Status of UGS for U.S. border monitoring

John H. McQuiddy
McQ Inc., 1551 Forbes Street, Fredericksburg, VA 22405-1603

ABSTRACT

The SBInet program to secure our border with physical fences and electronic surveillance uses Unattended Ground Sensors (UGS) to detect illegal crossing activity. The presentation will discuss the role of UGS in SBInet for cueing tower based surveillance systems and as an independent surveillance system in areas where tower surveillance is impractical. The presentation will provide a status of UGS integration into the SBInet Common Operating Picture (COP). McQ as the supplier of UGS for SBInet has supported the system integration with radars and long range imagers. McQ has worked with DHS and the Border Patrol in refining the UGS surveillance application and in training for their use. The presentation will address new UGS technology for border monitoring.

Keywords: Unattended ground sensors, virtual fence, border monitoring, sensor network, surveillance, sensor processing, sensor integration

1. OVERVIEW

1.1 Border monitoring approaches

There are a variety of approaches for using Unattended Ground Sensors (UGS) on U.S. Borders. The right approach has more to do with the goals of the user than with the technology. UGS technology can support many application requirements of the user. The following are examples of some of the UGS approaches that have been postulated for our border monitoring application.

a. Virtual fence – A line of UGS along the border that provides a trip wire to detect when the line is crossed. The virtual fence can be used behind a physical fence or it can be used as the only fence.

b. Monitoring in depth – UGS are deployed along natural routes leading into the U.S. to not only detect the incursion but to provide additional timeline information about the route used and the location of the intruders to aid in interdiction.

c. Layered detection – UGS are deployed in multiple lines combining the attributes of the Virtual Fence and Monitoring in Depth. The intruders are detected multiple times providing direction and timeline information to aid interdiction.

d. Contact alertment and turnover – UGS are used to cue other resources for target tracking and interdiction.

e. Gap filler – UGS are used to supplement other sensor capabilities in difficult terrain and foliage areas.

f. Surveillance – UGS are used to provide information on intrusion routes; intrusion tactics; type of activity (drug or people smuggling, illegal immigration, criminal activity); time of day, month, or year; collaborators aiding the activity; etc.

McQ has provided UGS for all of these approaches. The types of sensors used can be a wide variety ranging from seismic, acoustic, magnetic, passive IR, and switch closure devices; to imagers, micro radars, fiber optic cables, laser, or LED breakbeams, RF breakbeams, and EM field sensors. McQ's SBInet border monitoring sensors incorporate seismic, acoustic, magnetic, passive IR, switch closure, and day/night imagers.

1.2 SBInet

McQ is the UGS provider for the Secure Border Initiative Network (SBInet). SBInet is a Virtual Fence application on our southern and northern borders. In this case, the Virtual Fence is the combination of many elements in addition to UGS. These include the following SBInet subsystems.

a. Radar – A cost effective area coverage system that can also look across the border.

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b. Long range imagers – Day and night long focal length imagers with pan, tilt, and zoom capabilities to locate and identify intruders when cued by the radar or by UGS.

c. Unattended ground sensors – Detect people and vehicles using seismic, acoustic, magnetic, and passive IR sensors.

d. Tower systems – Provide a high elevation mounting for radars, imagers, and communications as well as power for the systems.

e. Tower integration – Remote Terminal Unit (RTU) data, as well as, command and control integration module for tower systems.

f. Communications network – Two way network tying the towers to the Command and Control Segment and to the Ground Mobile, Airborne, Surveillance, and Intelligence Segments.

g. Command and control segment – System servers and the Common Operating Picture (COP) user interface.

This Virtual Fence implementation backs up the physical fence installed along our southern border and fills in the gaps along the fence line. The system is designed to deter, predict, detect, identify, classify, track, respond, and resolve unauthorized border entries into the U.S.

1.3 SBInet UGS role

The UGS support the tower operations by detecting activity in the vicinity of the towers that might be attempts to damage the system, by cueing the radars and imagers when activity is detected between towers, and to fill in gaps where towers are not effective due to terrain or foliage. The UGS also can be used for Monitoring in Depth to provide deeper coverage of intruders to aid in interdiction and apprehension. The UGS can be used as temporary surveillance to investigate activities, patterns, and intrusion tactics.

