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Design and Test Plan of the Outdoor Test Facility Border Monitoring System (OTF-BMS)

C. Alan Runyan-Beebe and Timothy J. Crawford

Sandia National Laboratories

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C. Alan Runyan-Beebe and Timothy J. Crawford
Sandia National Laboratories
International Security Initiatives
Mail Stop 1373
P.O. Box 5800
Albuquerque, NM 87185-1373

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1. Introduction

1.1 Overview

Structure

The Outdoor Test Facility is an integrated system designed to test sensors, communications links, display technologies, assessment methods, and other integration issues for border monitoring applications.

The OTF consist of two major subsystems. The OTF Integration Test Yard (OTF-ITY) provides space to deploy sensors and camera systems in a simulated border configuration. The OTF-ITY includes an open, one-square-kilometer area to test seismic, electromagnetic, microwave, optical, and other open-area sensors. A fenced enclosure surrounding the tower installation is also present for testing such intrusion detection sensors as optical break-beams, mono- and bi-static microwave, taut wire, and fiber optic sensors. The OTF-ITY also includes visible-light and infrared cameras mounted on a 10-meter (~30-foot) tower, which also provides mounting space for communication antennas.

The second subsystem of the OTF is the Command Center, located at the Sandia National Laboratories International Programs Building. Sensor and video signals from OTF-ITY are transmitted through radio and microwave links approximately 4 km (2.6 mi) to the command center.

The command center is an integrated system for receiving and displaying data information from the OTF-ITY. This system allows for manual and automatic control of cameras and sensors systems. The command center also has the ability to store and retrieve video information from a digital recorder.

1.2 Objectives

Objectives of the OTF are as follows:

- To demonstrate and test technologies that detect intrusions by personnel and vehicles across borders or lines of control
- To operate independently of local infrastructure (communications, power, etc.) as required for remote applications
- To operate autonomously or with intervention of trained operators.

1.3 Design process

Design philosophy

The design of the OTF was based on the Design and Evaluation Process Outline (DEPO) developed for physical protection systems.[1] This process has been used extensively for domestic and international design of physical protection systems for facilities with high-value assets. It provides tools for quantifying the threat and consequences of protection system failure. It then provides guidance for deploying intrusion detection, access delay, and response force resources effectively to counter threats. For the design of the OTF, the DEPO process was adapted for use in border monitoring. In border monitoring situations, the assets to be protected, consequences of intrusion and protective force response times are generally different than those in a physical protection situation. However, with slight modifications, the DEPO framework is useful in characterizing a system's approach to border monitoring.

Process overview

An important feature of the DEPO process is that it is iterative, with evaluation being followed by improvement or redesign. In this way, the system can respond to evolving threat and border environments.

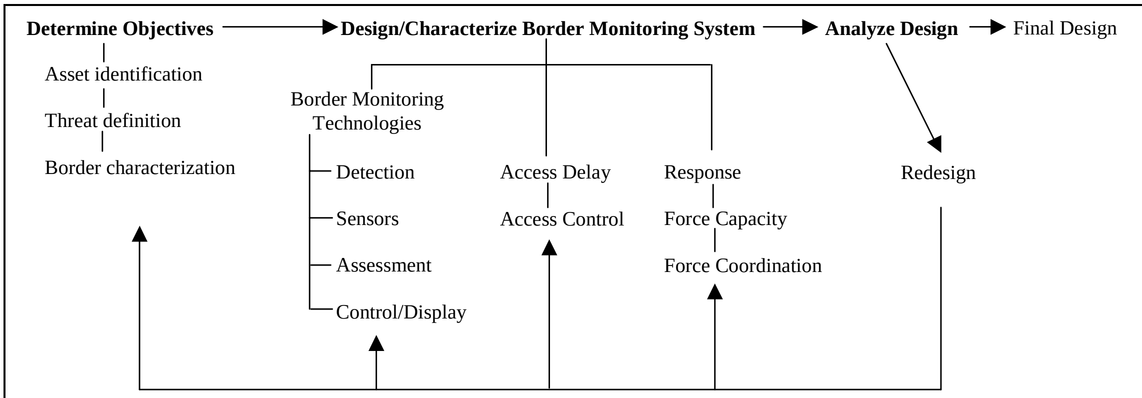

Figure 1: Border Monitoring System Design Process

Determine Objectives

During the design phase, the first step is to identify the system objectives that it is expected to accomplish. These objectives depend on the assets the system is intended to protect, the nature of the threats directed against the system, and the characteristics of the border itself.

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[1] Sandia National Laboratories, The International Training Course: Physical Protection of Nuclear Facilities and Materials, Vol. III. *Evaluating the Physical Protection System Design*. Albuquerque, NM, March 1998.

Design/Characterize Border Monitoring System

Once the system objectives have been determined and quantified, the actual system design can take place. The total border monitoring system includes sensors that detect intrusions and assessment equipment for characterizing the intrusions as well as communications and other support systems. Though the primary emphasis of this document is to test multiple technologies for detecting and assessing intrusions, this document will also give emphasis on general border monitoring technologies, and some consideration to access control and delay as well as response force characteristics.

Analyze Design

When the design is complete, a variety of tools can be employed to determine whether it is capable of meeting design objectives. Once the system is constructed, it is necessary to test and evaluate the system to determine whether it meets the objectives under realistic, operational conditions. Evaluation can provide verification that the system operates as intended; or requirements for design or construction improvements.

The following sections treat the phases of the design process in detail with particular consideration of the OTF design.

1.4 Determine Objectives

Asset Identification

In a physical protection situation, the assets to be protected are likely to be tangible, high-value items such as nuclear power plants, military installations (munitions dumps, missile sites, etc.), industrial facilities, etc. While a border monitoring installation may be part of the protection system for such assets, the primary objectives in a border monitoring are generally more diffuse, such as the safety and security of those living near the border or economic control of the border (to prevent smuggling or unauthorized immigration).

Threat Definition

The OTF design is concerned with two types of threats: personnel and vehicles. Insider threats will not be tested nor will scenarios involving collusion between the insider and outsider threats. These types of threats are outside the scope of this document, the OTF and the work done at the Command Center.

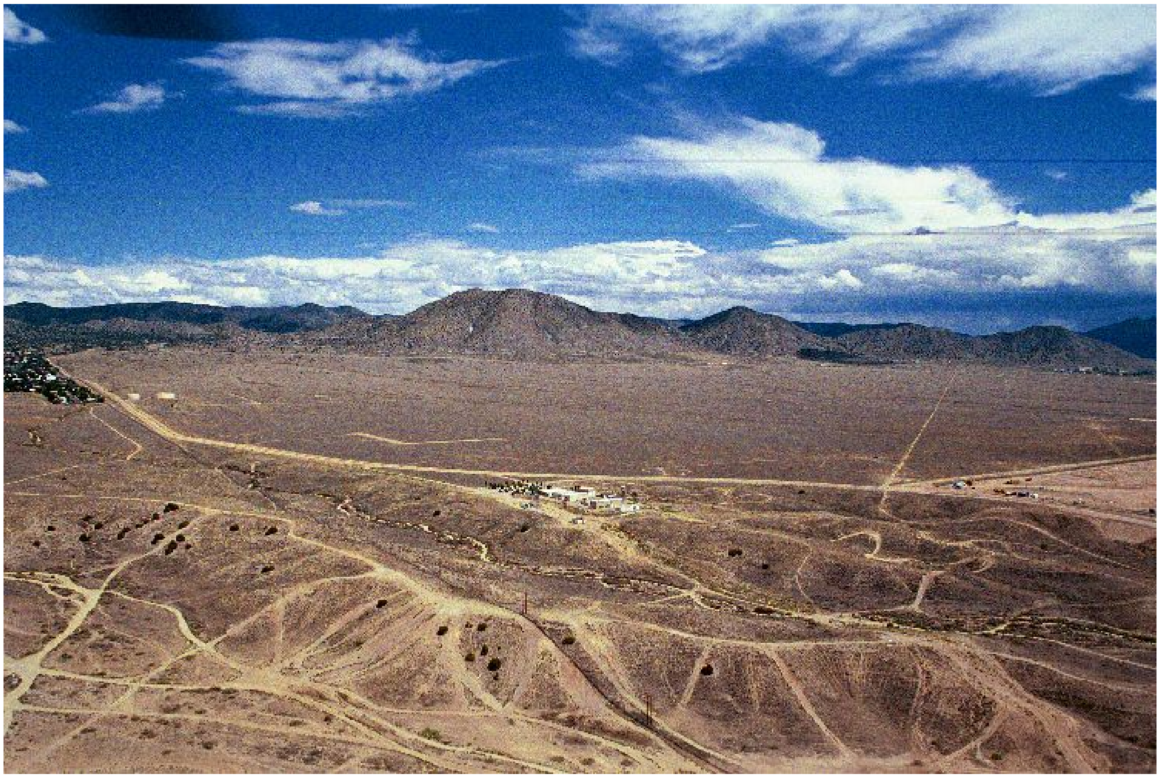
Personnel threats will further be broken into two groups. The first type is a single person trying to cross for illegal purposes or by accident. During the testing phase, an operator will make the assessment as to whether the person poses a threat or is crossing by error or accident. The second type of personnel threat is crossing by a group of people. During testing, the assumption will be that such a crossing is for the purpose of illicit activity. During the test, all group crossings will cause true alarms, and operators will be required to make note of the occurrences.

System response to vehicle crossings will be tested with three different types of vehicles. We are using a small (bicycle), medium (ATV), and large vehicle (truck) to represent a range of vehicles. These different vehicle types will help to assess whether the system can identify and report the differences in size of the vehicles and at what distance from the sensors the detection occurs. During testing, all vehicle movement across the OTF is assumed to represent a threat of illicit border crossing.

Border characterization

The OTF site is located in a remote area of Kirtland Air Force Base. The area is predominantly flat with a change of elevation of only 30 meters over a distance of 2 km in any direction. The vegetation is characteristic of an arid steppe, with low-growing grasses and undergrowth predominating. The site is well suited for long-range observation from the tower, and operators can monitor a large area with little obstruction.

1.5 Design/Characterize System: Border monitoring technologies



Outdoor Test Facility located on Kirtland Air Force Base, Albuquerque NM.

