Today's Thermal Imaging Systems: Background and Applications for Civilian Law Enforcement and Military Force Protection *

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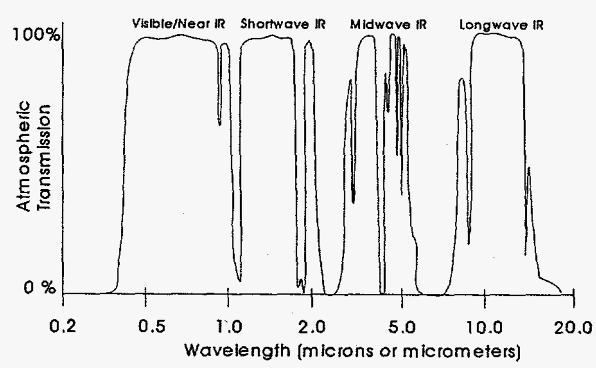
Abstract

Thermal (infrared) imagers can solve many security assessment problems associated with the protection of high-value assets at military bases, secure installations, or commercial facilities. Thermal imagers can provide surveillance video from security areas or perimeters both day and night without expensive security lighting. In the past, thermal imagers required cryogenic cooling to operate. The high cost and maintenance requirements restricted their use. However, recent developments in reliable, linear drive cryogenic coolers and uncooled infrared imagers have dramatically reduced the maintenance requirements and are leading to reduced system cost. These technology developments are resulting in greater accessibility and practicality for military as well as civilian security and force protection applications.

This paper discusses recent advances in thermal imaging technology including uncooled and cryo-cooled. Applications of Forward Looking InfraRed (FLIR) systems are also discussed, including integration with a high-speed pan/tilt mount and remote control, video frame storage and recall, low-cost vehicle-mounted systems, and hand-held devices. Other facility installation topics will be discussed, such as site layout, assessment ranges, imager positioning, fields-of-view, sensor and alarm reporting systems, and communications links.

Introduction

Infrared imaging devices utilize electromagnetic radiation in the optical portion of the spectrum, primarily in the mid-wave and long-wave infrared or thermal bands (Figure 1). These windows in the atmosphere allow for clear transmission of infrared radiation. Several detector technologies are available for imaging systems in each band. Detector technologies operating in the mid-wave band include lead-selenide, mercury-cadmium-telluride, indium antimonide, and platinum-silicide. In the long-wave band, detector technologies include barium-strontium-titanate, microbolometer, and mercury-cadmium-telluride. Each detector material operates with different conversion efficiencies. Some require cryogenic cooling, while others operate at or near room temperature. Detectors can be individual, single devices, linear arrays, or 2-dimensional focal planes. Accordingly, detector costs increase with the geometry. In both the mid and long-wave IR bands, germanium optics are employed to focus the incident thermal radiation onto the detectors.



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In the past, infrared imaging systems have been applied primarily to military applications such as anti-tank missile seekers. Recently, however, IR manufacturers have 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. Most of the work described in this paper was sponsored by the USAF Electronic Systems Center (ESC), Security Systems Products Group, at Hanscom AFB, MA. The next sections describe USAF-sponsored projects utilizing thermal imaging technology.

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.

The major drawback 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 (Figure 2).

Operators can also manually control the imagers using a joystick or move them to specific locations using preset points. These functions, along with camera control switches, are provided to the operator via a WARSS control panel mounted near the monitors.

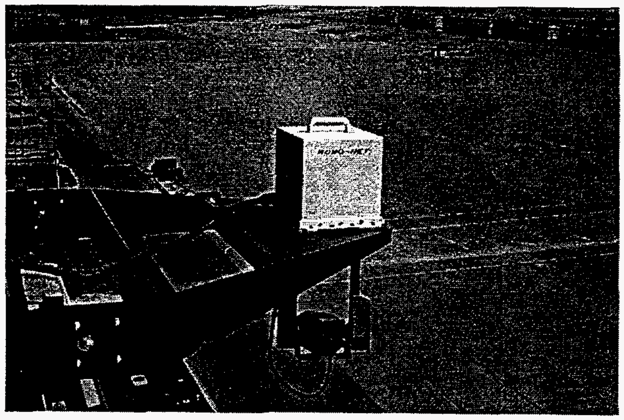

Figure 2. Wide-Area Ramp Surveillance System

WARSS provides operators with the ability to quickly assess alarms generated by other sensors in the area. 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.