2.0 SBInet UGS TECHNICAL CAPABILITIES

2.1 Current UGS technology is significantly improved relative to the systems previously used on the border. The principal UGS system technology ingredients are two way communications networking, UGS embedded advanced information processing, image and sensor integration, and low power consumption. These ingredients lead to important performance improvements that result in UGS playing a key role as part of a border monitoring system.

2.2 Networked UGS is an enabler that allows the UGS to be a more powerful tool in border monitoring systems. Figure 1 provides an architectural view of the SBInet UGS network. Networked UGS permit the operator to install the sensor quickly then adjust the performance over the network after observing the sensor performance at the user interface. Each sensor can be reconfigured to change the sensor sensitivity, the detection algorithms employed, and the internal fusion process of the individual transducers. Each SBInet UGS sensor can simultaneously process seismic, acoustic, magnetic, PIR, tamper, and switch closure transducers. Also available are Imaging Sensor Units (ISUs) that add day and night imagers as part of the fusion process. The UGS network provides the ability to manage thousands of sensors using hierarchical networking. The sensors report their health and status over the network and the system automatically generates reports on battery condition and on sensor issues. The sensors can be grouped by geographic deployment areas or by designated user. The network makes the management transparent to the user. The sensor network consists of Repeaters (shown in Figure 2) that extend the communication range to distance sensors and a Base Station (shown in Figure 3) that connects the UGS network to the SBInet at each tower. The UGS network Repeaters and Base Stations are very intelligent units that use a Mesh Ad Hoc Network (MANET) architecture. These units automatically recognize sensors and other network units that are within communication range and route the data based on establishing a reliable path to the Base Station. The data is automatically rerouted when "neighbors" join or leave the network. This self forming and self healing architecture makes it much easier for the user to set up and maintain. Importantly, networking the UGS system makes it easy to integrate with other subsystems and to integrate into a Common Operating Picture (COP). The integration of UGS with other systems becomes an open standards based network transfer of data from SQL databases using a non proprietary data structure. The UGS are integrated via the UGS network with the SBInet network and the SBInet COP. UGS networking extends the information easily to mobile and airborne units that can get the UGS information real time as they move around and through the border areas. An important enabler for the network operations is the use of a standard data structure. McQ developed the Common Data Interchange Format (CDIF) which provides the structure for information moving over the network and for storing data in a Structured Query Language (SQL) database on the server.