Sensors

Seismic

The primary sensors at the OTF are seismic strings buried throughout the border area. Seismic sensors detect movement of persons, animals, or vehicles through the area of interest by monitoring ground movements. Each sensor is sensitive to movement of persons at a distance of up to 9 meters, depending on the soil type, ambient seismic activity, number and type of intrusions, etc. Vehicles of the type being tested can be detected at distances of up to 50 meters[2].

At the OTF, the seismic sensors are deployed in 100-meter linear arrays along the simulated border. Within each seismic string, individual sensors are placed 17 meters apart, providing for a one-meter overlap between adjacent sensor sensitive areas[3].

Ported Coaxial Cable

Two hundred meters of Ported Coaxial Cable (PCC), also know as Leaky Coax, is installed along the simulated border area. A PCC consists of a coaxial cable with holes in

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[2] Per manufacture's specifications

[3] For further information, a data sheets on seismic sensors is in appendix A.

its shield conductor that generates an electromagnetic field around the cable. A second cable acts as an antenna to detect the field. When a person or vehicle enters the space permeated by the field, the resulting field disturbance is detected by associated electronics.

In use, ported coaxial cables are buried for concealment and protection against environmental hazards. Detection range depends on the size, electrical conductivity, and motion of the target. Calibration adjustments allow trade-offs between sensitivity (maximum range of detection) and false alarm rate. Other circuitry protects against hazards such as lightning.

PCC has been used extensively in perimeter monitoring systems, in which their effectiveness is well established when installed properly. The purpose for including PCC in the OTF is to determine its effectiveness in a border-monitoring application. A data sheet on the PCC sensor system is in Attachment A.

Infrared Intrusion Detectors

Though not currently used at the OTF, infrared sensors have been applied to active border monitoring areas for many years. It is important to understand the concept of infrared sensors and the possibility that they may be tested at a later time at the OTF. There are two types of infrared sensors, active and passive, that can be used for area monitoring and border applications.

Passive infrared sensors

Passive infrared sensors detect persons, animals, and vehicles by the changes—both increases and decreases—they induce with respect to the infrared background in the sensor's field of view. Short-range infrared sensors detect single persons reliably at a range of about 24 meters (80 feet). Vehicles can be detected up to 60 meters (200 feet) away. Long-range sensors increase the vehicle detection range to 150 meters (500 feet).

Passive infrared sensors are small and emit no infrared radiation, so they are very difficult to detect. The sensor output is communicated over a cable or RF link, depending on the installation. A datasheet on the passive infrared sensor is in Attachment A.

Active infrared sensors

An active infrared sensor consists of a transmitter, which emits a pulsed infrared beam, and a receiver that is activated when the beam is interrupted. Detection does not depend on infrared emissions from the environment.

Microwave sensors

A microwave sensor detects intrusions by the effective change on the electromagnetic field emitted by the sensor. There are two types of microwave sensors (Bistatic and Monostatic) available on the commercial market. Currently, a monostatic microwave is used for fence-line protection at the OTF and is not currently part of the overall testing. A data sheet covering both bistatic and monostatic microwave sensors are in Attachment A.

Bistatic microwave

In a bistatic microwave sensor, a transmitter directs a beam of RF energy to a receiver. The wavelength of the beam (approximately 3 cm) and beam width are small enough that persons or vehicles passing between the transmitter and receiver can significantly attenuate the beam, allowing detection. The beam is invisible and sufficiently narrow that it is difficult to detect, and the relatively small antennas (about 25 cm in diameter) can be concealed.

Mono-static microwave

A mono-static microwave sensor permeates a volume of space with an electromagnetic field, utilizing a transmitter and receiver in the same unit. When a person or vehicle enters the space, it disturbs the field and is detected. The active volume can be up to 120 meters (400 feet) long and 1 to 7 meters (3 to 23 feet) wide. By adjusting the emitted power and the antenna, the size of the volume can be tailored to the area to be monitored.

Sensor Summary

Predominantly, the current testing at the OTF is with seismic sensors and ported coaxial cables. Future tests at the OTF have been planned for multiple technologies that can have use for wide area and border monitoring applications. Examples of future tests are mono-static microwaves, fiber-optic intrusion detection, and ground surveillance radar.

Alarm assessment

Imaging systems

Dual infrared imager system

The OTF uses two infrared imaging cameras on a common mount. One has a normal, 25-mm focal length objective and the other has a 125-mm, telescopic objective. Both cameras are sensitive to thermal emissions and can be used in daylight or complete darkness. The common mount has motorized control of pan and tilt allowing remote, automatic or manual control of camera aiming.

EnviroDome® visible-light camera

The visible-light camera at the OTF is an integrated unit including color, charge-coupled device (CCD) camera, zoom lens, and motorized pan/tilt controls in a ruggedized, weather-tight enclosure. The camera has low-light capability and switches automatically to black-and-white operation in incandescent lighting. The 12X zoom lens is remotely controlled and is augmented by digital zoom for higher magnification (with resulting loss of resolution). The pan/tilt mounting allows continuous, 360-degree pan and 180-degree tilt[4].

Communications

Sensor communications

The sensors employed at the OTF-ITY contain their own, integrated radio transmitters. These transmitters operate at VHF frequencies and have a range of about 16 km (10 miles) in the OTF configuration.

Video Communications

Video and camera control information at the OTF is communicated through two microwave links. The microwave communication links chosen for the OTF operates in

[4] See Appendix C for camera formula information

the 21.3 to 23.6 GHz band with a bandwidth of 10 MHz. The practical range of the system at full bandwidth is 16 km (10 miles).

In the first phase of OTF testing, image data from all three cameras (visible light and two thermal) were fed into a video multiplexer which communicated over the one microwave communication link. During a re-evaluation of the OTF, an additional microwave link was installed so that only the thermal imagers had to be multiplexed. Dedicating a link to the dome camera increased the effective bandwidth and allowed the camera to be used to identify persons and vehicles at long range.

Figure 2. Test site tower facility

Ancillary systems

Tower Facility

The tower facility is located in a fenced area at the intersection of the Four Hills Road and the twin tracks road. The facility is 12 meters (40 feet) wide and 18 meters (60 feet) long. Inside the perimeter is a nine-meter (30-foot) tower, a solar power system with a battery bank, and an equipment trailer. A three-meter (10-foot) fence surrounds the facility for security and safety.

The tower (see Figure 2) is a commercially made, industrial tower designed to withstand harsh climatic conditions. The tower supports the daylight dome camera, two thermal imagers, microwave communications antennae, and a control box (C-Box). The tower is 9 meters (30 feet) tall and is set on a concrete foundation block that measures ten feet by ten feet and four feet deep (3m x 3m x 1.3m). An internal ladder provides access to a platform so that work can be accomplished on camera systems and microwave communications links. A major requirement on the tower is that it shall move no more than .5 degree in 90 mph winds. For actual installations in regional areas, this type of tower may not be required. For the OTF, however, it was decided that a strong tower would be required if the need arose for heavy equipment to be installed for testing.

OTF Control Box (C-Box)

Figure 3. OTF Control Box

The C-Box (Figure 3) is the control combiner enclosure for all the components for the OTF Site. The C-Box is mounted at the bottom of the tower and is constructed for easy access for calibration and testing of all the apparatus within the OTF site. As a key component to the OTF Site, the C-Box was made so that operators and maintenance personal can monitor the site either locally or remotely. For regular maintenance, the C-box monitors temperatures and humidity so that a log can be kept of electrical equipment temperature. Components mounted in the C-Box include the following:

- Terminal blocks and distribution wiring for power from the solar array and battery bank.
- Signal distribution unit for control signals from the dome camera and the thermal imagers. The signal distribution unit distributes serial data from the microwave communication link to the cameras. It enables an operator at the Command Center to control each camera independently and for alarm activations to move the cameras to given preset positions.
- Video multiplexer. The video multiplexer was intended to combine all the video signals from the cameras for transmission through the microwave communication link back to the Command Center. During initial testing, it was found that multiplexing all the signals seriously degraded the video quality at the Command Center and that, as a result, formulas for distance and target identification were incorrect. To correct this deficiency, an additional microwave communication link was installed to carry video from the dome camera, so that only the thermal imager video is sent through the multiplexer.
- Temperature recorder. The temperature recorder records temperature and humidity continuously along with minimum and maximum readings over time. Data from the recorder led to the installation of two fans to keep temperatures constant inside the C-Box by circulating air though the interior.

Solar Array and Battery Bank

One key feature of the OTF site is the ability to use remote power sources. Solar panels and a battery bank are employed to power all of the equipment on the tower. Since the site uses fully steerable cameras, power consumption can be very high to power the motors and the driver units. As a result, large array and battery bank are required to sustain the system year round. The power system provides 110 VAC, 24 VAC, and 24 VDC. The C-Box distributes the proper supply voltages to the equipment[5].

Figure 4. Solar panels at OTF remote site

Though the configuration of the solar array and battery bank required some custom work, the system uses off-the-shelf components and is very stable year round. The Siemens 110-Watt solar panels (Figure 4) are connected in both parallel and in series to generate a 24VDC output at up to1500 Watts during peak hours.

The battery bank (Figure 5) has a power allocation and control panel that handles all input and output power sources from the solar array, battery bank, and C-box. The panel also includes circuit breakers and fuses for safety and to prevent overloads. The high-power capability of the solar array and battery bank requires all maintenance and inspection personnel are to undergo electrical safety indoctrination and have proper safety equipment present before approaching the battery bank[6].

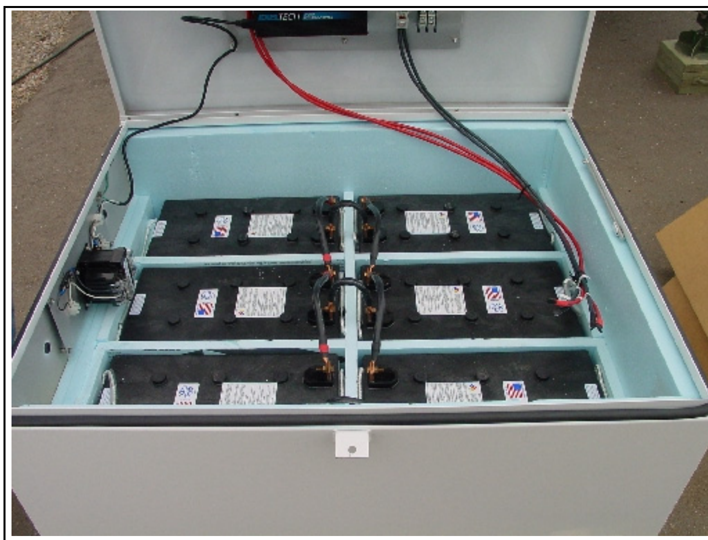


Figure 5. Battery bank at OTF remote site

[5] See Appendix A for fact sheet on solar array system

[6] For safety training and operating procedure requirements, refer to Section 3.2.