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 US Army Night Vision and Electronic Sensors Directorate (NVESD), Fort Belvoir, Virginia.

Operational Assessment Systems ImprovementS (OASIS) Project

This USAF project encompassed upgrades to the Thorn EMI Multi-Role Thermal Imagers (MRTI) which were in the inventory of the US Air Force 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 3).

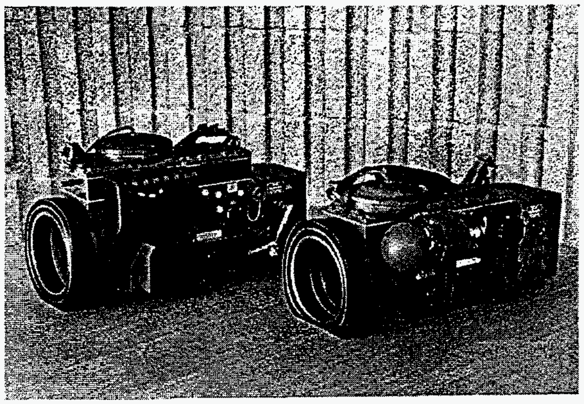

Figure 3. OASIS-improved MTRI (left) and MRTI prior to OASIS upgrades

Several years ago, the MRTIs in the USAFE inventory were experiencing limited deployment because of the requirement to change high-pressure air bottles approximately every two hours. The MRTI's open-loop cooler required a constant supply of high-pressure pure air to cool the detectors with Joule-Thompson cryostats. 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 from the operator.

A feasibility study 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.

The first retrofitted 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 (see Figure 4).

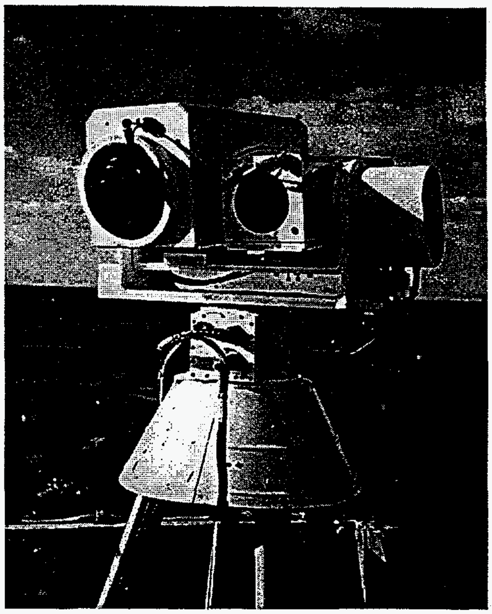

Figure 4. OASIS-improved MRTI thermal imager, camera, and pan/tilt unit

Video Imaging System for Detection, Tracking, and Assessment (VISDTA)

VISDTA is a mature technology developed out of a project begun in 1987 for the USAF. The system is comprised of an infrared thermal imager mounted on a computer-controlled pan/tilt mount, plus 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.

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 is 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 long-wave 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° 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 as part of the US Air Force 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 USAF bases. CCTV cameras and thermal imagers will be integrated with intrusion detection sensors and alarm annunciators to provide a complete detection and 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 on remotely controlled pan/tilt units and positioned to provide maximum assessment capability. 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 semi-permanent 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 installations of thermal imagers quickly reveals weaknesses in the environmental enclosure design.
2. Mounting locations must be considered carefully. Maximum visibility by a wide-area security system dictates that imagers be mounted on the tallest available structures, practical.
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. 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 6-12 months (4000 to 8000

hours) is not acceptable. Uncooled imagers may eliminate this issue as the technology matures and reliability improves. Users might consider thermal imagers to be high maintenance.