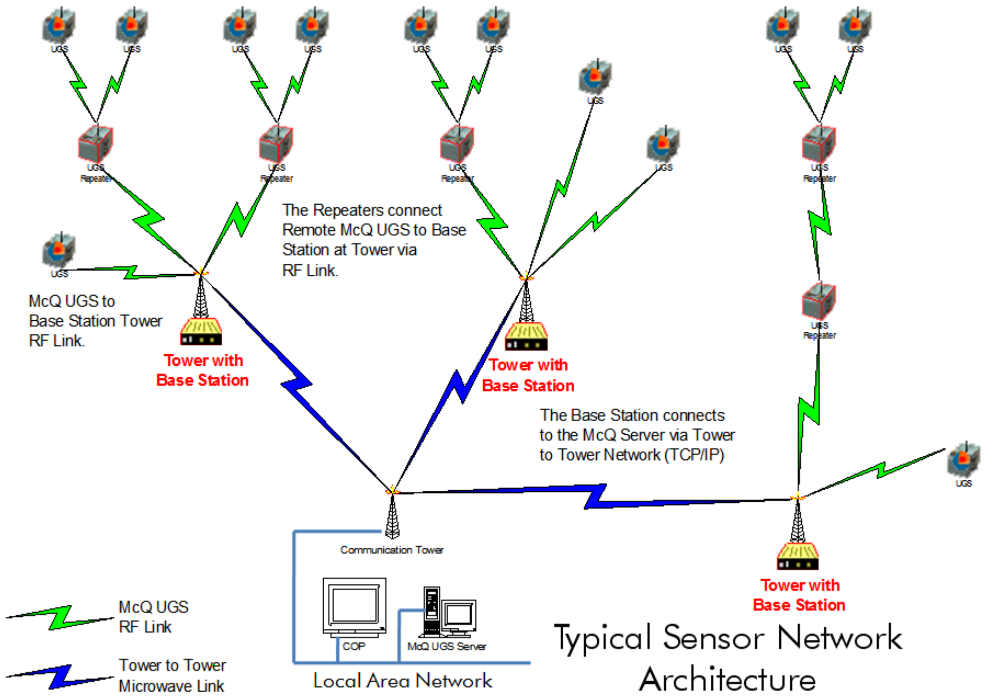


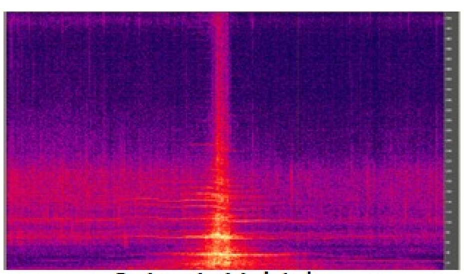
Figure 1. The UGS network combines sensor repeaters, base station nodes, and microwave relay links to connect distant sensors to the UGS sensor.

Figure 2. The UGS Repeaters are rugged units that relay sensor data to the Base Stations.

Figure 3. The Base Stations are installed in the equipment shelter at the towers and connect the UGS network into SBInet.

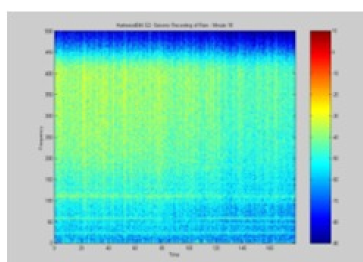
2.3 The UGS embedded advanced information processing provides vastly improved sensor performance. Figure 4 shows a picture of one of the McQ sensors used in the SBInet system. The UGS units used on the border perform extensive information processing to provide a very high probability of detection coupled with a low probability of false alarm. In the past, single mode sensors (seismic, acoustic, magnetic, etc.) provided the basis for target detection. These single mode sensors used simple detection algorithms compared with what is now in use. The target detection was based mainly on an energy (amplitude) or on time domain (counting) processing. Today the processing can be very sophisticated because low power consumption digital processors are available. This means power spectral density performed over time and advanced statistical processing can be used to evaluate target characteristics leading to decision processing to determine if a target is present. Figure 5 shows a power spectral display of a vehicle target using a seismic transducer. The time domain is shown on the abscissa, the frequency domain is shown on the ordinate, and the energy is shown in color variation with red as a high level and rainbow progression to blue being lower energy. Shown for contrast in Figure 6 is a similar power spectral display of rain which in older sensors might cause a false alarm detection. Clearly these seismic signals are significantly different and can be separated by a processing algorithm which will correctly classify the target as a vehicle and reject rain as an event that does not represent a target.

Figure 4. McQ's OmniSense® CORE sensors have seismic, acoustic, magnetic, and passive IR detectors built into each unit.



Seismic Vehicle

Figure 5. A vehicle has low frequency energy and spectral engine tones.



Seismic Rainfall

Figure 6. Rainfall has little total energy, lacks low frequency energy, and is broadband.

This processing can be made more robust by combining the seismic information with information derived from other detection modes such as acoustic, magnetic, or passive IR. Using attributes or features derived from several sensor modalities provides a better basis for rejecting false alarms and for insuring a high probability of detection. It also contributes to far better target classification. As an example, the seismic signature of a vehicle on an unpaved road will have an impulsive signal structure due to the vehicle bumping over an irregular surface. This can be similar to the signal structure of a group of people that also have an impulsive content due to the many overlapping footsteps and the substantial energy content that many people contribute as a group. The acoustic signal is, however, substantially different. The acoustic signal content of vehicles has the tonal content of the engine while the people signal has no engine tones but may have speech which is distinctly different. In this example, the use of a magnetic sensor signal added to the seismic and acoustic signals will have a dramatic difference due to the relatively large metal content of the vehicle when contrasted with the possibly small metal content of people even if they are carrying weapons. The fused information from these several sensor modes will provide an accurate target classification. The processor then determines that a valid target is present, classifies the type of target, and sends the report to the user. Additional processing at the server can take advantage of the GPS position associated with each detection and evaluate multiple target detections to determine the movement of the target through the sensor field. The embedded processor can evaluate the energy received from weather artifacts and screen these out to eliminate typical sources of false alarms such as rain and wind. The embedded processing is linked to the user requirements so that only target detections of interest are reported. This embedded processing provides the user with information that is needed and prevents sending false or misleading detections. The user cannot effectively deal with the large population of sensors typical of a border monitoring application unless only valid detection information is provided.

