# Sensor test facilities and capabilities at the Nevada Test Site

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## ABSTRACT

Sandia National Laboratories has recently developed two major field test capabilities for unattended ground sensor systems at the Department of Energy's Nevada Test Site (NTS). The first capability utilizes the NTS large area, varied terrain, and intrasite communications systems for testing sensors for detecting and tracking vehicular traffic. Sensor and ground truth data can be collected at either of two secure control centers. This system also includes an automated ground truth capability that consists of differential Global Positioning Satellite (GPS) receivers on test vehicles and live TV coverage of critical road sections. Finally there is a high-speed, secure computer network link between the control centers and the Air Force's Theater Air Command and Control Simulation Facility in Albuquerque NM.

The second capability is Bunker 2-300. It is a facility for evaluating advanced sensor systems for monitoring activities in underground cut-and-cover facilities. The main part of the facility consists of an underground bunker with three large rooms for operating various types of equipment. This equipment includes simulated chemical production machinery and controlled seismic and acoustic signal sources. There has been a thorough geologic and electromagnetic characterization of the region around the bunker. Since the facility is in a remote location, it well-isolated from seismic, acoustic, and electromagnetic interference.

## 1. INTRODUCTION

The Nevada Test Site (NTS) which is owned by the Department of Energy (DOE) hosts a number of test facilities.[1] Sandia National Laboratories/New Mexico (SNL/NM) has recently developed two new major field test capabilities for evaluating Unattended Ground Sensor (UGS) systems at the NTS.

The first capability provides infrastructure for testing sensors for monitoring vehicular traffic over a large area. The infrastructure consists of analog and digital intrasite communications links, an automated ground truth subsystem, secure control rooms, and a high-speed secure computer network link between the NTS, and the Air Force Theater Air Command and Control Simulation Facility (TACCSF) at Kirtland Air Force Base (AFB) in Albuquerque NM.

The second capability is known as Bunker 2-300. This is a facility for evaluating advanced sensor systems for monitoring activities in underground cut-and-cover facilities. The facility consists of an underground bunker for operating various types of equipment and the 1 kilometer diameter area around the bunker for testing sensors.

The following sections provide a general overview of the NTS and detailed descriptions of the two sensor testing capabilities.

## 2. OVERVIEW OF NTS FEATURES

The NTS has been used by the DOE and its predecessors for over 40 years primarily to support nuclear weapons development and effects testing. The current maintenance and operations contractor is Bechtel Nevada (BN). Fig. 1 is a map of the NTS showing site Area numbers, paved roads, and locations of interest for this paper.

## DISCLAIMER

There are a number of key geographic and infrastructure features of the NTS that make it an attractive location for large and small scale UGS testing activities. First is the large area and remote location. The NTS encompasses 1350 square miles of desert and mountainous terrain. It is surrounded on three sides by Nellis AFB and the DOEs Tonapah Test Range (TTR) which provide a total of 5,470 square miles of controllable air space and area for large scale test exercises. The NTS contains 300 hundred miles of paved roads and 400 miles of unpaved roads. Many of the unpaved roads are also suitable for heavy vehicles. Although in a remote location, the base camp at Mercury is only 65 miles northwest of Las Vegas. Mercury contains many of the amenities found in a small town including housing, cafeteria, medical services, fire protection, and recreational facilities.

Another major feature of the NTS is the existence of several tunnels. Some are over a mile long and have over 1000 feet of overburden. The tunnels are very sophisticated underground scientific laboratories with access control, ventilation, vacuum, pressure, chilled water systems, redundant electrical power, railroad tracks, gas sampling and radiation monitoring safety systems, etc. These tunnels meet all federal Mine Safety and Health Administration regulations.

There is a large staff of technical, craft and administrative personnel working at the NTS and at support facilities in Las Vegas. The resident staff is particularly skilled in conducting large scale, high technology, complicated field experiments in severe environments. There is also a strong capability for field test construction activities, especially drilling, mining, concrete and steel structures, electrical power, and other utilities.