Alarm control and display

Command Center

The OTF Command Center receives sensor and video data from the OTF site so that an operator can view alarm activations and live video images. It includes provisions for archiving the data for later review and storage.

Figure 6. Command Center

The Philips control system[7] is the processing system of the Command Center and Control, because it is the point where video and alarm information is gathered and distributed throughout the system. The main component of the Philips control is the processing unit, which controls signal distribution, alarm processing, and recording equipment. The processing unit also stores information on camera presets. For each separate alarm, an associated preset directs the cameras to move into designated pan, tilt, and zoom settings, allowing video assessment of the alarm response.

When an alarm occurs at the OTF, a digital recorder is activated to archive video information onto a hard drive. The digital recorder can store up to 90 GB of information before it overwrites the oldest information. When it is filled to capacity, the recorder automatically downloads all files to a CD writer, or downloading can also be commanded manually. Once information is written to a CD, it can be stored longer than conventional VHS tapes, taking up less space, and with no danger of being erased by magnets. Along with the capabilities of archiving video information, the digital recorder can transmit video images over the Internet, so that information can be viewed from any location with Internet capabilities. This feature is currently being utilized by the computer interface and through remote applications.

Software

Command Center software includes several modules:

- Processing unit software determines how alarms are to be handled and provides for stored or manual control of cameras. This software is configurable through Command Console Language (CCL) protocol.

[7] See Appendix A for fact sheet on Philips System.

- Since a variety of sensors are used in the OTF system, a separate processor with its own software system is used to translate the various sensor indications into a common format for use by the Phillips processing unit.
- A web server system allows image and alarm data to be viewed by authorized users remotely via the worldwide web.

Response

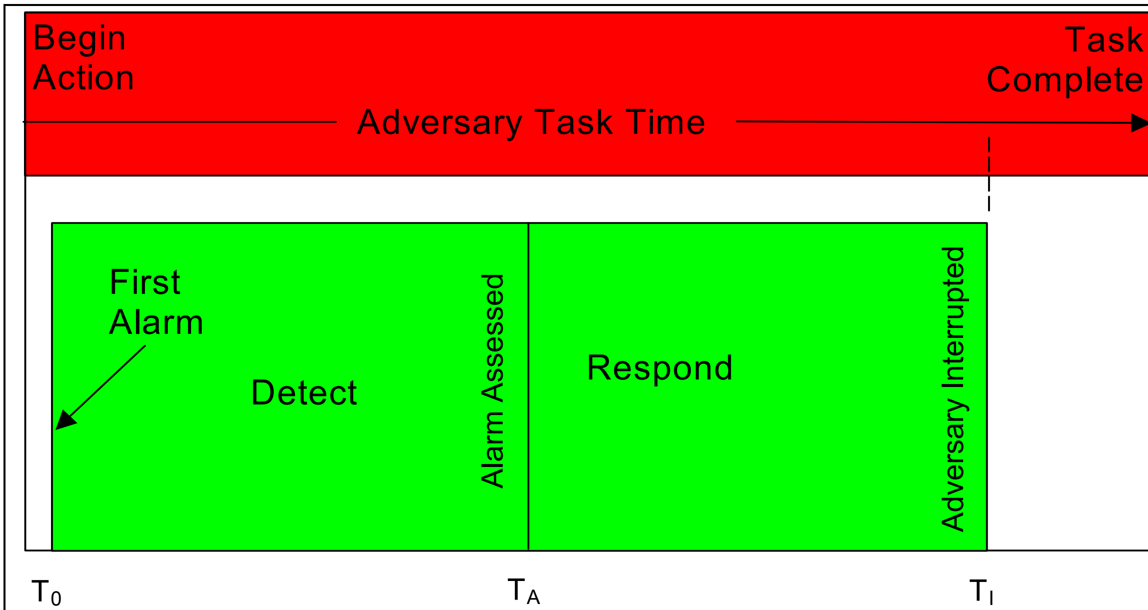


Figure 7. Border monitoring and response system performance

While the issues of response time and response force capability are beyond the scope of OTF operations, data provided by the OTF is crucial to the development of effective response. As shown in Figure 6, the goal of border monitoring and response is to stop an adversary force before its task (for example, to sabotage a defensive installation or to deliver smuggled goods) is complete.

The detection phase begins when the first sensor indicates (T_0) that an intrusion is taking place. During the detection phase, the alarm status is sensed and assessed to characterize the intrusion as to type, location, etc. The response phase begins when the alarm has been assessed (T_A) and ends when the response force has interrupted the adversary's task (T_I). The minimum requirement on the monitoring and response system is that T_I must be before the adversary task is complete. The border monitoring system embodied in the OTF contributes to meeting this requirement by making the time between T_0 and T_A as short as possible.

1.6 Analyze Design

The test procedure (detailed in Chapter 2) evaluates the OTF video systems, sensors, and command and control equipment. The test will be conducted in a one square kilometer area adjoining the twin track road, which serves as the simulated border (Figure 8). The Sensors have been laid out to simulate a mountainous terrain, which are marked with flags and cones to outline areas that are not to be crossed.

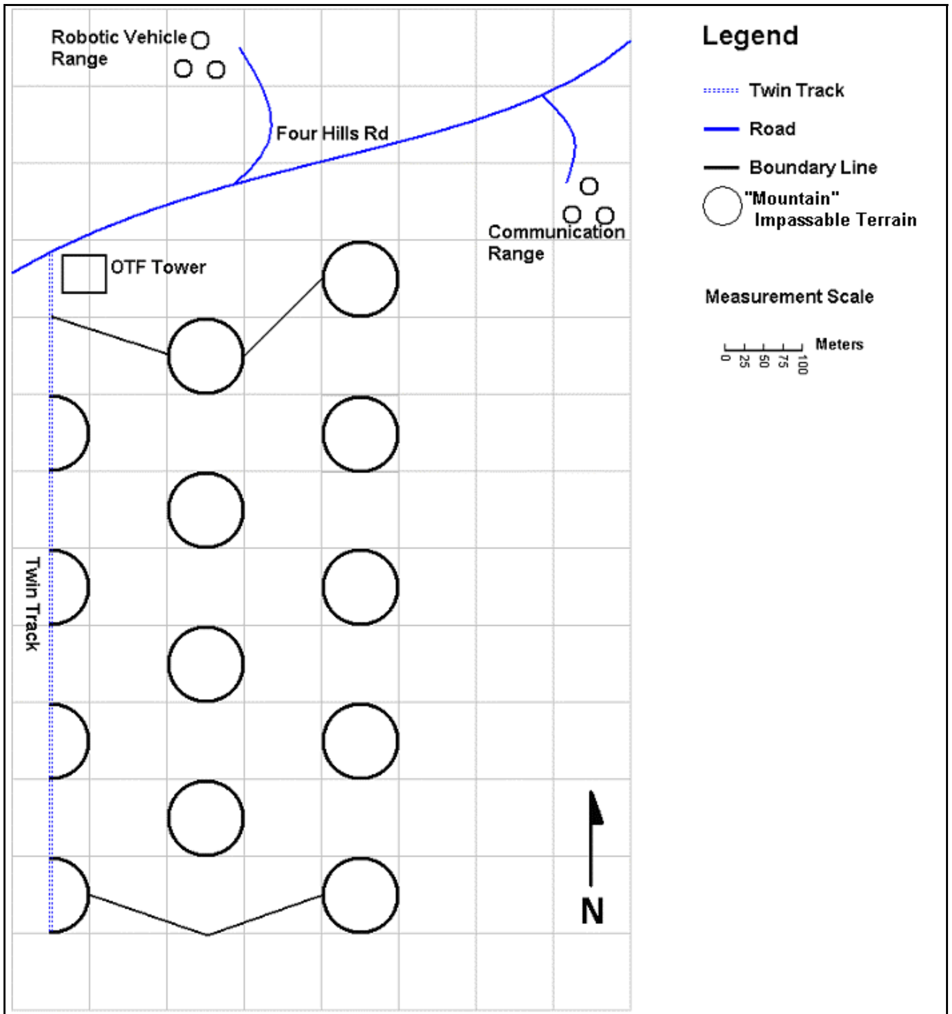


Figure 8. OTF remote site map with simulated mountainous terrain

Vehicles and humans will be able to make routes though the area, while sensors will be placed in layers to track movement. For the simulation, there are 48 different routes that can be chosen. During the actual test phase these routes will be chosen at random by the person, group, or vehicle that moves through the area. System operators will attempt to track the movements across the area and determine routes that are taken.

The seismic sensors are placed in layers parallel to the simulated border. Each sensor is installed in an open area between the simulated impassable mountain regions that are shown by the ovals at the site maps (Figures 8 and 9). In each test, intruders will cross the border via routes between the simulated mountainous areas. An operator at the Command Center will attempt to detect and track the intruders' movements using the sensor data. After each border-crossing test, the observers will verify the operator's account of the intrusion against the actual movements that the intruder made across the area.