2.4 Imaging sensor units (ISUs) are available for the border monitoring application. These ISUs turn on cameras and image processors to automatically capture a picture of the target and send it to the user. The ISUs can be deployed around tower locations to detect and image activity in the tower vicinity. They are also used to detect and image target activity in areas where terrain and foliage make it very difficult to use radars or long range imagers mounted on towers. The ISU can use its own sensors to detect and classify the target then image the target. The ISU can also be cued by another sensor to image a target detected and classified by the other sensor. This has the advantage of using a standoff imager with other activity sensors near the area of interest to detect the target. The ISU processes many images, identifies the presence of a target in the field of view, and sends the best target images to the user. This eliminates the problem of sending frames without targets and streamlines the operator’s task of identifying the activity by providing the best picture. The operator can reach back to the ISU over the network from the COP to obtain additional target pictures. This integration of sensor detection with target images is an important feature in determining whether a target is one that needs interdiction or is normal activity in the area of interest.

2.5 Low power consumption is a very important design parameter for unattended ground sensors. Minimizing power consumption for the battery powered units that make up the field deployed portion of the system is required. Long operational life is very important for system monitoring national borders. It is costly and in most cases impractical to have power sources for remote border monitoring systems. Power sources may be severed and can also lead to discovery of system unit installation locations. These systems typically use batteries to power the sensors and wireless RF communication relays. The unattended ground sensor systems used for border monitoring applications need to have a very long operational life to reduce the need for the user to replace batteries. Two important reasons to minimize battery replacement are the overall cost of labor and batteries to replace them frequently, and the exposure and possible compromise of the sensor locations. Unattended ground sensors and their communication relays are buried and camouflaged when installed to prevent knowledge of their location and tampering or removal by unauthorized parties. To achieve long operational life and hence very low power consumption every element of the unattended ground sensor system must be designed for minimal power usage. All of the system units interact; therefore, the overall system design has to be based on low power consumption. The SBInet UGS system has been optimized for low power consumption. The sensors provide one to two years of operational life based on activity. The RF communications relays provide multiple years of life operating with solar battery chargers.

3.0 SBInet UGS PERFORMANCE

3.1 The UGS segment of SBInet has been tested for approximately one year. These tests beginning at the Boeing System Integration Lab (SIL) in Huntsville, Alabama culminated in a System Qualification Test (SQT) for the entire integrated system at Playas, New Mexico. Sensor and communications towers were installed at Playas to integrate the SBInet system and perform the SQT. Figure 7 shows the sensor tower with communications relay antennas and Figure 8 shows the equipment shelter with both solar power array and a motor generator. The testing had several objectives. For UGS, testing addressed detection performance, false alarm performance, UGS network performance, UGS integration with the SBInet suite of sensors and the integration with the Common Operating Picture. Two more operational tests are now scheduled to evaluate the total system performance before widespread deployment. The first of these is the initial deployment at Tucson, referred to as Tus 1. The second is an operational test at Ajo, referred to as Ajo 1. Figure 9 shows the general areas where the initial SBInet system will be installed. Tucson 1is scheduled to be installed in April and be evaluated during the summer. Tus 1 will have 9 sensor towers and 8 communications towers along 23 miles of border near Sasabe in southwestern Arizona. Tus 1will deploy 200 of the McQ UGS along with the UGS network which relays the information to the COP via network connections with McQ's Base Stations at the 9 sensor towers. These sensor towers range from 40 to 120 feet in height and are equipped with long range pan, tilt, and zoom day and night cameras; with radars; with Remote Terminal Units (TRUs); and with power generators. Ajo 1 is scheduled to start in June or July and will have 6 sensor towers, 6 communications towers, and 200 of the McQ UGS on 3 miles of border located near Ajo, Arizona.

