

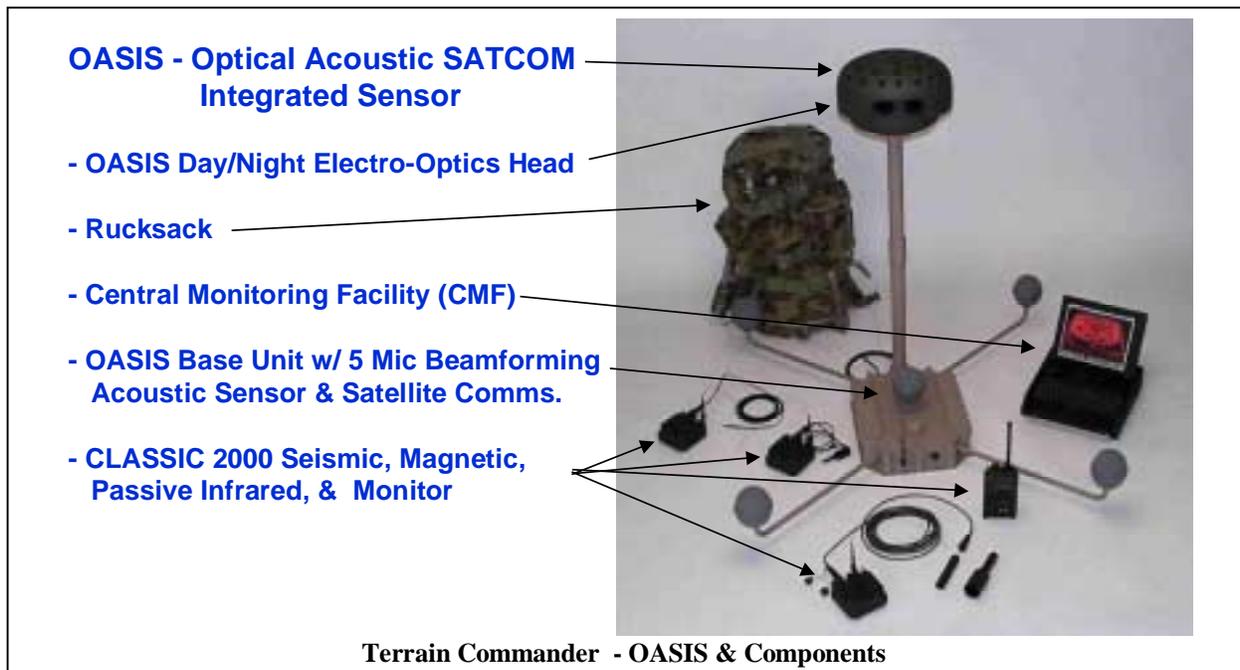
Terrain Commander

Unattended Ground-Based Surveillance System

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Introduction

This paper describes Textron's remote unattended ground-based surveillance system called Terrain Commander and its major field sensing component called OASIS (Optical Acoustic Satcom Integrated Sensor). Terrain Commander is a powerful new concept in surveillance and remote situational awareness. It leverages a diverse suite of sophisticated unattended ground sensors, day/night electro-optics, satellite data communications, and an advanced Windows based graphic user interface. Terrain Commander OASIS provides next generation target detection, classification, and tracking through smart sensor fusion of beam-forming acoustic, seismic, passive infrared, and magnetic sensors. The filtered and processed data derived from these sensors autonomously cues the integrated day/night electro-optics imaging system. The system monitors remote sites 24 hours per day, months at a time, and features high probability of detection with very low false and nuisance alarm rates. With its fully integrated SATCOM system, virtually any site in the world can be monitored from almost any other location in the world. Multiple remote sites such as airfields, landing zones, base perimeters, road junctions, flanks, and border crossings can be monitored with ease from a central location. Intruding personnel or vehicles are automatically detected, classified, imaged, and reported. Comprehensive threat information including target images are rapidly presented to the remote operator for appropriate response. .