Another advantage of the NTS is its communications infrastructure. This system is normally used both for test data and general range communications including remote voice and data telephone lines, radio networks, and live video. Radio Frequency (RF) retransmission equipment are strategically located on hilltops throughout the site to provide full-site VHF and microwave communication coverage. There are also available a number of self-contained RF/Video relay trucks and trailers for use at and between remote test locations. Finally there are a several single- and multi-mode fiber optic cable runs between major facilities at the site. Most communications system are routed toward the NTS Control Point in Area 6.

The NTS has an experienced security force with the capability of clearing and securing virtually the entire test site. In addition the communications support group has experience in deploying and using a variety of intrusion detection UGS including the RF data transmission links.

Because of the need for containment of the underground nuclear tests that have been conducted at the NTS, the site has a large library of geologic characterization data and the ability to collect more when needed.

## 3. VEHICLE MONITORING SENSOR TEST CAPABILITY

A major use of UGS is in monitoring vehicular traffic to determine the presence, type of vehicles and purpose of the traffic. The large controllable area and road network including the tunnel access roads make the NTS an attractive site for conducting large scale vehicle monitoring sensor test exercises. Sandia, DOE, and BN have recently developed the infrastructure capability to seed sensors over the majority of the NTS area and collect both sensor and ground truth data at either of two secure control centers. We have invested a significant effort in augmenting and reconfiguring the existing NTS communications and computing network infrastructure to make it suitable for supporting such tests. This infrastructure has been used in two test exercises. These exercises are described in more detail later.

The automated ground truth capability consists of differential Global Positioning Satellite (GPS) receivers mounted on test vehicles and live TV coverage of critical road sections. All of the GPS and selected frames of TV data are captured and stored on the computers at a control center. A differential GPS system is used to accurately track the true position of vehicles used in a test exercise. We currently have 10 GPS receiver/data retransmission modules suitable for mounting on vehicles. The host GPS receiver combines GPS vehicle position information with data from the differential receiver to produce final position data accurate to 5 meters. The system operates at a one second per sensor update rate.

The live TV portion of the ground truth was implemented using the video monitoring, transmission, and display system which has been used for many years for observing activities at unattended, remote test locations throughout the site. We used this capability to provide video coverage of selected road portions of the vehicle monitoring sensor test exercises. All of the analog video is recorded along with precision time information on tape recorders. In addition we have incorporated a video frame digitizing capability into the computer network. Selected images are digitized based either on sensor cues or human intervention and stored along with the sensor and GPS ground truth data.

The sensor and ground truth data communications make heavy use of the existing NTS microwave and VHF communications infrastructure described previously. Fig. 2 shows a block diagram of the RF communications networks for both the sensor and ground truth data.

Sensor and ground truth data are transmitted to communications and computing equipment in one or both of two different secure control rooms at the NTS. Both control rooms are in alarmed and lockable Vault Type Rooms (VTR) and approved by DOE and DoD for unattended classified computing operations. The first is in Building 909 in Area 12 which is in the north central portion of the NTS and is noted in Fig. 1. This control center was used to support the Vehicle Monitoring Demonstration (VMD) test in Sept. 1995. The second is in Bldg. CP-14 in Area 6 which is in the center of the NTS. This control center was used to support the Traffic Monitoring Experiment (TME) conducted in Sept.- Oct. 1996. The two control rooms are connected by a 24-fiber wideband single-mode fiber optic cable. We can also encrypt the data on this cable.

We have assembled a computer network to support vehicle monitoring sensor tests. The network consists of SUN SPARC 10 workstations and Personal Computers (PCs) at NTS. Also SUN workstations are used at SNL/NM for software development and system management. Fig. 3 shows a block diagram of this computing network. The SUNs are used for sensor and GPS data collection and display. The PCs contain the video digitizing boards and control software for video frame capture. The NTS portion of the network is linked to one of the lab-wide networks at SNL/NM via an 800 kilobit per second Wide Area Network. This speed can be increased to a full T1 channel of 1.55 megabits per second if required for a given test.