Figure 7. The towers provide an elevated position for radars and imagers, as well as, for microwave relays.

Figure 8. Equipment shelters are located at the tower site for electronic equipment including the McQ Base Station.

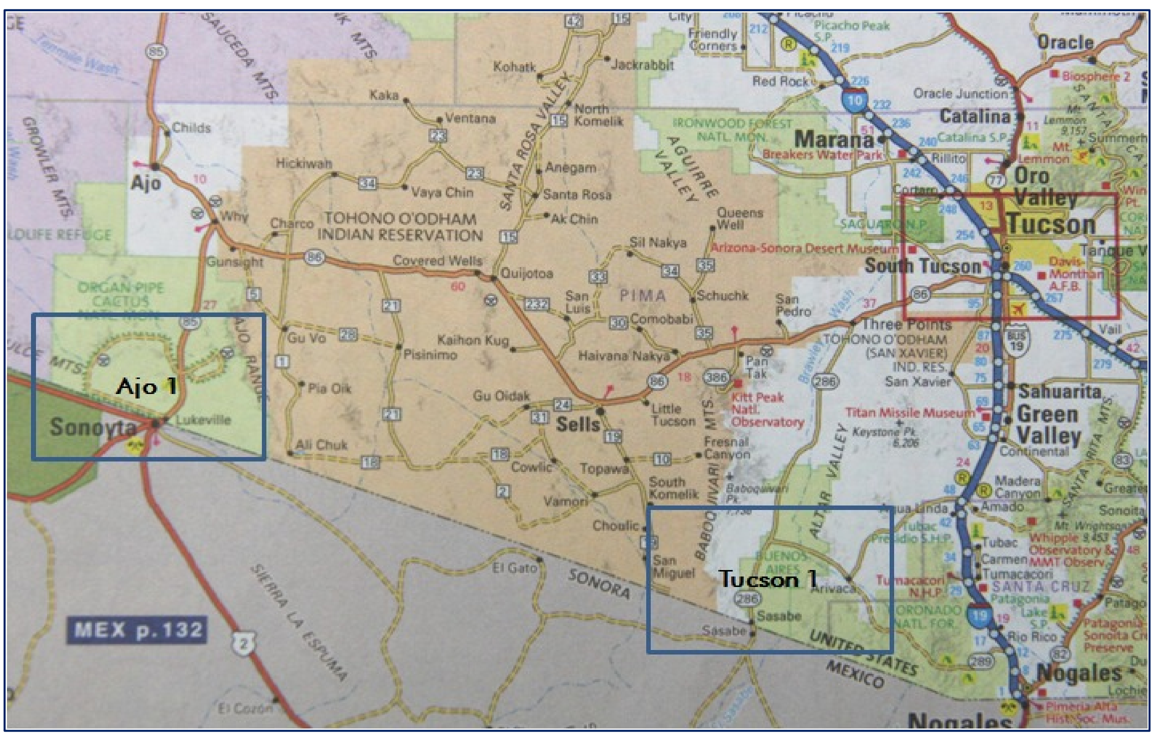


Figure 9. The initial Tucson 1 and Ajo 1 SBInet installations will be in the general areas shown.

The SQT performed at Playas in December identified some minor issues not associated with the UGS that have been resolved. The SQT was a prerequisite to begin the Tus 1 and Ajo 1 initial SBInet installations on the border. The UGS detection and false alarm performance was performed at Playas. Also at Playas the UGS integration with the tower Remote Terminal Unit, the UGS network performance, and the integration with the Common Operating Picture were all subjected to structured qualification tests. The UGS met all of their system requirements and were approved for the initial deployments.