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

Latest Generation Thermal Imaging Technologies

The following table presents some information about several of the most recent introductions of advanced thermal imaging technology. Photos of these devices are presented in Figures 5 - 15.

Source	Model	IR Band	Detector	Range
Agema	Thermo-vision 570	LWIR	Micro-bolometer	--
Amber	Sentinel	LWIR	Micro-bolometer 320x240	--
Hughes	MAG-1200	MWIR	PbSe linear array	500 m
Hughes	MAG-2400	MWIR	InSb 256x256	2 km or more
Infra-metrics	Therma-CAM	MWIR	PtSi 256x256	Depends on lens
Infra-metrics	MilCAM	MWIR	InSb 256x256	Depends on lens
Texas Instru-ments	PalmIR	LWIR	BST 2D array 320x240	200-600 m
Texas Instru-ments	NightSight	LWIR	BST 2D array 320x240	200-600 m Depends on lens
Texas Instru-ments	SRTI-I	LWIR	BST 2D array 320x240	Depends on lens

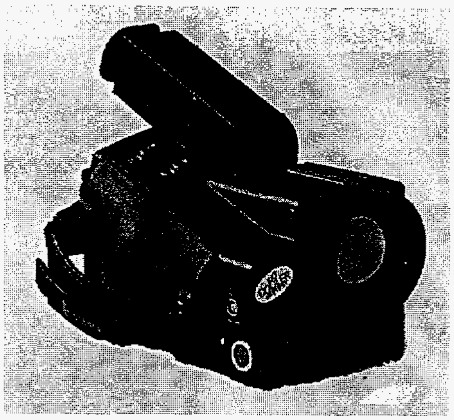

Figure 5. Agema Thermovision 570

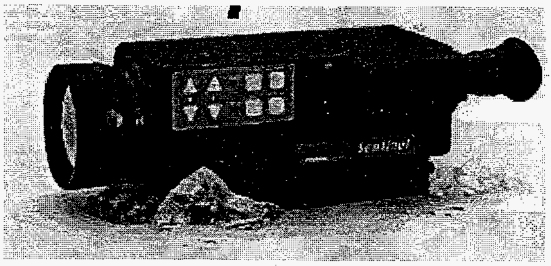

Figure 6. Amber Sentinel

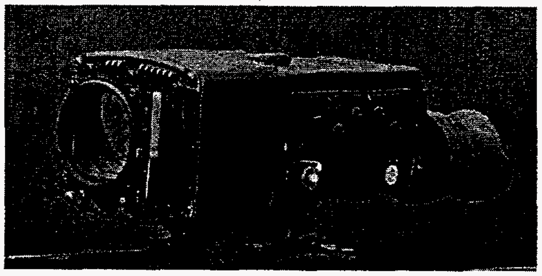

Figure 7. Hughes MAG-1200

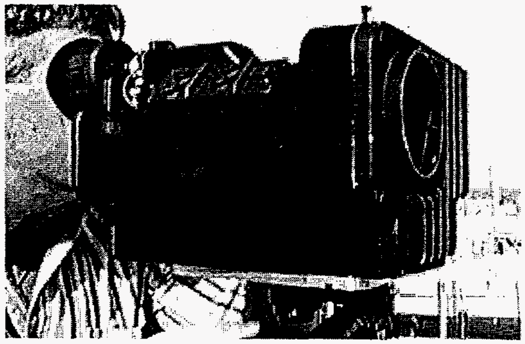

Figure 8. Hughes MAG-2400

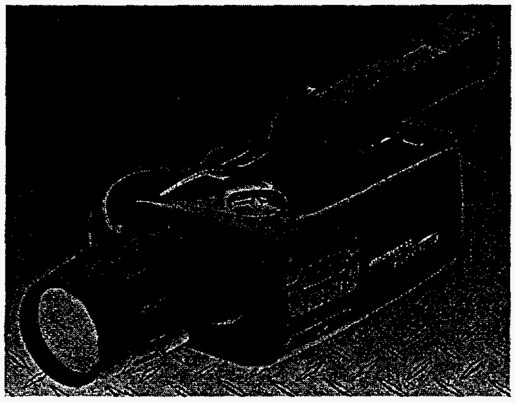