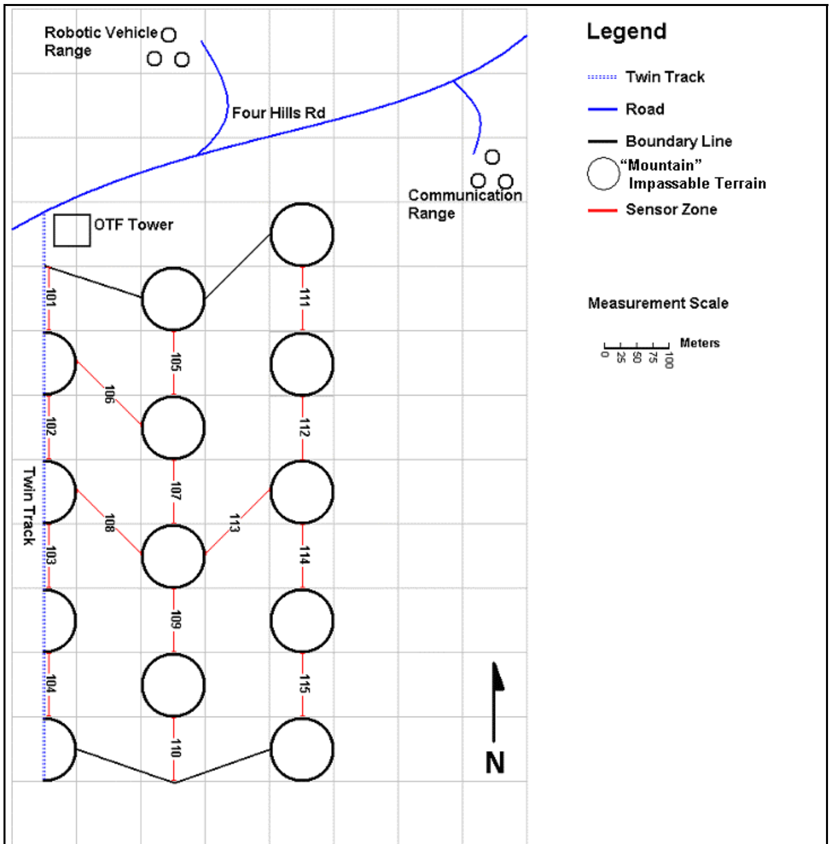


Figure 9. OTF map with sensor locations

2. Test Plan

2.1 Test Overview

The OTF design was predicated primarily on the identification of humans crossing the border on foot. Assessment was not intended to determine whether the crossing is hostile or not, but rather whether an individual or group has crossed the border area. For this test, the requirement is that operators must be able to track a person over a long distance of land to provide the response force enough time to intercept unauthorized intrusion.

For the purposes of this test, the primary detection and assessment information will be from the sensors. Seismic sensors have been installed in a layered configuration that monitors the border as well as a strip of land several hundred meters from the border. A ported coaxial cable sensor is placed along the border, to show a different variable for the test. With sensors in this configuration, an operator should be able to detect border crossings and track the intruders to provide location and direction information to the response force.

For this test, camera assessment will be used only as verification that the operator has made correct assessment of the alarms using sensor data. The reason that the cameras are not an integral part of this test is because of the simulated mountainous terrain. In mountainous terrain, cameras may not be able to track intruders over long distances and thus cannot be relied upon for assessment.

Along with the tests of human intrusion, limited testing of vehicle intrusions will be conducted. Environmental restrictions on Kirtland Air Force Base preclude large-scale vehicle testing because of the potential for damage to the area. Therefore, for this test limited vehicle crossings will be conducted on paths that will not affect the area. Statistically, the vehicle crossing tests will not provide enough data to make scientific judgments on the performance of the system.

At least two trained operators will be required at the command center to observe alarm activations and video assessment. These operators will keep a log and monitor the test crossings. They will also be required to use the digital recorder to make a video archive of the test to verify the border crossings.

Along with the operators that are at the command center and the OTF site, the test procedure will require unbiased arbitrators to verify that the test is being conducted according to the test objectives and requirements. These arbitrators will keep logs as to the success of the test and will be involved in the evaluation of the system.

2.2 Test postulates

The OTF system is only intended to notify operators that there is an intrusion by vehicles or personnel crossing but not to indicate the intruders' intentions.

Procedures for a response force or the halting of personal or vehicles will not be tested at this site. Response to border crossing will be the responsibility of the regional agencies that are interested in this system.

The system operates twenty-four hours a day, seven days a week. Before each test, OTF operations will be checked to verify that there are no physical problems or operational errors.

During the testing phase, a qualified operator must be at the command center observing alarm and video systems. This operator needs to be impartial so that an unbiased judgment of the system can be discussed.

The person(s) or vehicle(s) crossing the border area during the test will not have prior knowledge of where the sensors are located. Of course, they are expected to act upon what they physically witness during the crossing of the border site. If there is evidence or presumptions where a system may be located this will be discussed at the end of the testing phase. During the testing phase, neither vehicle(s) nor people will try to willfully damage system components.

2.3 Environmental conditions and terrain stipulations

Twelve simulated "mountains" are scattered through the test area. Each mountain zone is one hundred meters in diameter and is separated from adjacent zones by 100 meters (200 meters on centers). Each zone is marked with white flags, stakes, and orange cones.

Vehicle(s) or human(s) will be able to use the clear routes between zones and will not be allowed to cross the simulated mountains. Forty-eight different routes can be used, and during the tests these routes will be chosen at random by the person, group, or vehicle that moves through the area. System operators attempt to track the movements across the area and identify the routes that are taken.

2.4 Simulated Border Crossing—Human Test

The first part of the test will involve individual human crossings. Volunteers will be briefed that they must reach a point at the end of the area without moving into simulated mountainous terrain. They will be given the option to move in any way that they choose, but that they should try to avoid sensors that they observe. Sensor installation information will be withheld from these volunteers, so they will know the location of only those sensors that they actually observe.

For each test, the point of completion may be changed at random, and the volunteers will be asked to move through the area using a different route. This is to ensure that the intruders do not offer the operators a predictable pattern.

The second part of the tests will involve groups of three to five people trying to cross the area as a group. Though the group crossings will follow the same stipulations as the individual crossing, there will be two added functions to these tests. Groups will have the added testing of scatter and decoy tactics. For the scatter tactic, the group, while crossing the simulated border area, will separate to test whether the command center can follow and assess that a group has scattered across the area. The decoy testing will be the use of an individual crossing the area before the group moves into the vicinity. For testing, an operator at the command center will have to assess and identify that the group is using a decoy while crossing the open area.

2.5 Simulated Border Crossing—Vehicle Test

Limited testing of vehicle crossings will be performed due to environmental protection requirements, terrain, and resource availability. Three different types of vehicles will be used in the tests. The first type is a truck that can only move through a subset of the available routes. The second vehicle is an all terrain vehicle (ATV) that is able to use more routes than the truck. The last vehicle is a mountain bicycle that can travel over all of the simulated routes that are available to persons on foot.

The three different types of vehicles allow testing the system against targets of a variety of masses. The vehicle test data will be used mostly for calibration and validation of the sensors.

2.6 Test Forms

Three different forms will be used during each test (Appendix B). One form is for the use of volunteers crossing the area, one for operators observing the area, and the third for arbitrators observing the test. Volunteers will be handed forms that they will fill out before each test run with information on movements, how they will cross the area, and speed (walking, running, or stealth). Volunteers will be provided a blank map of the area that only has information on the simulated mountain terrain and open routes. On this map, they will mark their path through this area. Arbitrators will be given this information to validate that it follows the test provisions.

Operators will be provided with maps of the area and the sensor placement (with GPS coordinates), so that they can mark where alarms originate. Operators will not know where and when a test is running. Operators will make the determination that there is an intrusion, and will mark the map on their forms as a log of where they believe that a person(s) or vehicle(s) are crossing the area. Operators will share their information with the arbitrators and this information will be logged for later evaluations of the system.

Arbitrators will know all relevant information during the test. They will be informed as to when and where a test will be conducted and where sensors are placed. Therefore, they can validate whether an operator is seeing an actual intrusion. The information that arbitrators possess will require protection so that it is not disclosed to either the operators or the volunteers during the test. Arbitrators will also be required to supervise the test of the system and to ensure that the test is working properly. They may be required to stop the test if there are any inappropriate actions and require that the test be recreated.

3. Safety and Environmental Considerations

3.1 Environmental protection

NEPA determination

The National Nuclear Security Administration Office of Kirtland Site Operations determined that the OTF-ITY was categorically excluded from the requirement for an environmental assessment or environmental impact statement (NEPA ID No. SNA –1-0682, February 26, 2002)

Land use permit

The OTF-ITY is located on the Robotic Vehicle Range, which is operated by Sandia National Laboratories under a land-use permit from the Department of the Air Force.

3.2 Safety

PHA

The OTF is covered by Preliminary Hazard Screen (PHS) number SNL1A00236-001, created August 21, 2001. The special hazards identified in conjunction with OTF operations concern the photovoltaic system with its associated storage batteries.

Operating procedures

OTF operating hazards are addressed in the Standard Operating Procedure (SOP) titled "5324 Battery and Photovoltaic Cell TWD," dated October 1, 2001.

4. Appendix A. Fact Sheets

These fact sheets are representative of different technologies and manufactures. They represent systems currently employed for test and demonstration purposes at the OTF.

4.1. Monitron Sensor System

Receiver System

The Monitron Base Station functions as a central data-gathering unit and is designed for indoor use. The display (vacuum Fluorescent) module is built into the enclosure, and the system can transmit (RS-232) serial information to either a PC Database and/or printer. An internal real time clock is used for time stamping Alarms inputs. The unit can be utilized as a desktop or rack mounted monitor.

The Base station can monitor multiple systems at different frequencies and handle up to 4000 different Sensor ID's.

Monitron Transmitter

The Monitron Transmitter is encased in a watertight corrosion proof enclosure. Assuring proper functionality in any hostile environment that may be encountered, including salt water. The sensor and antenna connectors are also watertight and corrosion resistant.

The character recognition filter uses a combination of techniques. These include frequency selection (narrow band synthesized VHS), energy level/duration, and voltage ratio measurements. These circuits provide classification and discrimination against nuisance alarms.

Operators can utilize micro-controllers, allowing for setting a variety of parameters:

Sensor sensitivity
Single/multiple inputs
Classification and direction
Sleep mode
Channel selectable transceiver

Specifications:

- Two sets of receivers and displays
- Independent RS-232 (4) Serial ports
- Operating Voltage: 110/220 V AC
- Can handle up to 10,000 Alarm IDs

Monitron Base Station

Monitron Transmitter

4.2. Mini-Intrusion Detection System (MIDS)

MIDS (Mini Intrusion Detection Sensors) Seismic

MIDS Receiver System

The Mini-Intrusion Detection System (MIDS) receiver can handle up to 100 different ID's on a single Freq. Channel. The display module is built into the enclosure, and the system can transmit (RS-232) serial information to a software monitoring system or placed into a PC database. ID's can be blocked or grouped as sequential codes and directional alarms can be activated.

MIDS Transmitter System

The MIDS Transmitter is encased in a watertight corrosion proof enclosure. Assuring proper functionality in any hostile environment that may be encountered, including salt water. The sensor and antenna connectors are also watertight and corrosion resistant.