3.2 McQ performed UGS testing at Rodeo, New Mexico in support of the SQT to verify UGS detection performance and network communication ranges. McQ, in conjunction with DoD and with DHS, is also performing testing as part of a Border Patrol initiative to evaluate the use of UGS for monitoring in depth. These tests in April are to determine the performance of UGS when used along natural ingress routes to identify illegal intrusion activity. An ongoing DHS/S&T technology assessment effort at Douglas, New Mexico will be using McQ UGS along with other detection technologies to evaluate new capabilities and operational approaches. This DHS test site will be used to identify improvements that can be made over a longer period of time in the performance of a virtual fence. McQ is continuously performing UGS R&D efforts to enhance the performance of the sensor system. These efforts include advanced network technology, sensor performance advances, image processing advances, and multiple sensor fusion technology. The results of our R&D efforts will migrate into the border monitoring testing underway under DHS and into demonstrations along the border with CBP Border Patrol operations.

McQ will be supporting Boeing during the installation and performance evaluations at Tus 1 and Ajo 1. These systems placed on the border will be the first comprehensive operational test of the integrated SBInet system. The system evaluation will continue through the summer of 2009. The goal is to make improvements and take corrective actions to reach a decision for employing the system along all of Arizona's 350 miles of border. The virtual fence for the entire border will be completed in 2011 or 2012.

3.3 McQ UGS testing performed in Playas and Rodeo, New Mexico consisted of seismic and passive IR (PIR) detection data. The soil conditions at these sites for seismic sensors are very similar to border areas where the UGS will be deployed. Figures 10 and 11 show UGS units installed in the local Playas vegetation as part of the testing activity. Boeing sensor testing at Playas quantified detection ranges and false alarm rates. The various UGS network topologies also were tested to insure the UGS network performed according to requirements and the network integration with the SBInet worked well. Figure 12 shows a picture of a sensor during the range testing at Playas. The sensor ranges to Repeaters and Base Stations were tested. McQ assisted Boeing in the set up, checkout, and training for the testing leading up to the SQT. The preliminary testing and the SQT were conducted by Boeing independent of McQ. The sensors, the UGS network, and the UGS interface with the SBInet network and COP all successfully completed testing and passed the SQT milestone.

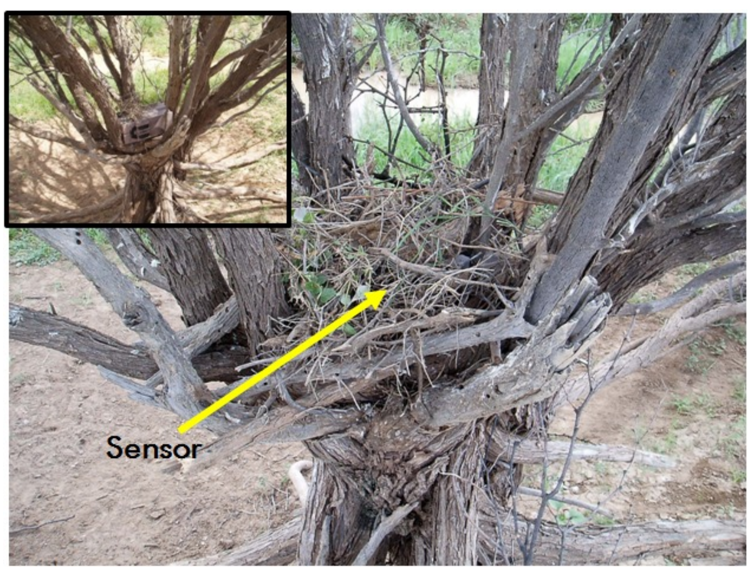


Figure 10. Sensors were located in foliage and also buried at Playas as part of the UGS testing.