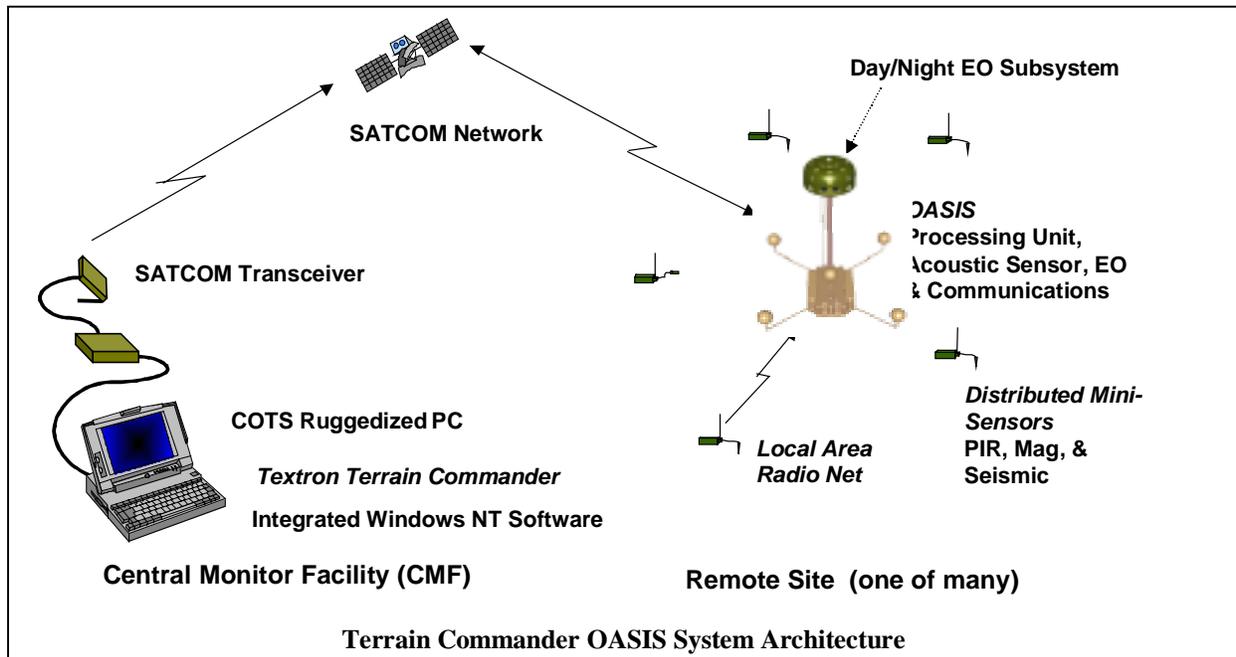


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Terrain Commander - Background

Terrain Commander was based initially on sophisticated acoustic vehicle tracking capabilities developed for the US Army's Hornet Wide Area Munition and Air Deliverable Acoustic Sensor (ADAS). The ADAS component, developed with US Army ARDEC (Picatinny Arsenal, NJ), was first field tested in 1998 during the Rapid Force Projection Initiative (RFPI) where it was the sensing component of the Integrated Acoustic System (IAS). Since then a fully integrated system, with a wide range of sensors, has been developed by an international industry team led by Textron Systems. The latest sensor to be added is Textron's Optical Acoustic Satcom Integrated Sensor (OASIS) that incorporates sophisticated Electro-Optics and long-range satellite based communications. A pre-production of the OASIS variant of Terrain Commander was developed under Textron IR&D funding in 1999 and has been successfully tested under



a variety of field conditions. The complete pre-production system illustrated above, fully integrated with CLASSIC 2000, is available today for evaluation and demonstration. The production OASIS is considerably smaller than the pre-production version shown.

Detection, Tracking & Positive Visual Identification

OASIS uses an advanced beam-forming acoustic sensor, similar to that developed for ADAS, to detect and accurately track almost any type of motorized vehicle. Upon deciding that the target may be of interest, OASIS precisely cues its day/night Electro-Optic imaging system to capture a series of images. At the same time it initiates a connection via an integrated SATCOM system to the remote Central Monitoring Facility. Each OASIS image set consists of three images taken over a one second period. Images deltas are derived for the second and third frames and sophisticated video compression is applied to the whole image set before transmission. Thus target images can be relayed rapidly despite the very low bandwidth typical of available small and low power SATCOM systems. Multiple image sets are normally captured during an encounter triggered by changes in target position or at specified intervals. Target detection, classification, and tracking reports are updated in near real time following the brief SATCOM connection delay.