We have also developed software in the C language for SUN workstation to read, display, and store both the sensor and the GPS vehicle position information. The software for the video digitizing in the PCs was obtained from ProShare Inc.. The ProShare software actually supports video conferencing, but it provided a quick, inexpensive way to implement the frame capture feature.

Another important sensor testing infrastructure component is a secure link to the Air Force TACCSF located at Kirtland AFB in Albuquerque NM. The TACCSF contains a number of powerful computers and specialized flight simulators which provide realistic man-in-the-loop emulation of a wide range of air attack operations scenarios. In addition, the TACCSF is linked to many other DoD simulation facilities. We intend to use this link to support combined live/simulated exercises. Live vehicles and sensors would be operated at the NTS, and attack and airborne sensor scenarios would be simulated at the TACCSF. Writing and getting approval for the Computer Security Plans proved to be a challenging task since both DOE and DoD were involved, and both the Albuquerque and Nevada DOE operations offices were involved. The TACCSF link was not used in either of the NTS demonstrations because we had not received final approval for the computer security plan. The plan has now been approved and all of the hardware including encryption devices are in place. The TACCSF link is ready for activation for the next test activity.

The vehicle monitoring infrastructure described above has been used in two test exercises. The first was conducted in Sept. 1995. In this exercise we manually emplaced 60 intrusion sensors of various types in the road network in Area 12 as shown in Fig. 1. The intrusion sensors used were seismic, passive infrared, and beam-break obtained from Eagle Telonics Corp. and from Qual-Tron Corp. We also tested a Sandia prototype day/night imaging sensor in this exercise. Area 12 contains a number of tunnels that were used for weapons effects testing. The tunnels are mined into the side of Rainier Mesa which rises about 1000 ft above the tunnel portals. The exercise was conducted in an area approximately 8 miles by 10 miles and used the portal access roads to two of the tunnels. These roads go up steep canyons. By placing our RF relays on top of the mesa and on top of a small hill on the east side of Area 12, we were able to achieve RF communications over nearly the entire area. The control center for this test was located in Building 909 in Area 12. This building contains a number of VTRs to support secure computing operations.

The Sept. 95 exercise had two major purposes. The first was to demonstrate the systems integration of the sensors, communications, recording and display subsystems. Second was to collect data sets for developing and testing a rule-based expert system for vehicle tracking using data from simple UGS. The exercise consisted of scripted vehicle movements of 10 convoys over a two-hour period. Four runs were conducted. The vehicles in the convoys consisted of passenger cars, pickup trucks, vans, and heavy construction vehicles such as water trucks, and tractor-trailer rigs. The first two sessions were conducted with incidental site traffic included. The second two were conducted with the area closed to all other vehicles. All of these sessions were successful in utilizing nearly all features of the sensor and ground truth data collection infrastructure and in collecting data sets for evaluating the vehicle tracking software.

A second similar but smaller exercise was conducted in the fall of 1996. This time the road network in Area 25 was used. We monitored the traffic associated with the launch of a rocket by Sandia from the NTS to the TTR. The control point for this exercise was moved from Area 12 to the Sandia secure computing facility in the CP compound in Area 6. Again the GPS and live video were used for ground truth. The second exercise used a completely different set of RF relay points than the first thus further illustrating the capability to conduct exercises over a large area.

## 4. CUT-AND-COVER FACILITY MONITORING (B2-300)

A second major use of UGS is to monitor activities at various types of fixed facilities especially underground ones such as a cut-and-cover facility. This is one where a deep hole is excavated. The facility is built, and is then covered and protected by layers of concrete and dirt. An old hardened underground instrumentation bunker at the NTS, known as B2-300, has been refurbished to serve as a testbed for sensors for monitoring activities in a cut-and-cover facility.[2] As shown on the map in Fig. 1, B2-300 is situated in Area 2 which is in the northwestern part of Yucca Valley. This valley was the site of many atmospheric and underground nuclear tests. The bunker was originally used for data recording instrumentation for several atmospheric nuclear tests.[3] B2-300 is in a very remote location. There are no other facilities or regularly traveled roads within over 2 miles of the test facility. This makes it ideal for conducting sensor phenomenology tests in a well-controlled environment.