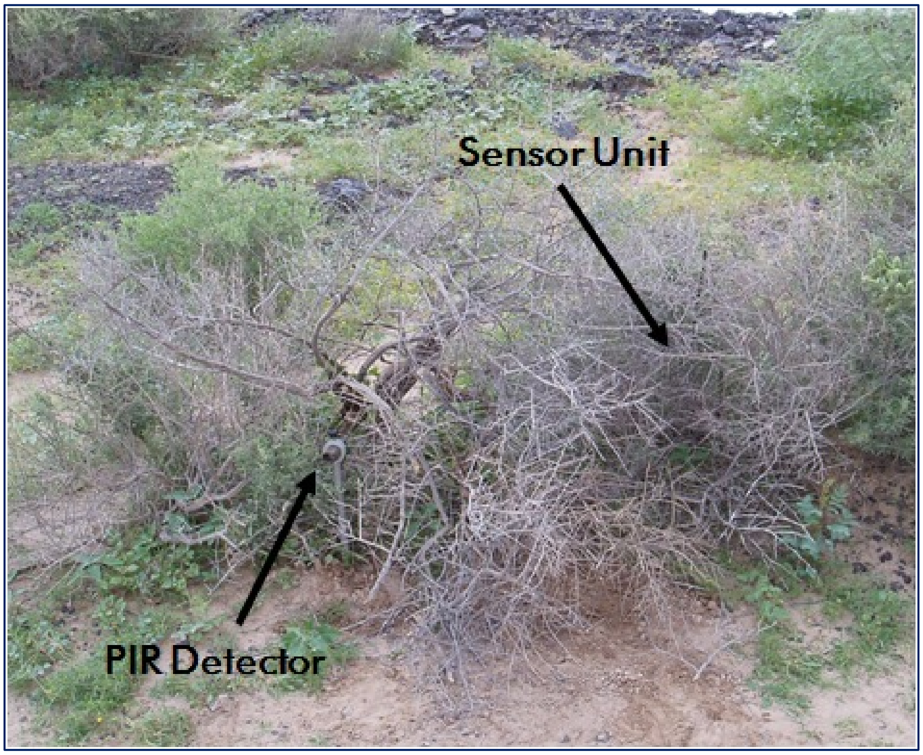


Figure 11. Sensor units at Playas were hidden in local foliage.


Figure 12. Sensor communications ranges to distant Repeaters and Tower Base Stations were tested at Playas.

McQ performed people seismic detection tests at Rodeo in February of this year to provide our engineers with quantitative data to compare with testing McQ has performed in other areas of the U.S. and in the world. Rodeo is approximately 25 miles west of Playas with very similar soil conditions consisting of pumice like rocks and very dry, dusty soil. The wind during our tests was between 20 and 30 mph with gusts to 40 mph. These tests produced 100% successful personnel detections (10 out of 10 tries) for a single walker at ranges of 5, 10, 15, 20, and 25 meters.

4.0 SBInet UGS STATUS SUMMARY

4.1 The UGS implementation on the U.S. border is still evolving. Importantly, the first operational testing and evaluation of the UGS system installed on the border is taking place very soon. The UGS are part of the integrated SBInet solution. The UGS are used to alert the operator when unauthorized activities are occurring and cue the operator to use the radar and long range imager to maintain contact on the targets of interest. The overall system target detection and false alarm probabilities will be evaluated. The overall system evaluation will include the tower mounted radar and long range imager, the UGS, the system networking, the Common Operating Picture user interface, and the process for alerting and directing Border Patrol resources to interdict targets. Based on the evaluations of Tus 1 and Ajo 1 the final system solution will be refined and approved for implementation along the Arizona border. The performance of the virtual fence will not be quantified until later this year.

Tus 1 and Ajo 1 are comprehensive examples of the SBInet technology solution. These deployments use a system approach backed up by documented system requirements and system qualification testing that is based on the requirements. They will provide a good live operational environment for DHS/CBP to determine the performance of a multisensor architecture for detecting unauthorized border crossing and entry into the U.S. They will also allow DHS to evaluate the effectiveness of a virtual fence in apprehending illegal aliens crossing into the U.S.

Many challenges will still exist for a virtual fence application. The current SBInet architecture and implementation may work well along the Arizona border but may need to be retailored for areas such as Texas and the Northern border where terrain, foliage, and large areas of lakes and rivers will likely force a change in the system approach. UGS are adaptable to a wide variety of scenarios and are likely to remain a core capability of any border monitoring system. The radar and long range imagers are also important system capabilities in these challenging areas but their role may change somewhat. Radar and long range imagers are ideal for monitoring boat activity on lakes and rivers. UGS are more suited for detecting activity once it arrives on land. The use of a physical fence in rugged terrain areas and in water areas is very difficult. Therefore, a version of the virtual fence will be needed. For the difficult areas along the northern U.S. border new concepts utilizing manned or unmanned aircraft cued by UGS may allow the quick response needed across vast areas to locate unauthorized incursions and stay in contact with the target until a interdiction on the ground can be made.