Recent Applications of Thermal Imagers for Security Assessment

Terry L. Bisbee
Sandia National Laboratories
Security Engineering Department 5831
P. O. Box 5800
Albuquerque, NM 87185-0781
505-845-8760

Abstract
This paper discusses recent applications by Sandia National Laboratories of cooled and uncooled thermal infrared imagers to wide-area security assessment systems. Thermal imagers can solve many security assessment problems associated with the protection of high-value assets at military bases, secure installations, and commercial facilities. Thermal imagers can provide surveillance video from security areas or perimeters 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 uncooled infrared imagers have dramatically reduced maintenance requirements, extended MTBF, and are leading to reduced system cost. These technology developments are resulting in greater availability and practicality for military as well as civilian security applications.

Introduction
This paper describes the modification of a military Forward Looking InfraRed (FLIR) imager to convert the maintenance-intensive, open-loop cooler to a high-reliability, linear drive, closed-loop cryogenic cooler. Also described is the recent installation of an uncooled thermal imager combined with a high-speed pan/tilt mount and remote control capability providing a powerful surveillance and alarm assessment capability. This system incorporates automatic computer-controlled positioning and video frame capture to help security operators access alarms from remote sensors. Other recent applications of thermal imagers to solve real-world security assessment problems will also be presented.

Application of thermal imaging technology to site security solutions is just one aspect of the overall system design; many other considerations must be factored into the assessment system equation. Variables such as the physical site layout, required assessment ranges, imager mounting locations, fields-of-view, sensors, alarm reporting systems, communication linkages, and timing issues, all must be considered and addressed in the design of a successful system. This paper will briefly discuss some lessons learned from dealing with these variables in actual system installations.

In the past, infrared (IR) security technology has been applied primarily to military applications. Recently, however, IR manufacturers have successfully identified and addressed many commercial applications. Developments in IR technology and improvements in reliability and performance have also helped to bring about an increased demand for this equipment in both the military and commercial markets.

The commercial market for infrared systems is more diverse than the military market. While the Defense Department typically purchases large quantities of infrared sensors as part of larger weapon systems programs, commercial customers are more apt to buy single units or small lots of off-the-shelf systems. However, advances in technology, driven by military requirements, have brought about changes resulting in significant cost reductions to levels that are affordable to commercial end-users.

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Wide-Area Ramp Surveillance System

The Wide-Area Ramp Surveillance System (WARSS) was developed to provide day/night assessment capability in support of the B-2 aircraft physical security system at Whiteman AFB, Missouri. WARSS utilizes non-cryogenically cooled thermal imagers and high-speed computer-controlled pan/tilt mounts to provide near immediate assessment of alarms from buried sensors on the massive aircraft parking ramp at Whiteman.

One of the major drawbacks to the use of cooled thermal imagers has been the need for frequent maintenance of the cooler system. As a result, these systems are not very effective in permanent installations where the units need to be mounted high-up on towers or on structures where access for maintenance activities can be difficult. Such is the case at Whiteman where the imagers had to be mounted very high in order to see the entire sensor detection area and so that the field of view would not be blocked by aircraft and flightline maintenance vehicles.

WARSS provides operators with the ability to quickly assess alarms generated by a Ported Coaxial Cable Sensor (PCCS) buried in the concrete ramp. When an alarm is triggered, WARSS automatically positions pan/tilt units and thermal imagers to view the appropriate alarm sector. Video from the thermal imagers is transmitted to monitors located in the Central Security Control (CSC) building, approximately one kilometer away. Operators can then assess the nature of the intrusion and determine the appropriate security force response.

To accomplish this, WARSS utilizes high-speed accurate positioning of one or more thermal imagers by computer control over a digital data link. WARSS can cover a complete 360-degree area within two seconds and all pan/tilt motion is computer controlled. Assessment of fast-moving intruders is aided by immediate video image storage and replay in a snapshot-toggle mode. When an intrusion is detected by the PCCS, video monitors in the CSC display live video from the thermal imagers while other monitors play back the stored alarm snapshot images in a toggle mode. By comparing the two images, captured one half second apart, as they toggle on the same screen, the operator can more easily detect movement and determine the cause of the alarm. Multiple alarms are assessed in the order in which the alarm signals are received and the respective snapshot frames are stored for recall by the operator.