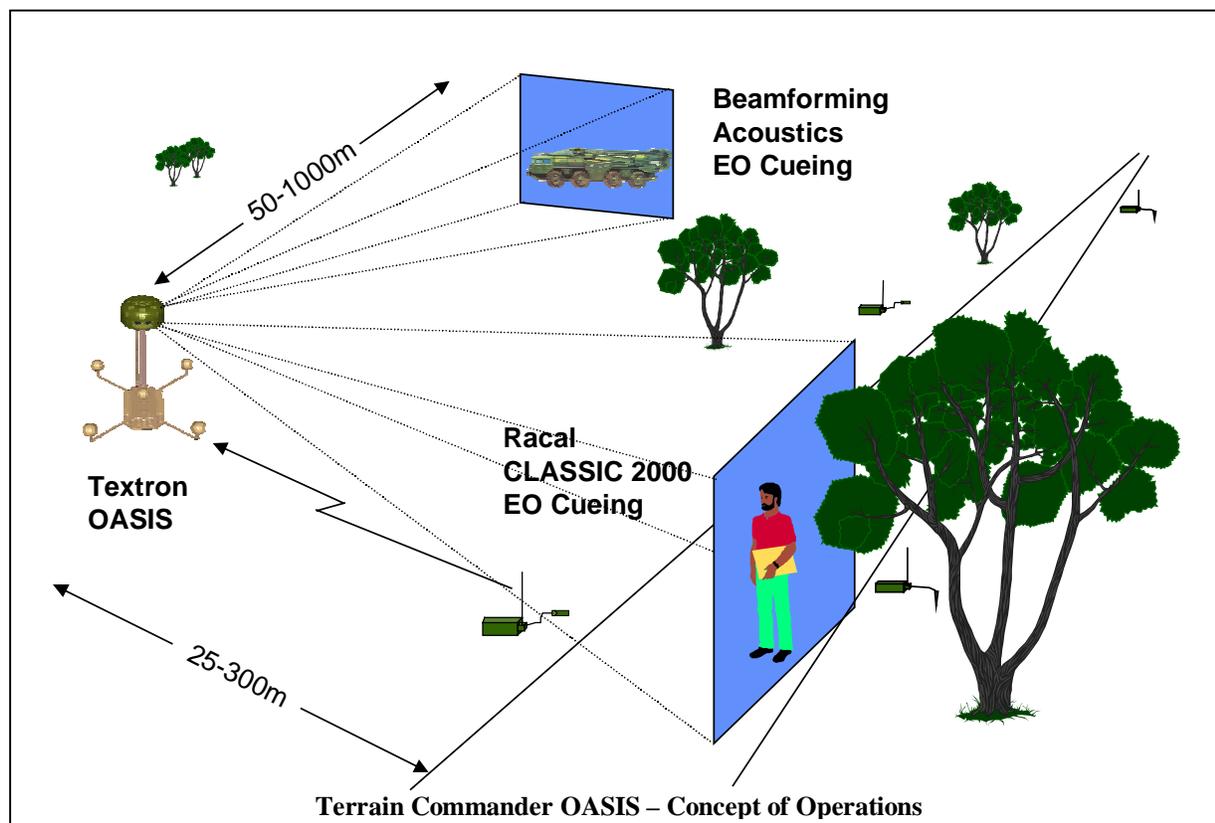
Power Management & Endurance

A critical aspect of unattended sensors is conservation of available power for extended operational life with reasonable battery size. In practice this means that average power including all detection,

processing, and communications must be just a fraction of a watt. Textron Systems has developed power conserving “sleep” modes for many of its unattended sensor systems. All Textron Systems unattended sensors systems use low power electronics and limit relatively high power devices such as the Satcom and the Electro-Optics to only mission essential operations. For example, keeping the Electro-Optics powered up with an open communications link to relay continuous video to the operator is prohibitive from a power (and cost) standpoint. Terrain Commander architecture avoids this by using highly reliable low power sensors to cue activation of the camera and communications only when necessary. Solar chargers can give substantial relief but cannot be relied upon worldwide such as during extended periods of overcast or under tree cover. Terrain Commander OASIS provides up to 3 months of operation on its small internal battery. This can be greatly extended with an optional external battery or solar charging.

