. Odometry, along with the entered distance from the start of the sensor sector (ref. Figure 2) provided the location along the sector, or X coordinate. A ramp and reel system deployed and retrieved the Test Vehicle. The reel used to deploy and retrieve the Target Vehicle was encoded to determine the lateral distance that the Target Vehicle had traveled. This distance was added to the ultrasonically determined fence distance to derive the Target Vehicle location across the sector, or the Y coordinate. A keyboard and monitor displayed menu items and accepted operator input. Another input to the Mother Vehicle is a Pendant (see figure 4). It could be connected to the Mother Vehicle to allow the vehicle to be manually driven via switches and joysticks. The two joysticks controlled the front and rear steering and the rotary switch controlled the gear. A trigger, located in front of the Pendant handle (not shown in figure 4), controlled the throttle and the brake.

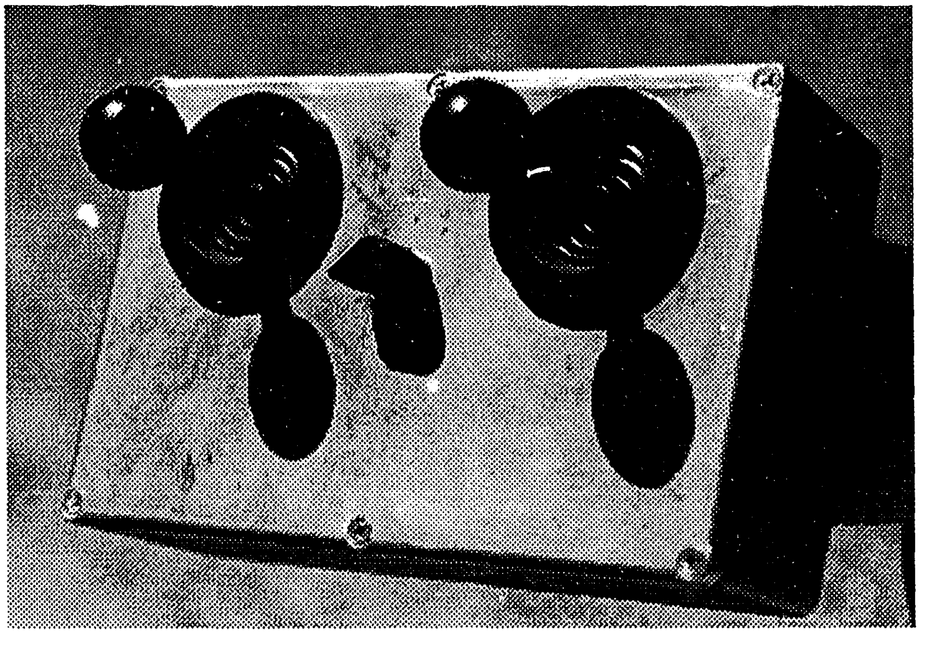

Figure 4. AST Pendant

A major characteristic of the Mother vehicle was the ability to provide range information to a chain link fence. This was important because the Mother Vehicle had to autonomously move from one end of a PIDAS sector to the other (up to 100 meters) while maintaining a location reference, and not colliding into any objects. A Sandia designed 8 channel ultrasonic electronic printed circuit board was used. This board could be populated for either 27 Khz or 40 Khz ultrasonic transducers. The system uses two transducers on the front and two transducers on the rear of the Mother Vehicle to look sideways. These ultrasonic pairs are used to determine the distance of the front of the vehicle and the rear of the vehicle to the fence. This distance information is used to generate independent front and rear steering commands during the autonomous testing. The fence following algorithm not only maintained a constant distance from the fence distance, but also kept the vehicle parallel to the fence by making adjustments to the steering commands according to the difference in front and rear distances. The fence distance was maintained by calculating the angle the wheels should be steered to arrive at the next test location. A correction factor was either added or subtracted to correct for the difference in front and rear distance to maintain a parallel orientation to the fence.

Figure 5 is a plot of the front and rear tracking distances from the chain link fence during a typical test run of the AST. The units of both the X and Y axis are in tenths of feet. The X axis is the distance the Mother Vehicle has traveled along the fence from the initial test location. In this case the test interval was 20 feet. The Y axis is the Mother Vehicle distance from the fence. The solid line represents the distance from the front of the vehicle and the broken line is the distance from the rear of the vehicle. The desired tracking distance is the average of ten ultrasonic samples taken after the final menu information is entered and before the first test is run. For figure 5, this distance was 5.3 feet from the fence. During this run the maximum error was +0.4 / -0.1 feet. Other runs showed similar results and the fence following error generally was less than 0.5 feet. This level of accuracy was adequate for AST purposes.