The B2-300 testing complex consists of the underground building and the 1 kilometer diameter area surrounding the building. The building consists of a number of underground rooms at various depths as shown in Figs. 4a,b. The generator room in the northeast quadrant is a steel-reinforced concrete rectangular shaped structure. The south elevation, the roof, and part of the east elevation are exposed. The rest of the room is buried. The concrete walls are 2 ft 8 in thick and the roof and floor are 3 ft thick. The entrance to the structure is through a 4 ft x 8 ft door. Two generator exhaust pipes extend into the room from the ceiling, and a 1000 gallon fuel oil tank is located outside the northeast corner of the structure.

The instrumentation portion of the building is also of steel-reinforced concrete construction. There are four separate rooms. An open ramp 130 ft long and 16 ft wide and sloping at approximately 15 degrees provides access from grade level to the facility's underground entrances. A concrete loading platform is located at the bottom end of the ramp. On the south side of the platform, a 4 ft x 8 ft door provides access to a corridor that leads to the individual rooms. The interior walls, floors and ceilings have steel utility mounting struts embedded on 2 ft centers. The walls are 2 ft thick and roof and floor are 1 ft 6 in thick and 1 ft 8 in thick respectively. Up to 15 ft of earth fill rests above the instrumentation rooms. There are heavy steel blast doors at the entrance to the instrumentation portion of the facility and to each of the equipment rooms.

The northwest and southwest rooms are the only ones routinely used for placing test sources. The northeast room is nearly full of old pumps and other utility fixtures. The southwest room is blocked off and is not currently available for testing.

The B2-300 building had not been used for over 20 years. Refurbishment consisted of cleaning, painting, installing new electrical power, telephones, ventilation, a parking area and bringing in two portable office/light lab trailers. The area for 1000 meters in diameter surrounding the facility has been surveyed and a marked grid installed on a 50 meter spacing. The grid was intended to provide for easy precision emplacement of sensors.

The facility is equipped with standard 110 volt 60 Hz and 208 volt 3-phase power. There are also provisions for generating 50 Hz power either by a generator or by an inverter from the 60 Hz power.

There is a permanent weather station located approximately 100 feet from the bunker complex. This station is part of a large array of weather stations operated at the NTS by the Air Resources Laboratory. This weather station provides wind speed and direction, temperature, pressure, relative humidity and precipitation data.

The B2-300 rooms can accommodate a variety of equipment. Initial sensor tests were done using compressors, generators, and pumps available from surplus stores at the NTS. In addition a 350 lb. electrodynamic shaker, an acoustic system (power amplifier, signal generator, and speakers) are available. The facility has also hosted tests using a variety of pumps running off 50 Hz power.

With proper approvals and coordination it is also possible to air deliver sensors in the B2-300 area. We have delivered three sensors from a helicopter from a height of 1000 feet. It would also be possible to deliver sensors from a high speed aircraft.

The B2-300 facility was developed to be a scientific testbed optimized for studying signals than emanate from underground facilities. Because of underground nuclear tests conducted in the area, the geology has been extensively studied and is well-characterized.[4] In addition as part of the site development, seismic and electromagnetic surveys of the surrounding area were conducted. This was to provide a better understanding of the near-surface geologic and conductivity structures and their effects on signals propagating from the facility.[5]

The seismic survey was accomplished with seismic refraction data sets to determine compressional velocities, velocity spatial structure, surface wave velocities and frequencies. These data sets were generated through a series of deep and shallow refraction lines utilizing both explosive charge and hammer blow source terms. Electrical resistivity soundings and transient electromagnetic profiles were used to determine the electrical conductivity structure of the surrounding area.

The B2-300 facility has been used for two production test exercises whose purpose was to investigate the phenomenology of seismic, acoustic and electromagnetic signals emanating from a simulated cut-and-cover production facility.