Operators can also manually control the imagers using a joystick or move to specific locations.

Figure 1. Wide-Area Ramp Surveillance System
using preset points. These functions, along with camera control switches, are provided to the operator via a WARSS control panel mounted near the monitors.

Thermal imagers were chosen for WARSS over standard visible imaging closed-circuit television (CCTV) cameras to provide immediate visual assessment in daylight or in total darkness without the need for ambient lighting. The large, open ramp at Whiteman cannot be sufficiently illuminated by traditional means. The thermal imager used with WARSS is a component of the Texas Instruments Security Sensor, Infrared (SSIR) developed under the Low Cost Uncooled Sensor Prototype (LOCUSP) program sponsored by the U. S. Army Night Vision and Electronic Sensors Directorate (NVESD), Fort Belvoir, Virginia.

Operational Assessment Systems ImprovementS (OASIS) Project

This ESC project encompassed upgrades to the Thorn EMI Multi-Role Thermal Imagers (MRTI) which were in the inventory of the US Air Forces in Europe (USAFE) Security Police. The upgrades included changing the detector cooler, incorporating remote control capability, and integrating a pan/tilt mount. These upgrades produced the OASIS-Improved MRTI (see Figure 2).

Figure 2. OASIS-improved MTRI (left) and MRTI prior to OASIS upgrades

In October 1993, Sandia and ESC discussed the development of a cooler upgrade “kit” for the MRTIs. At that time, the MRTIs in the USAFE inventory were experiencing limited deployment because of the requirement to change gas bottles approximately every two hours. The MRTI’s open-loop cooler required a constant supply of high-pressure pure air to cool the detectors.

Recharging the gas bottles requires special high-pressure equipment and safety training. Deployment was also restricted because the MRTI lacked remote control capabilities that allowed the unit to be mounted and operated at some distance away from the operator.

Following an initial technical evaluation, it was determined that the existing units could be retrofitted at a significant savings over buying new units with the desired features. The retrofit included integration of a split-Stirling closed-loop cooler to the MRTIs. The project goal was to provide a complete upgrade kit that could be installed and repaired by depot-level maintenance personnel at the Pirmasens Army Repair Depot in Germany.

The feasibility of a closed-loop cooler retrofit was demonstrated by Sandia in October 1993, using a Hughes cooler temporarily strapped to the side of a MRTI with the cold finger laying loose in the Dewar. (The Dewar is a glass vessel that contains the detector array and that the cold finger fits into.) Based on the success of this demonstration, ESC and USAFE decided to pursue development of the cooler kit, the remote control upgrades, and a pan/tilt unit that would operate with the upgraded MRTI. These development activities became the OASIS project.

Sandia’s task was to provide technical guidance for the MRTI upgrades and to increase USAFE’s use of thermal imaging devices for security assessment. Specific requirements were to:

- find a commercial supplier to develop a closed-loop cooler upgrade kit
- integrate a pan/tilt unit
- integrate remote control capabilities
- conduct site surveys of USAFE bases, as requested, for installation of thermal assessment systems

Options were provided in the tasking for procurement of 12 additional cooler kits and remote control upgrades if development and testing of the prototype was successful.

A feasibility study conducted by Sandia recommended prototyping of a MRTI cooler retrofit kit which replaced the open-loop Joule-Thompson cryostat detector cooler with a split-Stirling closed-loop detector cooler. The technical risk of replacing the Joule-Thompson cooler was considered low because the Stirling...
cooler was a proven design and available as a commercial off-the-shelf (COTS) item.