Advanced Beamforming Acoustic Sensor

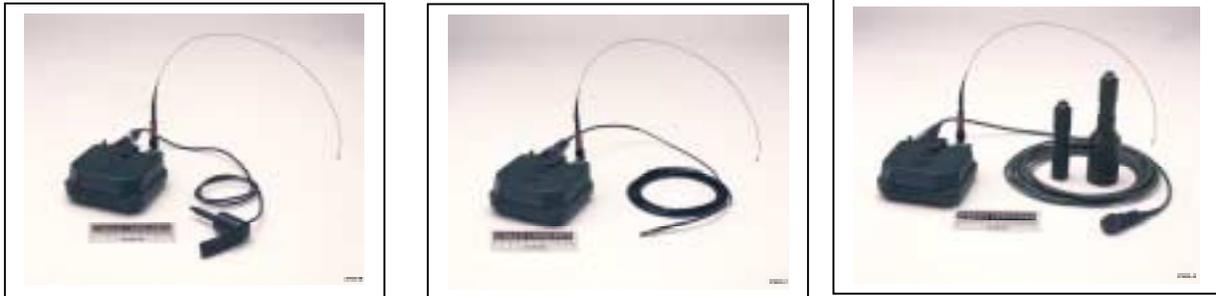
The OASIS processor wakes from power saving sleep mode every few seconds to quickly sample ambient sound. If a suspicious narrowband signal is present then OASIS stays awake and commences tracking the target whilst analyzing spectral, spatial, and temporal characteristics of the signal to determine if it is a target of interest. This level of advanced processing is necessary to avoid the flood of false or nuisance alarms often seen in other acoustic sensors. Thresholds in this regard are automatically



adjusted but may be adjusted remotely by the CMF operator if required. This technology was developed over the last 10 years on a number of projects at Textron. Beam-forming techniques, whereby the signal in the target’s direction is enhanced and noise from other directions is rejected, are employed to obtain improved signal to noise ratio (SNR), range and bearing accuracy. The acoustic sensor can localize a target within a very few degrees. Typical detection and tracking range extends out to 500m for light trucks depending on target characteristics and environment. Heavier vehicles, airplanes, and helicopters can be detected at much longer ranges. If the contact is determined to be a target of interest, the OASIS commences reports of target type and location to the remote CMF and concurrently pans the electro-optics for imaging as described above.

Seamless Operation with CLASSIC 2000 and Similar Mini-Sensors

OASIS also acts as the central processing unit for a distributed array of multi-spectral mini-sensors deployed in its vicinity developed by Textron partner Racal. CLASSIC 2000 passive infrared, magnetic, and seismic sensors are fully integrated with the Terrain Commander system for this purpose. Again, target reports are validated and filtered by OASIS without human intervention before the electro-optics are activated to capture target images. CLASSIC 2000 provides remarkable personnel



CLASSIC 2000 - Geophone Seismic, Piezo Cable Seismic, & Passive Infrared Sensors

detection and discrimination capabilities for Terrain Commander especially when combined with the filtering logic embedded in OASIS. For example the CLASSIC seismic sensor readily discriminates human footsteps from those of animals. These sensors also provide a backup to the long range acoustic sensor for vehicle detection and vehicle EO cueing. Terrain Commander can easily be integrated with many similar mini-sensor systems now in service.

Sophisticated Electro-Optic and Image Processing Capability

An advanced image capture and processing capability is embedded in OASIS along with a 360° panning electro-optic imaging head and COTS video cameras. The electro-optic imaging head has been tested extensively with both a CCD day and Generation 3 image intensified night camera fitted. Alternate cameras including many existing or developmental uncooled thermal (IR) imagers are also compatible.

The electro-optics system provides positive visual verification in accordance with the table from full daylight down to as little as 0.01 millilux (obscured starlight) with a Generation 3 Image Intensified camera without artificial lighting. There is no lower light limit when an optional infrared illuminator or thermal (Imaging IR) camera is fitted. The table gives sample recognition ranges for the system (applicable day and night).

Target Type	RECOGNITION RANGE	RECOGNITION PROBABILITY
VEHICLE	500M	97%
PERSONNEL	150M	97%

The electro-optics head is compatible with a wide range of cameras including the new generation of low cost uncooled thermal imagers just now becoming available. A precision panning mechanism plus a sensor that automatically switches between the day and night cameras are included in the electro-optics. The EOIS is automatically configured for day or night operation and slewed precisely onto the targets bearing cued by sensor reports. Images are normally captured in sets of 3 in rapid succession. This is done to take advantage of a powerful and proprietary feature in the image processor and CMF imaging software. It compresses the first of the three images using JPEG-like techniques but the next two images will be processed to consist of a compressed version of the differences from the first image. Typically three images in close succession can be sent to the CMF in little more time than it takes for one. With a stationary camera, target motion is the predominant cause of image differences. Moving targets are thus readily detectable by the CMF operator even when targets are obscured or camouflaged.