## 5. CONCLUSION

Sandia National Laboratories in conjunction with the DOE and Bechtel Nevada have recently established two test capabilities at the Nevada Test Site for evaluating UGS systems, one for monitoring vehicle traffic and one for monitoring activities at a cut-and-cover facility. The vehicle monitoring capability consists mainly of RF and computer communications infrastructures for sensor and ground truth data. This infrastructure is in place and has been used successfully on two field exercises. The cut-and-cover sensor test facility consists of a refurbished underground bunker and the well-characterized region around it. This facility is also in place and has also been used in two production test series.

## ACKNOWLEDGEMENTS

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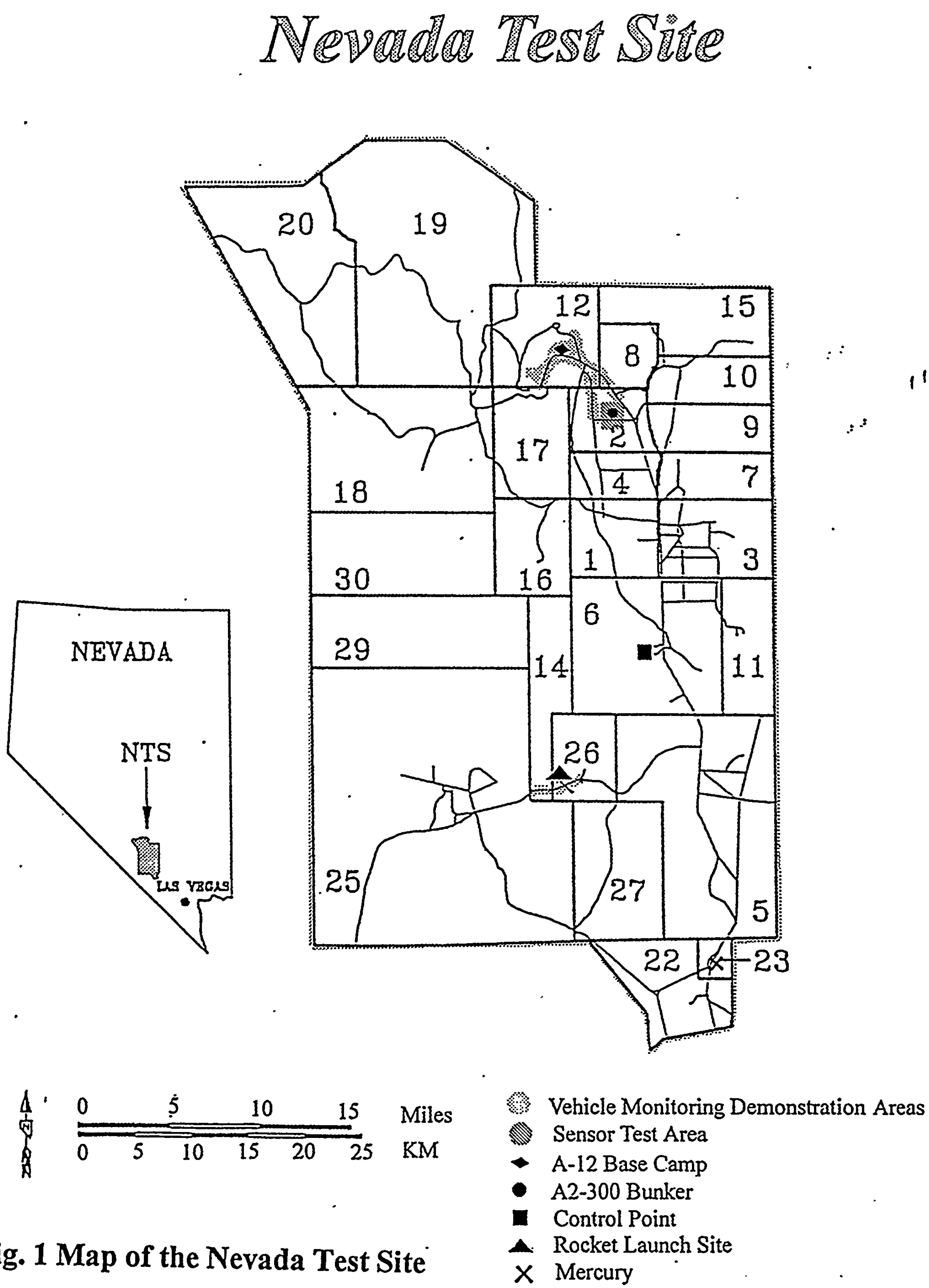