The transmitter is a single channel (25Khz spacing) VHF radio with programmable ID codes. During normal operations, an external sensor connected through a Mil-Spec connection triggers the transmitter. Though relatively inexpensive, operators cannot control parameters except for ID classification.

Specifications:

- Stores last 10 messages in memory for later recall.
- Can operate on one of 600 channels.
- ID lockout as individual or group.
- Adjustable audio level during operations.
- Backlight LED display.
- Serial Interface with selectable baud rates.

4.3. Sparton Security System

Transmitter

Summary:
The Sparton transmitter is encased in a watertight corrosion proof enclosure. Assuring proper functionality in any hostile environment that may be encountered, including salt water. The sensor and antenna connectors are also watertight and corrosion resistant.

Sparton Transmitter

The Sparton Transmitter has 2 inputs for sensors (seismic and directional) and transmits encoded messages up to 10 miles line-of-sight. The unit sends self-test messages at user-selected intervals. Internal batteries typically last up to one year.

Operators can utilize micro-controllers, allowing for setting a variety of parameters:

Sensor sensitivity
Single/multiple inputs
Classification and direction
Channel selectable transceiver

Receiver

Summery:
The Sparton Base Station functions as a central data-gathering unit for receiving and displaying alarms information. The system can transmit (RS-232) serial information to either a PC Database and/or printer. It has two different frequencies that can handle up to 2000 alarms simultaneously. An internal real time clock is used for time stamping Alarms inputs. The unit can be utilized as a desktop or rack mounted monitor.

Sparton Receiver

The Base station can monitor multiple systems at different frequencies and handle up to 4000 different Sensor ID's.

Specifications:

- Two sets of receivers and displays
- Wide band crystal VHS
- Independent RS-232 (4) Serial ports

4.4. Eagle Telonics

Summary:

The Eagle Intrusion Detection System (EIDS) is an intelligent discriminating remote sensor system designed to operate in extreme temperature ranges over long periods of time. The EIDS has three different processor/ transmitters for different application needs. Long-term deployment models, medium-sized tactical units and miniature short-term units are available. EIDS uses seismic, magnetic, passive and active infrared. Signals generated by the detectors are processed to classify and report via RF transmission, unauthorized intrusions or illegal activity.

Transmitters:

Each transmitter (Long-term, medium-sized, and short-term) can receive, process, and transmit information generated by seismic, infrared and magnetic detectors either individually or in various combinations. Microprocessor-controllers allow user selected parameters via a handheld programmer.

PT-100: A processor/transmitter housed in a compact ruggedized case that facilitates storage, transportation, and concealment. This unit is ideal for long-term deployment up to one year. Constructed of high impact resistant polypropylene, that may be deployed either above ground or buried for covert monitoring.

PT-200: Designed for quick deployment in tactical or covert operations. The electronic elements are sealed in a waterproof, high impact resistant ABS housing. The PT-200 will operate from three to four months of two (2) 9-volt batteries.

PT-310: A small quick deployment unit for short-range detection. The PT-310 units are configured as either seismic processors (PT-310S) or passive infrared/magnetic processors (PT-310IM). The PT-310S includes the ability to discriminate between vehicles and pedestrians then report separate identifying messages. The electronics are sealed in an impact resistant aluminum housing. The standard power supply, standard 9V batteries), provides up to 90 days of operational life.

Receiver:

RM-2000: Designed to receive, display and store digital messages from the PT-100, PT-200 and PT-310 processor/transmitters. All adjustments for the R M-2000 are done via a 4-button keypad interface in conjunction with a backlit Liquid Crystal Display (LCD).
The RM-2000 also utilizes a Store-On-Board memory feature, which allows up to 250 messages to be stored in memory and retrieved at a later dates. Each message is time and date-stamped and can be exported to a computer terminal or serial printer.

Specifications:

Transmitters	
Frequency:	Narrow-band synthesized RF, from 138-174 MHz
RF Power:	5 Watts (PT-100), 2.5 Watts (PT-200), 1.5 Watts (PT-310)
Operating Voltage:	7-14 Vdc

Receiver	
Frequency:	Wide band synthesized RF, From 138-174 MHz
Alarm Storage:	250 messages
Operating Voltage:	9-48 Vdc
User Interface:	4 button Keypad, serial (RS-232) communications.

4.5. *Seismic Sensor Systems—Monitron, Sparton, Eagle Telonics and MIDS*

Summary:

A seismic (geophone) sensor is a passive intrusion detection system that responds to seismic stimuli created by either vehicles or persons within the area under surveillance. The processor accepts the signals sent by the seismic detectors, processes them, determines the activity, establishes whether the intrusion is a pedestrian or vehicle, and transmits the appropriate alarm. The Seismic activity is monitored in conjunction with an Automatic Gain Control (AGC) circuit to reduce the effects of background noise (natural seismic occurrences).

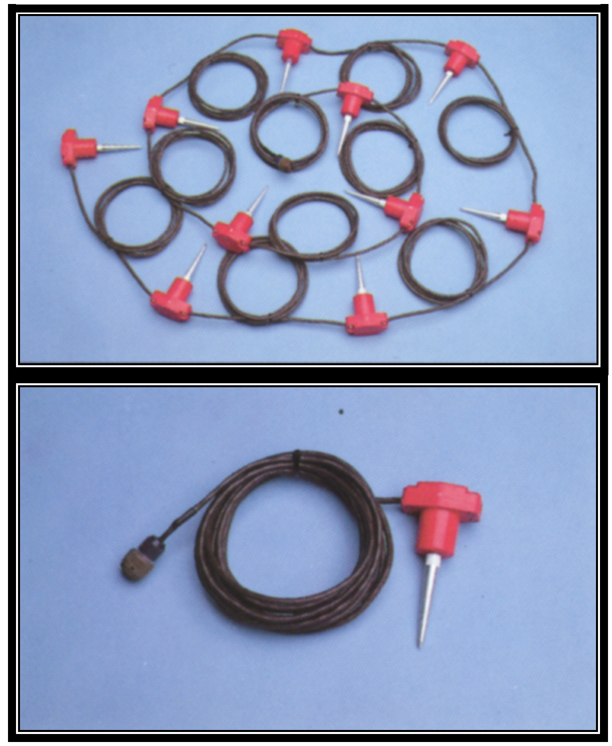
A buried seismic sensor detects seismic activity at the detector location and generates an electrical signal that is analyzed by a micro-controller to determine if a specific type of intrusion has occurred. A single seismic detector is used to monitor a small area or trail, or detectors can be combined in a string to monitor large open areas and perimeters. Detection range will depend on several variables such as type of terrain, sensitivity setting, number, and type of intrusions.

A seismic sensing pattern is circular. The sensing pattern for a seismic string depends on the number and spacing of the seismic probes used. Up to twelve seismic probes in a string may be used with a single processor in seismically quiet locations, which can provide a considerable economic advantage when used on extended boundaries and perimeters.

The Seismic Sensor and Seismic Line String operate satisfactorily in a variety of soil types, environmental conditions, and intrusion profiles. Nonetheless, specific site selection may be an important factor in providing a reliable input signal.

Guidelines for installation:

Select areas where the surface is firm and relatively dry. When possible, avoid loose sand, swampy areas, or areas that are springy from roots or heavy surface vegetation.



Seismic point and string sensors—Monitron, Sparton, and Eagle Telonics

Specifications:

Typical Detection Ranges	
Personnel	25-100ft
Vehicle	170 ft
Power Requirements	12-18Vdc

4.6. Ported Coaxial Cable

Summary:

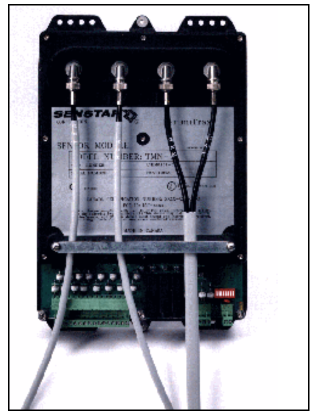
Ported Coax is a high-security covert perimeter intrusion sensor that generates an invisible electromagnetic field around buried ‘leaky’ sensor cables. A gap in the transmit cables outer conductor allows for energy to escape and be detected by a corresponding parallel receive cable. If an intruder disturbs this field, an alarm is declared.

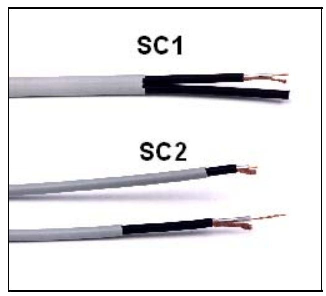
The Ported Coax uses a large volumetric field to detect moving targets based on their electrical conductivity, size and movement. The system also allows an operator to calibrate the sensor so that people and vehicles crossing can be detected, while small animals are ignored.

The length of each zone can very from 10m to 200m and is customized to suit site requirements. The cables are available in two configurations. SC1 has the transmitter and receive cables in a single jacket. Only one burial trench is required for the SC1 while an SC2 cable has its transmitter and receiver cables buried separately. The SC2 will cover a longer width but requires two trenches for installation.

Specifications:

Zone Length	Min 10m Max 200m
Calibration Outputs:	2 analog outputs for voltmeter recording
Detection Threshold	Adjustable for each zone
Power Consumption	12Vdc @ 500 mA
Outputs	4 Alarm relay outputs


Controller



Cable configurations


Installation

4.7. Philips System

LTC 8800 Allegiant CPU

Summary:

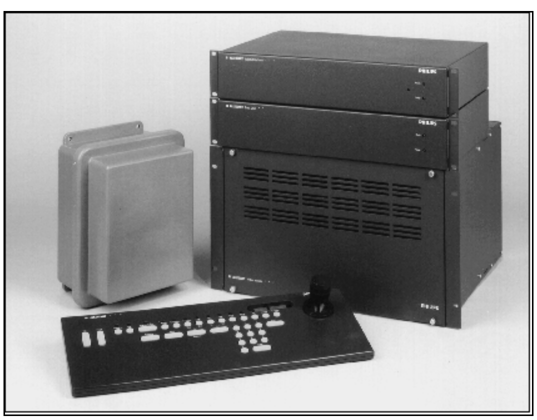
The LTC 8800 video switcher/control system performs full matrix switching to display any camera to any monitor. Can handle up to 256 camera inputs, 64 monitor outputs, 32 keyboards, 1024 alarm points, and 2 computer interface ports.