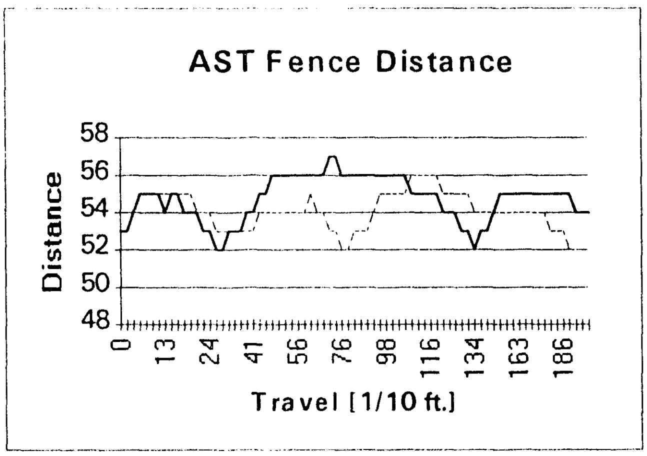

Figure 5. Ultrasonic Distance Plot

Alarm Interface / Data Logger

Figure 6 is a picture of the Alarm Interface / Data Logger. The AIDL consists of a STD bus chassis with a processor, A/D card, floppy disk drive, and a spread spectrum modem. The function of the AIDL is to monitor the alarm lines of the intrusion sensor being tested and record the location coordinates of the Target Vehicle when alarms occur. The alarm output of most intrusion sensors is relay contacts. When the intrusion sensor is connected to a security monitoring system, the relay contacts are included in a resistor network to detect shorting or tampering of the alarm lines. The alarm lines are usually connected at a junction box located within the PIDAS (see Figure 1). The AIDL is connected at the junction box where the alarm condition appears as a voltage level outside a certain voltage window, and is monitored with a single A/D channel.

To operate the AIDL, the operator would insert a floppy disk, connect the A/D input to the alarm lines at the junction box, and plug in the power cord. The AIDL would then boot and automatically run its program. The processor LED would flash 10 times to indicate that the program was running. Any time the AIDL detected an alarm condition, the LED would illuminate. This allowed the operator to verify the operation of both the intrusion sensor and the AIDL prior to running the AST. The AIDL then waits for a "header message" from the Mother Vehicle. After receiving this message, it returns an acknowledgment and awaits a "test start" message. An alarm condition detected after the "test start" message and before a "test end" message causes the AIDL to record the next Target Vehicle coordinate data to a file. The test file is stored in a format that can be easily imported into a spread sheet, such as Microsoft Excel or Lotus 1-2-3. When the testing of the sector is complete the Mother Vehicle sends a "test finished" message to the AIDL. The data file is the transferred to the 3 1/2 floppy disk and the program terminates. The operator can retrieve the disk and process the data later on a PC.

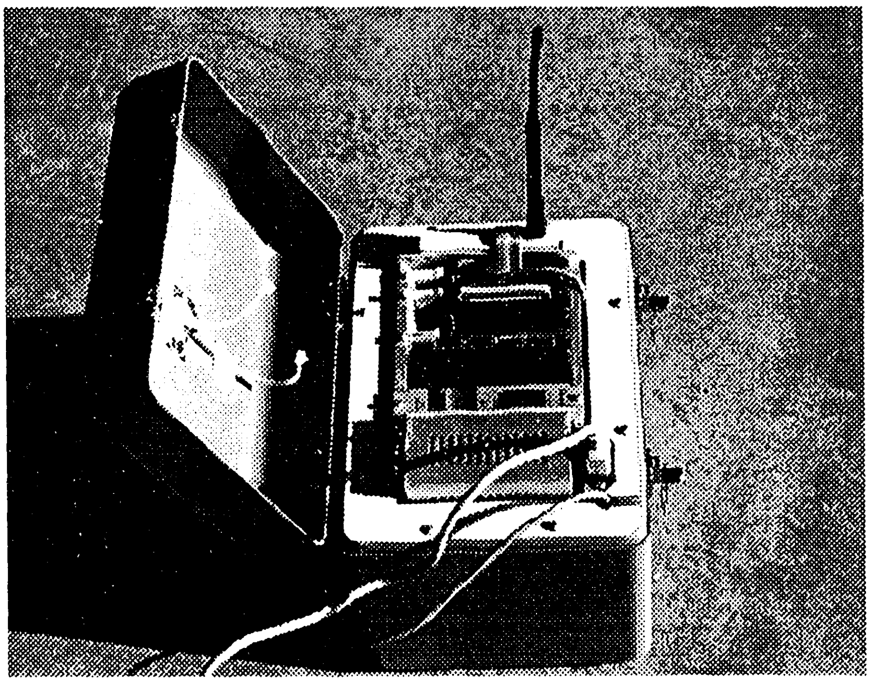

Figure 6. Alarm Interface / Data Logger

Conclusion

The first prototype of the AST system was built during the first half of 1993. The prototype demonstrated that ultrasonics can indeed be used outside to follow a chain link fence. Most of the required functions of the AST were achieved, but due to schedule constraints, were not refined. It is felt that autonomous operation of a robot to perform exterior intrusion detection sensor testing is feasible.

A man portable system will likely be derived from the elements of the present prototype. This system will likely use refinements of the Target Vehicle and the AIDL. Although not completely automated, this modified AST will still achieve a reduction in manpower required for the testing (from 2 to 3 to only 1 man), and will provide consistent testing, since the Target Vehicle will still be used. The only AST element missing from this new system will be the Mother Vehicle. This is the element that would require the most development effort to achieve a deployable AST system. It is felt that this scaled back approach will meet the goals of the project in the most economical and timely manner.

Definitions

A/D	Analog to Digital
AIDL	Alarm Interface / Data Logger
AST	Automated Sensor Tester
D/A	Digital to Analog
DOE	Department of Energy
I/O	Input / Output
PIDAS	Perimeter Intrusion Detection and Assessment System

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