**Fig. 1 Map of the Nevada Test Site**

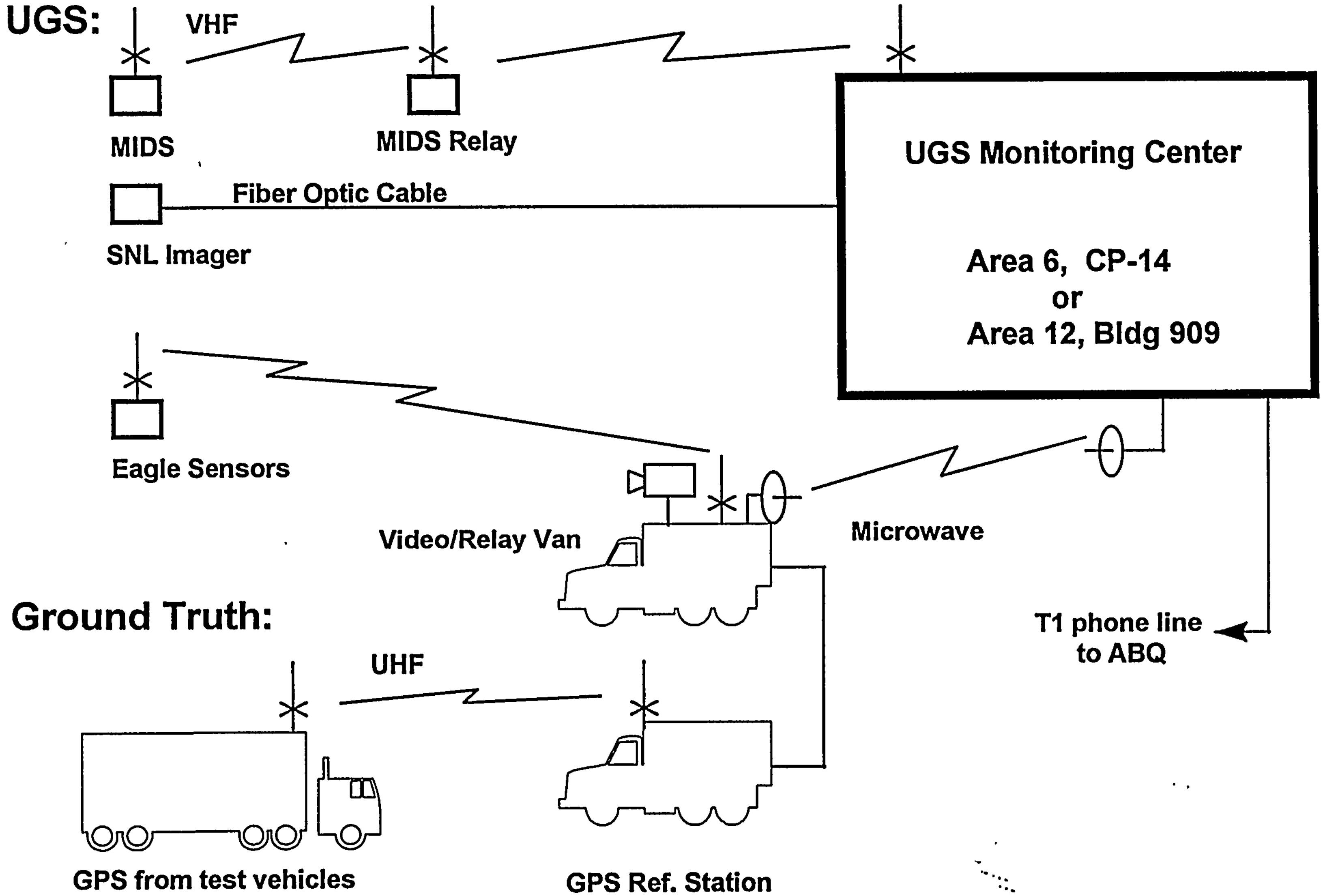


Fig. 2 Block Diagram of the Vehicle Monitoring System RF Data Transmission Networks