Operators can control remote pan/tilt/zoom units through keyboards, pre-positioning, and random scan. The system provides macros and programming languages for site-specific requirements.

Included is a Programming GUI that will enable the user to read matrix programs and to set up specific requirements for each camera and monitor

Specifications:

Video Inputs:	256
Video Outputs:	32
Keyboards:	32
Alarm Inputs:	1024
Power:	100 – 140 V AC 200 W



LTC 8800

KBD-Universal Keyboard

Summary:

The IntuiKey digital keyboard is a full function, multipurpose keyboard used for system control and programming. Includes a variable P/T/Z joystick and splash resistant design. Powered by Allegiant or Multiplexer. Menu driven macros for advanced programming and camera settings.

Philips Keyboard

LTC 2821/90 Universal Multiplexer

Summary:

Multiplexers can display any camera to either monitor A or B and include camera sequencing and alarm action call-up. Selected video camera(s) will simultaneously record and view on multi-screens and can playback previously recorded images from multiple recording devices.

Quick Setup features can configure the system for site-specific parameters and enable the system to automatically connect to required camera inputs.

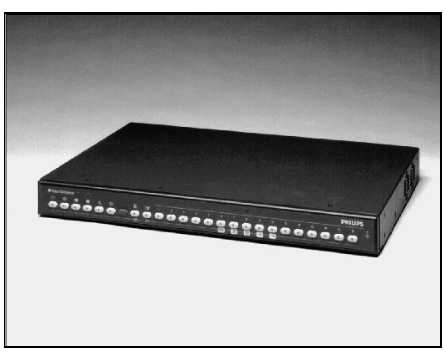
To enhance the recording of cameras, digital 4x zoom, within the Multiplexer, can be used during alarm activation.

System 4 Multiplexers can be used for main command control or at the remote site to allow for multiple cameras to be transmitted over one transmission link.

All units are compatible with normal VHS format or High Density Digital recording.

Specifications:

Power:	110 – 220 V AC @ .3 A
Digital Memory	720 H x 576 V
Cameras Inputs:	9 or 16 (BNC)
Alarm Inputs:	16 individual
Relay Outputs:	Two relay outputs



LTC 2662 Universal Multiplexer

ENVD2460 G3 EnviroDome Day/Night

Summary:

The G3 EniviroDome is a small, easy-to-install, weather-resistant package, with a sealed camera that can scan a continuous 360 degrees with vertical auto-correct.

The day/night EnviroDome can be automatically switch into night mode (from color to b/w) using an IR Filter when light levels drop below a specified threshold.

Standard shutter control allows the camera to reduce speed to as little as ¼-sec, thus increasing the sensitivity to nearly .03 lux.

Remote addressing capabilities allows for the operator to set either logical or programmable addresses when multiple cameras are within a site.

Transmission integration allows for video/data information to be sent over bi-phase or RS-232 for use with multiple wireless transmission links.

Specifications:

Lens:	18X zoom (4.1 mm – 73.8 mm)
Focus	Automatic with manual Override
Iris	Automatic with manual Override
Field of View	2.7 to 48 degrees
Digital Zoom	12X
Horizontal RES	470 TVL
Pan/Tilt	360 continuous pan, 0 to 90 tilt from horizontal plane
Accuracy	.50 degrees
Power	21—28 V AC @ 20 W
Control	Bi-phase or RS-232

Dome Camera

LTC 8568 Signal Distribution Units

Summary:

Main site (Bi-phase) control code distribution and line driver unit. Used for communication to camera receiver/driver from Allegiant CPU. Provides 32 separate outputs for driving up to 256 cameras.

Specifications:

Power:	12 V AC @ 3W
Input:	9-pin for Data/Power
Output:	32 Bi-phase contacts

LTC 8540 Alarm Interface Unit

Summary:

Unit accepts up to 64 contact closures or logic level inputs from remote sensing devices such as door contacts, PIRs, etc. and then reports the "alarm" information to the main CPU bay. Alarm inputs may be configured into groups of 32 to accept either normally open or normally closed contacts. Unit also contains eight relay outputs, which operate upon alarm conditions.

Specifications:

Power	12Vac @ 8 W
Alarm Inputs	64 contacts
Alarm outputs	8 relay contacts
Data/Power	9-pin connector

LTC 8712 Console Port Expander

Summary:

The LTC 8712 Series "expands" an Allegiant system's Console port to permit up to 4 external computing devices to communicate with the system via RS-232 protocol. Any computing device, which can normally communicate directly with an Allegiant (via its console port), can be used with these port expanders.

Specifications:

Power	120Vac @ 10 W

LTC 8780 Data Converter Unit

Summary:

The LTC 8780 Series are accessory units that convert bi-phase control code into RS-232, and converts RS-232 back to bi-phase. This provides the capability of transmitting the control code over conventional RS-232 mediums such as modems or Microwave Links.

Philips Accessories

DVR1 Digital Recorder with CD Writer

Summary:

The DVRI recorder replaces traditional analog time-lapse recorders in conventional CCTV systems. They are compatible with Multiplexers and are simple to install.

Digital recorders provide fast, uninterrupted video access available locally and via network connections. Provides recording modes, speed, and overwrite capabilities.

Events can be stored directly to a PC hard drive, CD format, or on the internal hard drive.

Access to recorded events, accomplished by simply specifying camera and time or alarm event, will allow an operator quick response for reviewing.

DVRI Digital Recorder

Specifications:

Power:	12 V DC @ 35 W
Digital Resolution	720 x 484
Internal Hard Drive	80 GB
Search Features	Camera, Time/Date, & Alarm
Recording Modes	Event, Schedule, Manual
Recording Speed	60, 30, 20, 10, 5, 3, 2, 1, .5, .2, and .1 IPS
Connectors	RS-232, DB-9 I/O Port Video Inputs/Outputs: BNC SCSI-2: 50 Pin Network: Rj45 10/100BaseT

4.8. Raytheon Thermal Imager

Overview

The Thermal Imager is an infrared imaging surveillance system that provides day/night capabilities. It senses heat changes and generates real-time video pictures in all lighting conditions including total darkness. Infrared has wavelengths that are shorter than visible light and are longer than microwave (Radio). Near infrared (3-5 micron) refers to that region of infrared that is closest to visible light and far infrared (8-12 micron) refers to the part that is closer to the microwave region. The primary source of infrared radiation is heat or thermal radiation. Any object that has a temperature above absolute zero (-459.67 degrees F or –273.15 degrees C) radiates heat in the infrared. Even objects that we think of as being very cold, such as an ice cube, emit energy when compared to absolute zero. The warmer the object above absolute zero, the more infrared radiation it emits.

The thermal imaging camera can give the capabilities of viewing over a wide spectrum in the infrared

Description

Thermal imagers can solve many video assessment problems associated with the protection of valued assets at various installations, or facilities. Thermal imagers can provide video perimeters monitoring both day and night without expensive security lighting. Until fairly recently, thermal imagers required open loop cryogenic cooling to operate. The high cost of these systems and associated maintenance requirements restricted their widespread use. However, recent developments in reliable, closed-loop, linear drive cryogenic coolers and un-cooled infrared imagers have dramatically reduced system cost. These technology developments are resulting in greater availability and practicality for many applications.

Technical Details

Spectral Response: 3 to 14 microns
Time to Operation [Typical] <25 seconds @ 25 Celsius
Gain Control: Automatic or Manual
Level Control: Automatic or Manual
Black/White hot: Automatic or Manual
Power Requirements [Typical]: 12 VDC

4.9. Photovoltaic (solar) panels: Preliminary Requirements for making an array in a monitoring system

Using solar panels for any remote monitoring system requires many different variables for correct coverage of the system. Solar panels should be part of the last set-up procedure, so that the operator knows exactly how many panels will be needed to keep the system running over a period of time.

The following clarifications will need to be addressed before a person (operator) can confidently know the amount of solar panels required.

1. Load calculations

This is probably the most important area that needs to be done before any array decision can be made. This calculation shows what will be in the remote site and what the draw will be during peak use. This section should also show what the system will work on, and if the system will be on AC or DC. If there are any devices that require AC then an adapter will need to be placed into the calculations so that the chart shows a correct load.

This chart should also show how many days out of the week the system will be active and also when peak times may occur. The chart should also reflect the location and time of the year. Photovoltaic systems do not have a constant energy source throughout the year. During cold seasons, the system will give a lower current, and the locations will reflect how much a single panel can draw.

2. Current and array tilt

This area of the calculations shows the location of the array and the best possible draw that can be accomplished from the design aspect. The operator needs to know the location of the site in relationship to Longitude and Latitude. They also need to know at what time during the day the system will receive the most current. In the calculations, the operator should also give a threshold number of how many days the system can stay operational without any light. This will also be discussed later in the battery options. At this point the operator needs only know how much time they are willing to give the battery before the system goes down

3. Battery size and type

The battery type and size will determine how many solar panels will be needed at a monitoring site. Not all batteries are suitable for a remote site nor are they suitable for a solar array. The operator needs to decide which type of battery would best suit the system and what will be required, in Amps, for the system. Using NiCad batteries or deep cycle marine batteries will usually suit a system design. To find out what type of battery will be best for a system, the operator will need to know what the current load will be during peak hours and how long the system will be operating during the day.

The trick to any system is the constant fight between the battery life and how many amps the solar panels can give. A good rule of thumb is to always make sure that the solar panels give more current than the system requires.