Five suppliers were independently contacted to discuss the feasibility of replacing the open-loop cooler with a closed-loop cooler. Each was then asked to respond to a request for quote (RFQ) for the effort. Following a technical appraisal of the five RFQ responses, Litton Industrial and Life Support Division was awarded the contract to develop the prototype cooler kit in July 1994. In January of 1995 Litton demonstrated the prototype OASIS-Improved MRTI with the cooler retrofit kit and remote control upgrades. (As it turned out, the remote control upgrades were a proprietary option from Thorn and did not require a development effort or competitive bidding.) The MRTI was mounted on a pan/tilt unit manufactured by Kylmar Ltd. Remote control of all imager functions was demonstrated through a Kylmar hand control unit. As a result of the success of this demonstration, a decision was made to purchase cooler kits and remote control upgrades for 12 additional MRTIs.

The prototype OASIS-Improved MRTI has since been installed at a USAFE base in England. The imager is mounted at the top of a 100 foot communications tower.

Installation of the imager and system integration with the communication linkages was performed by Kylmar. A CCTV camera is mounted beside the imager on the pan/tilt unit (see Figure 3). A primary and secondary operator control console have been provided.

With only one OASIS-Improved MRTI now operational, it is difficult to accurately determine the reliability and cost-effectiveness of the cooler retrofit. As for the performance of the imager, the image quality is considered to be equal to that of the open-loop cooled MRTI.

Twelve additional MRTIs have been upgraded with the Thorn remote control option and twelve additional cooler upgrade kits have been delivered to the Pirmasens Repair Depot in Germany for installation.

With the prototype system operating as a test installation, Sandia and USAF/ESC are now evaluating the installation of similar equipment at other USAFE bases.
Video Imaging System for Detection, Tracking, and Assessment (VISDTA)

VISDTA is a mature technology developed out of a project begun in 1987 for ESC and the USAF. The system is comprised of an infrared thermal imager mounted on a computer-controlled pan/tilt mount, plus a video motion detection (VMD) processing capability for detection of human and vehicle targets. VISDTA was developed as an automated wide-area surveillance capability for ground-based security applications and was motivated by experience in the use of thermal imagers for surveillance at AF bases during anti-nuclear protest activities. These experiences revealed that thermal imagers were very effective in detecting intruders at night; however, it was also reinforced that continuous monitoring of a video scene by security personnel was a manpower-intensive and tedious activity. VISDTA was designed to address these problems by using image processing electronics to detect changes in the scenes under surveillance and alert the operator only when significant changes were detected.

Originally, four VISDTA systems were built and installed. However, Sandia has recently been tasked to provide two additional VISDTA systems. This underscores the continuing need for commercial systems of this type for wide-area security applications. The VISDTA technology has been dusted off and integrated with newer thermal imagers and pan/tilt units to meet this ongoing requirement. The design and performance of this system can be greatly improved by incorporating recent technology advancements which impact every major component of the system architecture. The processing platform, image processing electronics, VMD algorithms, pan/tilt units, and thermal imagers could all be upgraded leading to performance and cost benefits.

Valuable experience gained from the VISDTA development was applied to the WARSS design and is currently being applied to the development of an Advanced Exterior intrusion detection Sensor (AES) at Sandia. AES was funded by the Defense Special Weapons Agency as a research program to investigate current and emerging technologies that could be applied to the design of an advanced sensor meeting the requirements of the user community. AES incorporates multiple sensing phenomena to overcome environmental and man-made limiting factors. Data from a longwave infrared linear scanning array, a visible linear scanning array, and a low-power radar are fused by the system and processed by an advanced Video Motion Detection algorithm. The three sensors are mounted on a rotating platform that performs a continuous $360^\circ$ scan once every second. The prototype AES system is nearing the development testing phase at Sandia.

Flightline Security Enhancement Project (FSEP)

FSEP is new work just getting started and is part of the Force Protection Initiative. This AF initiative will apply the type of assessment capability developed under the OASIS project to flightline and base perimeter security problems at several OCONUS bases. CCTV cameras and thermal imagers will be integrated with intrusion detection sensors and alarm annunciators to provide a complete detection/assessment system.