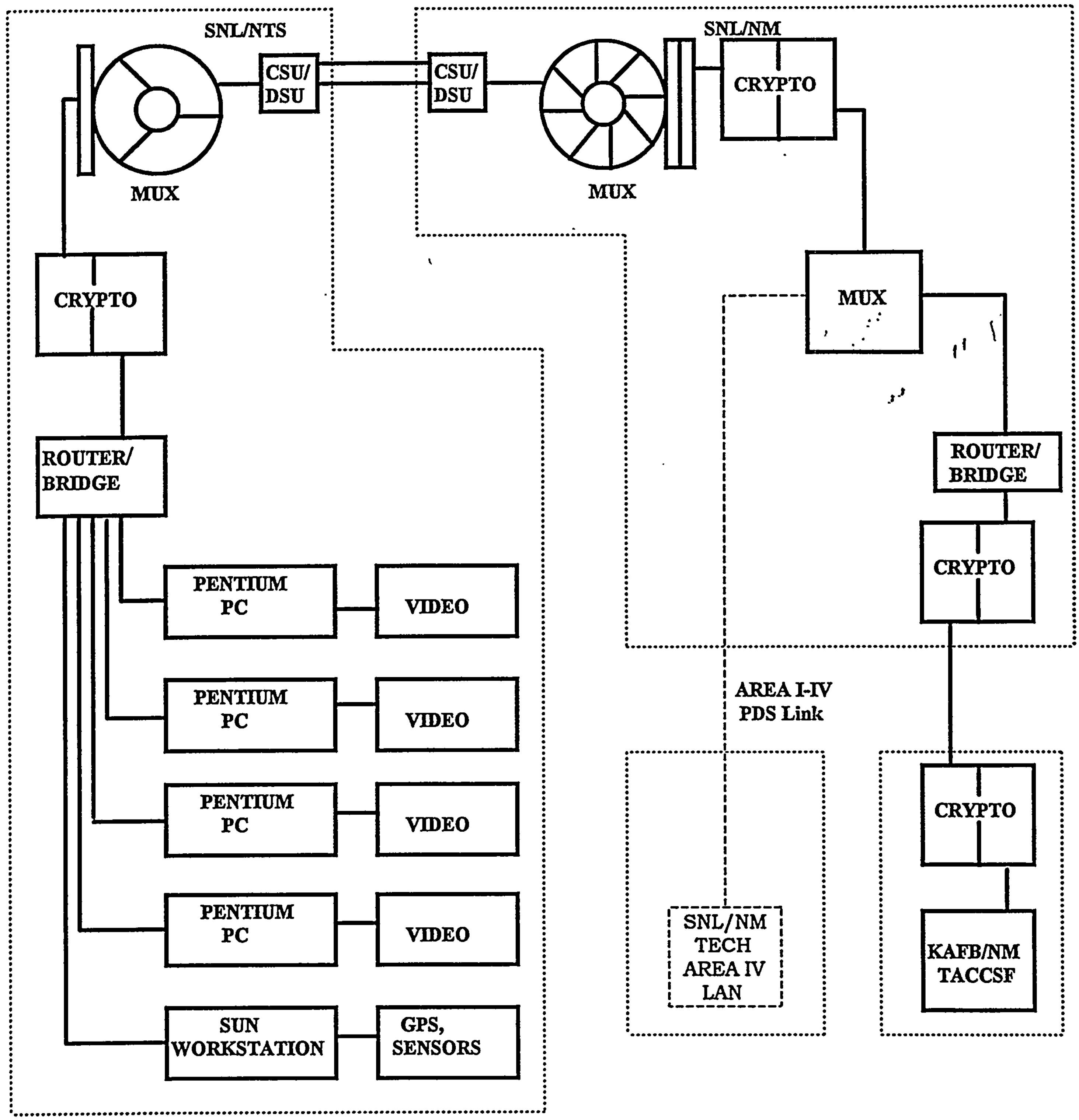


Fig 3 Block Diagram of the Vehicle Monitoring System Computer System including secure link to TACCSF