This will ensure that the batteries will be charged while still operating the system. This will also help with those times when the panels are not in operation. This will dictate how many batteries will be need for the site, and also on how many solar panels will be placed into the array

4. Array size

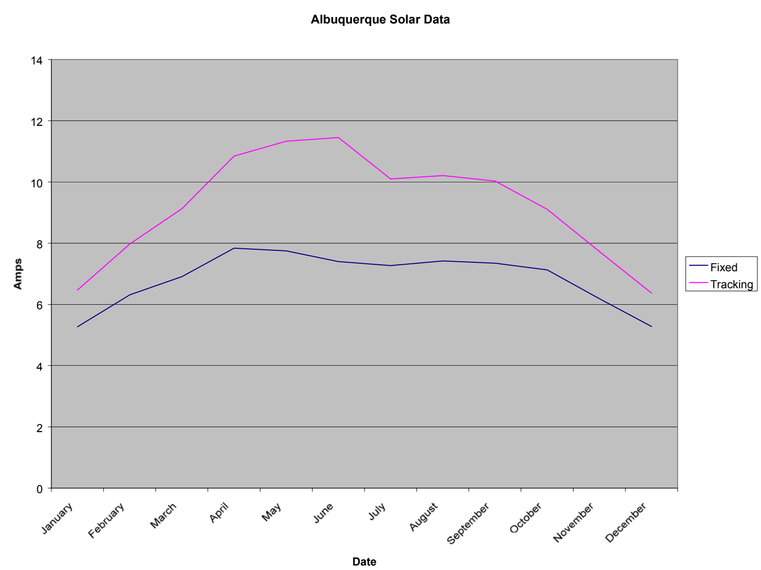
This is the area where the operator is actually making the decisions on the solar panels and on how many will be used for the system. This area will give the operator a rough draft of the amount, size, and type of panels required for the array.

There are many different types of solar panels on the commercial market but they all relatively do the same thing. There are really only two major types that need to be decided on. The first type is the tracking array. A tracking array will give more current throughout the day because it is following the movement of the sun in the sky. This unit will give the monitoring system the highest current possible because it will always have optimum light on the panel. The problem with this system is in the expense. These types of panels can easily double in price compared to fixed arrays.

The fixed array is a stationary panel that does not get the highest current from the sun. This type of panel will fluctuate in current, because it does not receive direct light throughout the day. The good thing about this system is that it requires no calibration and is fairly inexpensive.

The areas stated above for making proper judgment on a solar array are only the major concerns for a monitoring sight. There are also optimization problems that would have to be address such as wire gauge, overall life of the battery, power surges, harsh climate, and installations. The areas covered above are only for a broad base for finding out how many panels will be needed (minimum) for the monitoring sight.

Below is a chart on the possible current that can be drawn from the sun during the year by either the tracking or fixed array. To find the same data on an area where a monitoring site will be installed; the operator will need to find a contact in that area that does insolation data. They can also contact the Southwest Technologies Institute for rough worldwide insolation data. Major US cities have had collections done by Sandia National Laboratories.



4.10. Microwave Video and Data Transmission Link

Summary:

Microwave transmission links are used for long-range wireless video transmission requirements. Built-in sub-carriers are capable of carrying an analog or digital signal for remote camera controls: pan, tilt, zoom and switching. Sub-carriers also allow for transmitting audio or data information to and from the remote sites through multiple interface modes.

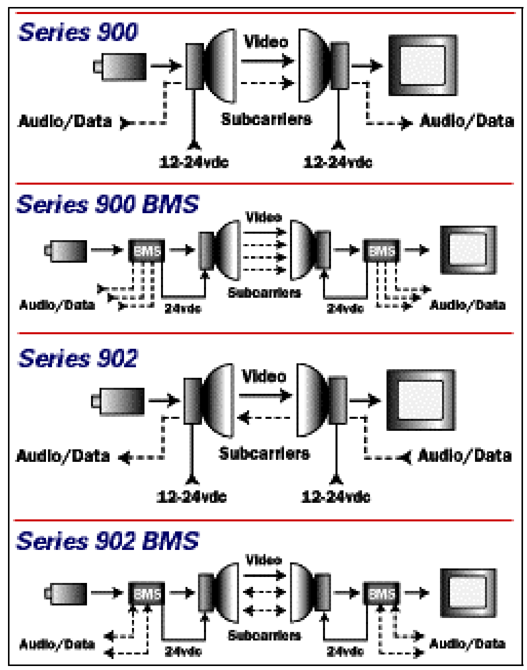
High selectivity and precise beam control enables the links to be located close together for multiple channel operations. Normal designs (FM Super-heterodyne) assure picture quality in adverse weather conditions.

Systems are individually tuned to a specific assigned frequency between 21.2 and 23.6 GHz. Frequencies are obtained through an FCC license and site surveys.

Specifications:

Frequency Range:	21.2 to 23.6 GHz
Modulation	FM (+/- 4 MHz)
T/R Separation	50 MHz
Video Bandwidth	10 MHz
Input Voltage	12 – 24Vdc @ 1.2 Amp
Power output	20mW typical
Polarization	Vertical or Horizontal
Beam-width	1.6 degrees

Series 902 Microwave Link



Video and Sub-carrier diagrams

5. Appendix B. Test Forms

Border Crossing—Volunteer Sheet

Name of Volunteer(s): ____

Name of Arbitrator: ____

1. Type of Crossing (please circle all that apply below)

	Person: Individual Group	Vehicle: Truck ATV Bicycle
Speed:	Run Walk Stealth	MPH: ________________________________

2. Time and Date: ________________________________

Day or Night (Circle one)

3. Path through simulated area and Location of ending point (Please fill out on Map Below)
(Location to be determined by arbitrator)

4. Time to cross the area ________________________

5. Sensors found during the crossing and description ______________________________

____

____

6. Notes ____

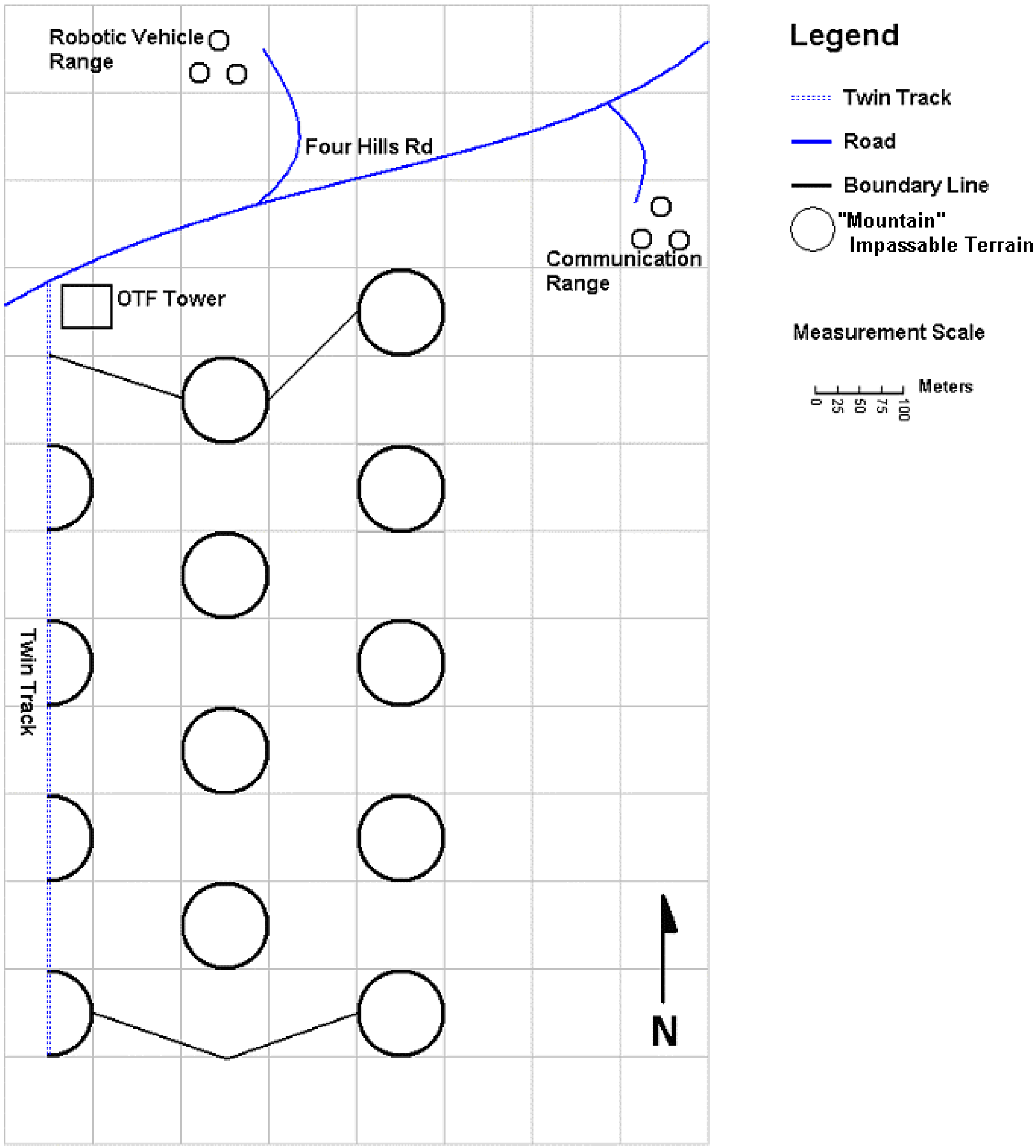
____

____

____

____

____


Robotic Vehicle Range
Four Hills Rd
Communication Range
OTF Tower
Twin Track
N
Legend
Twin Track
Road
Boundary Line
"Mountain" Impassable Terrain
Measurement Scale
Meters
0
25
50
75
100