Figure 9. Inframetrics ThermaCAM

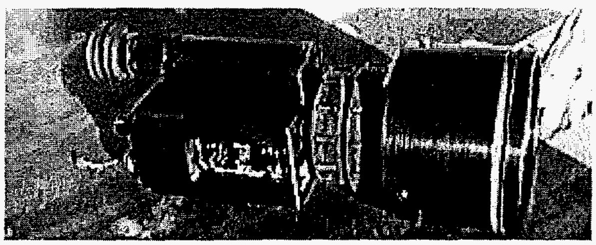

Figure 10. Inframetrics MilCam

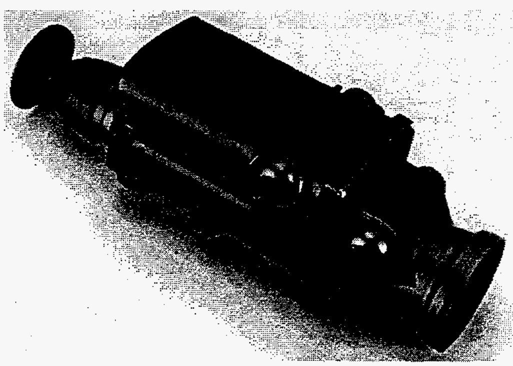

Figure 11. Texas Instruments SMRTII

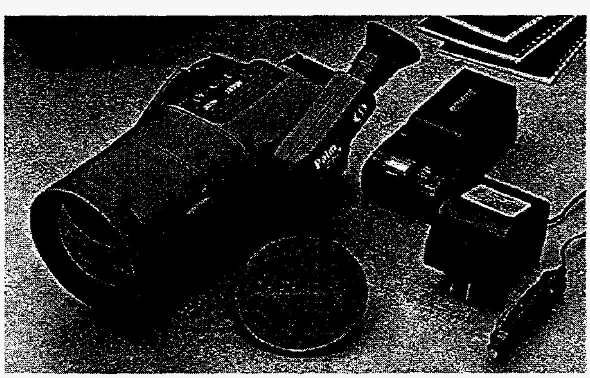

Figure 12. Texas Instruments PalmIR

Vehicle Mounted Thermal Imager

Texas Instruments has been selling a model of their uncooled thermal imager product line designed for civilian law enforcement or maritime applications. The range is quite good for a comparatively low cost unit with built-in pan/tilt mount and remote controls.

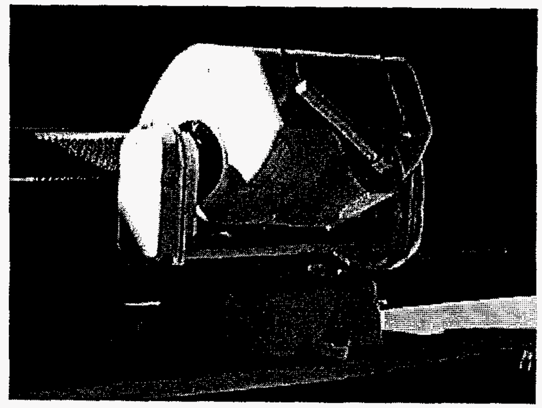

Figure 13. Texas Instruments NightSight

Figure 14. NightSight Monitor and Control in Police Vehicle

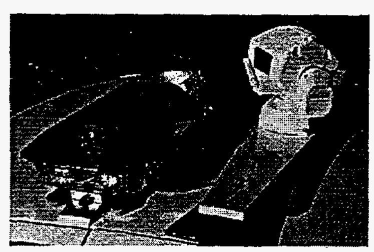

Figure 15. NightSight on Top of Police Vehicle

Summary

Thermal imaging cameras 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

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3. Glenn E. Herosian, "Wide-Area Ramp Surveillance System," *Proceedings of the 10th Annual Joint Government-Industry Security Technology Symposium and Exhibition*, Williamsburg, VA, June 20–23, 1994.