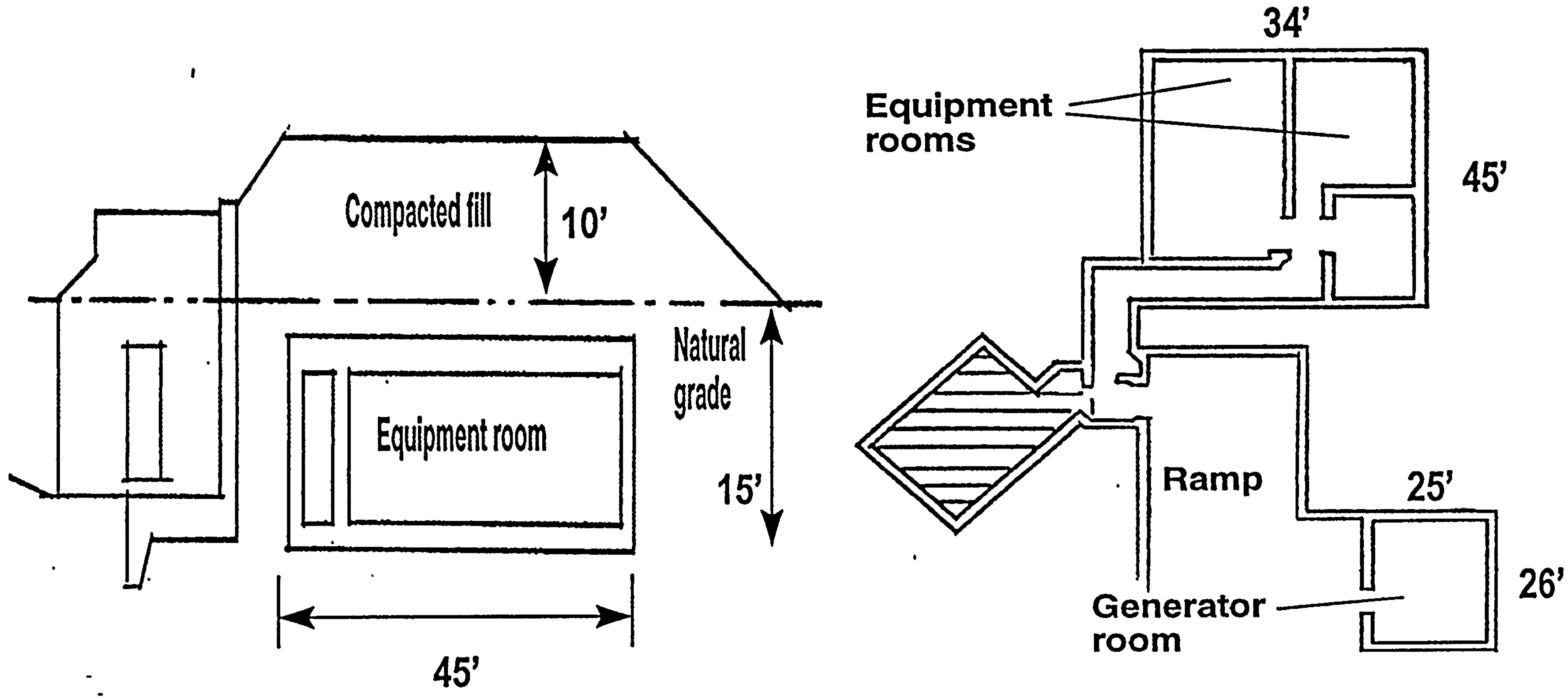


Fig. 4 Elevation and Plan views of the B2-300 bunker