Border Crossing—Operator Sheet

Name of Operator(s): ____

Name of Arbitrator(s): ____

1. Date / Time: ____

2. Day or Night (circle one)

3. Possible intruder path (please circle alarm activation then trace on map)

4. Determine Ending Point: (circle on map)

____

5. Type of Crossing (please circle one) Individual Group

Vehicle (if vehicle please specify type) -- Truck ATV Bicycle

6. Video Assessment: Yes No

7. Video Archive Date and Time:

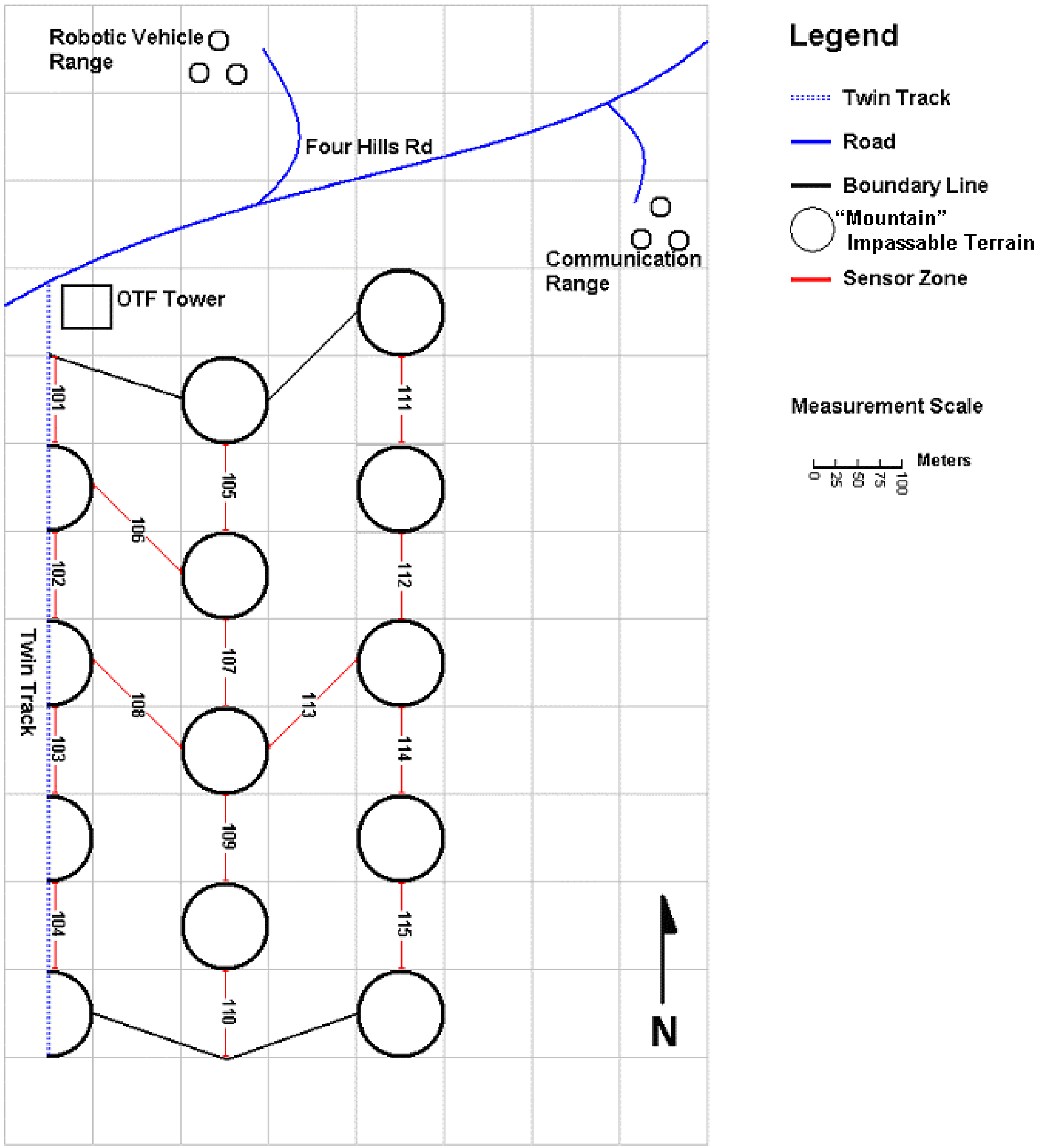
____

8. Notes and Comments:

____

____

Alarm Activations ID's	
101	102
103	104
105	106
107	108
109	110
111	112
113	114
115	


Robotic Vehicle Range
Four Hills Rd
Communication Range
OTF Tower
Twin Track
101
102
103
104
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106
107
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113
114
115
N
Legend
Twin Track
Road
Boundary Line
"Mountain" Impassable Terrain
Sensor Zone
Measurement Scale
Meters
0
25
50
75
100

Border Crossing—Arbitrator Sheet

Name of Arbitrator:____
Name of Volunteer(s): ____

____

Name of Operators: ____

____

Date and Time:____
Type of Crossing (please circle one) Individual Group
Vehicle (if vehicle please specify type) -- Truck ATV Bicycle
Day or Night (circle one)

1. Successful assessment to intrusion by operators: Yes No
   If NO, please explain: ____

   ____

   ____

2. Successful completion of course by volunteers: Yes No
   If NO, please explain: ____

   ____

   ____

3. Final Destination of intruders: (mark on map along with path that will be followed by intruders. Mark Final Destination on Intruder Map)

4. Alarms activated during Test Run

Alarm Activations ID’s	
101	102
103	104
105	106
107	108
109	110
111	112
113	114
115	

5. Alarms that were not activated when intruders Crossed

Alarm Activations ID’s	
101	102
103	104
105	106
107	108
109	110
111	112
113	114
115	

6. Alarms that activated when there was no intrusion

Alarm Activations ID’s	
101	102
103	104
105	106
107	108
109	110
111	112
113	114
115	

7. If observing video system; was the camera following the intruder(s): Yes No

8. Did the operator assess the correct location of the intruder: Yes No

If NO, please explain: ____

____

____

9. Was the path that the operator made correct with intruder path: Yes No

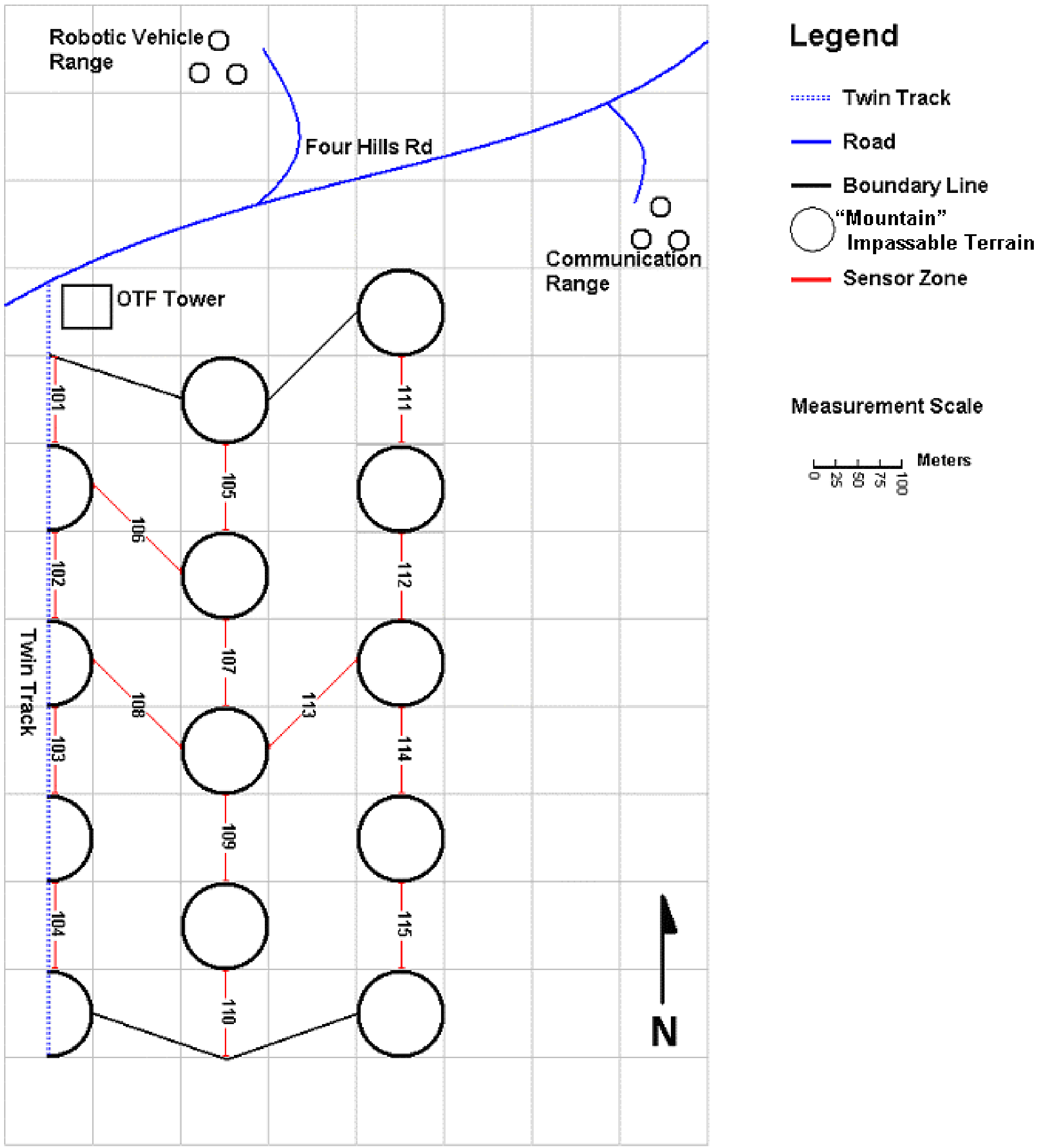
If NO, please explain: ____

____

____

9. What was type of intruder crossing: Walk Run Stealth

Notes:


Robotic Vehicle Range
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Legend
Twin Track
Road
Boundary Line
"Mountain" Impassable Terrain
Sensor Zone
Measurement Scale
Meters
0
25
50
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100

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6. Distribution

1		U.S. Department of Energy National Nuclear Security Administration Attn: Scott Davis (NA-241) International Policy and Analysis Div. Forrestal Building, GA-007 1000 Independence Ave SW Washington, DC 20585-0440
1		U.S. Department of Energy National Nuclear Security Administration Attn: Sean Oehlbert (NA-241) International Policy and Analysis Div. Forrestal Building, GA-007 1000 Independence Ave SW Washington, DC 20585-0440
1		U.S. Department of Energy National Nuclear Security Administration Attn: Mary Cobb Neighbors 1000 Independence Ave SW Washington, DC 20585-0440
1		U.S. Department of Energy National Nuclear Security Administration Attn: Pritham Khalasa Forrestal Building, GA-007 1000 Independence Ave SW Washington, DC 20585-0440
1	MS 1231	Thurman J. Allard
1	MS 1361	John C. Matter
1	MS 1363	M. Teresa Olascoaga
1	MS 1371	Ricardo A. Contreras
1	MS 1373	Doris E. Ellis

1	MS 1373	Kent L. Biringer
1	MS 1373	Timothy J. Crawford
1	MS 1373	Michael G. Vannoni
1	MS 1373	Christopher A. Runyan-Beebe
60	MS 1373	CMC Library, 5341
1	MS 1374	Robert M. Huelskamp
1	MS 1379	James F. Chapek
1	MS 9018	Central Technical Files, 8645-1
2	MS 0899	Technical Library, 9616

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