Site surveys at each base will identify the primary areas of concern. At a typical base, we expect that three to five camera locations will be required to provide the necessary coverage. CCTV cameras and thermal imagers will be comounted on remotely controlled pan/tilt units and positioned to provide maximum assessment capability. Existing structures will be utilized as much as possible for mounting locations; towers will be installed where necessary. Video and control signals will be transmitted over suitable communications links to a primary monitoring station. Multiplexing may be utilized to compensate for limited availability of communications lines in the base cable systems. Video display and switching will be provided at the monitoring stations, as well as a video recording capability. Security operators will be able to select and position the cameras using a joystick or by entering preset points. The first phase of the project will be to provide this stand-alone assessment capability.

The assessment phase will be followed by the integration of intrusion detection sensors and an alarm annunciator. Sensors will be installed in semipermanent and portable configurations to provide protection of individual priority resources. RF communication links will tie the sensors to the primary monitoring station where the alarm annunciator will be located. Future addition of Video Motion Detection (VMD) is also being considered.
Lessons Learned from System Installations

Some interesting experience has been gained during the fielding, testing, and integration of the assessment systems described in this paper. Although security system operators appreciate the capability provided by thermal imagers for nighttime assessment, they are not as accepting of the current limitations of this technology. For example, when weather conditions degrade the performance of an imager and reduce assessment ranges, or when the normal daily warming and cooling cycle necessitates adjustments to contrast and brightness settings, some operators may judge the system to be problematic or unreliable. This is a user education problem that must be addressed during training and reinforced continually.

Other factors affecting the acceptance and perceived effectiveness of thermal assessment systems include:

1. Permanent outdoor installation of thermal imagers in wide-area assessment systems quickly reveals weaknesses in the environmental enclosure design. Leaks around seals allow dust and moisture to damage sensitive and expensive equipment. This has been a problem with the pan/tilt units as well as the imagers. Manufacturers must improve the ruggedness of their environmental enclosures.

2. Mounting locations must be considered carefully. Maximum visibility by a wide-area security system dictates that imagers be mounted on the tallest structures available. However, reasonable access to the equipment for repairs and routine maintenance is very important.

3. The speed and accuracy of the pan/tilt unit are key system design criteria if alarm response time and repeatability are absolute requirements. The rigidity of the mounting bracket is also very important if VMD is going to be applied.

4. Because of the high cost of thermal imagers, customers may be tempted to push for fewer camera locations to cover large areas only to be disappointed with performance. Careful consideration of the range and resolution of the imager must be given by the system designer.

5. Pan/tilt units should be robust enough to operate properly in heavy icing conditions.

6. Around the clock operation of a thermal imager quickly exposes the limits of reliability. Users may feel that the need to replace or rebuild a cryo-cooler every six to twelve months (4000 to 8000 hours) is not acceptable. Uncooled imagers may eliminate this issue as the technology matures and MTBFs rise. Users familiar with traditional CCTV surveillance systems might consider thermal imagers to be high maintenance.

7. Developing and testing the communications protocol between the operator control console, the pan/tilt unit and the camera/imager can be very tedious and frustrating. An industry standard protocol is badly needed. Communications between the pan/tilt and the imager will become an issue if an imager change is desired down the road.

8. Lightning protection should be provided in every installation design.

9. In some applications, hand-held and vehicle mounted thermal imagers are being provided to security forces as backup to the permanent wide-area assessment system. These devices can be positioned close to the security perimeter during periods of bad weather or when the primary system is non-operational for maintenance or repair activities.

Summary

Thermal imagers bring a very powerful new assessment capability to video surveillance security systems. On their own or coupled with CCTV cameras, thermal imagers give the security system operators a much greater opportunity to identify and track intruders at their facility. Although not a panacea for assessment under all conditions, their ability to see intruders on foot or in vehicles in total darkness allows operators to make informed response decisions and threat assessments while maintaining confidence in the intrusion alarm system. However, issues affecting reliability, environmental hardening, cost, and performance must continue to be resolved if users are to be ultimately satisfied with the benefits of this powerful technology.
References