Using the method above, a number of image sets are captured during an encounter triggered by pre-programmed changes in target bearing and estimated range or by tripping CLASSIC 2000 sensors in succession. Images sets are rapidly transmitted to the CMF in low resolution associated with pertinent target data from the sensor. The CMF operator may select only the most interesting and revealing image or images for full resolution display. Positive visual target recognition is quickly and reliably facilitated despite the constraints of limited SATCOM bandwidth. All received data and images are archived and

**Central Monitoring Facility (CMF)
Video Central (VC)
Control Screen**

OASIS cued to azimuth by Racal Sensor, or OASIS Acoustic array
Takes three pictures & compresses
Sends to CMF:
Picture 1
Pixel difference for photo 2 & 3
4th Quadrant shows Rapid view of 1, 2 & 3
Draws the eye to motion



Terrain Commander OASIS – Imager Display with Moving Target Detection Feature

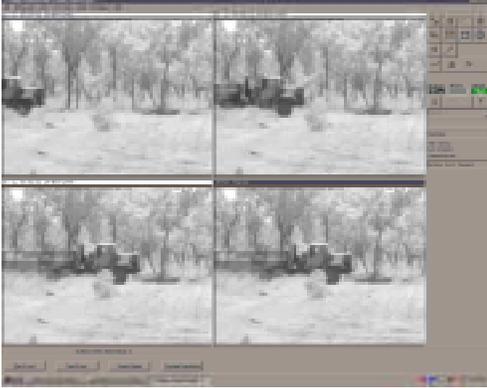
time tagged at the CMF and a printer is provided for immediate hard copy. Bandwidth is dedicated to the sensor data reports so they are not delayed by EOIS image transmission although this may be overridden.

Central Monitoring Facility

The remote Central Monitoring Facility software is also very sophisticated. Textron’s Terrain Commander for Windows software suite supports near real time graphical display of target reports, background maps derived from virtually all available digitized maps and even satellite imagery, target image display with motion detection feature, and full control and status of large numbers of remote sensors. It seamlessly integrates customized. The operator can even take manual control of remote Electro-Optics for panning and image capture. If desired, Terrain Commander can be configured to route target data from the display unit elsewhere with a variety of standard PC interfaces. The system automatically archives all target reports and images and audibly alerts the operator upon a validated target detection. The software suite is designed to operate on a standard PC. This can be a ruggedized laptop for portable operation in the field or a permanent desktop in a central office or headquarters. A compact Satcom terminal is the only other required hardware. An ordinary commercial printer is a useful option for hardcopy.

**Central Monitoring Facility (CMF)
Video
Control Screen**

Example of accurate camera aiming based on acoustic tracking



Terrain Commander – Acoustic Cueing

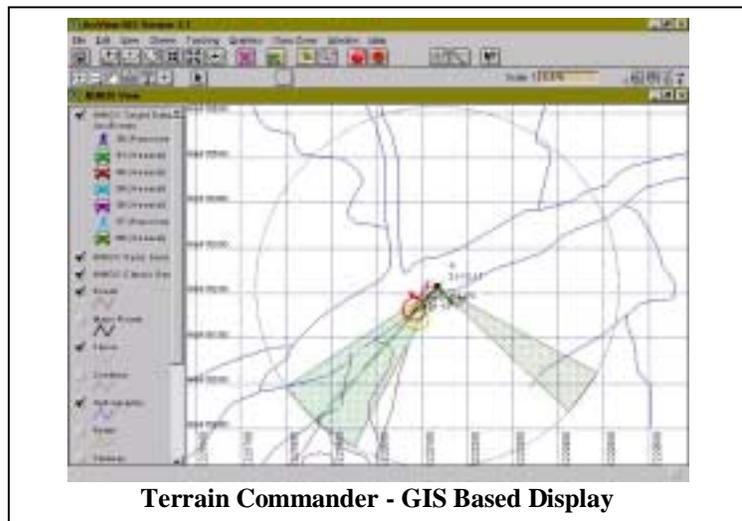
Communications

Terrain Commander is compatible with several existing commercial systems and terminals. Considerable testing has been done with the Inmarsat Satcom service. For this system a compact planar array antenna is deployed externally to OASIS on a cable and is roughly aimed (within 15 degrees) at an Inmarsat geostationary satellite during deployment – an easy task using a common compass. Service is available worldwide except in some regions at high latitudes. Existing and planned Low Earth Orbit (LEO) systems such as GlobalStar, and TCO are smaller, use less power, and do not require antenna aiming. Ordinary cell phone data connections can be used to reduce connect costs in areas (and for missions) where cellular service is available and acceptable. Many military communication systems may also be integrated.

Easy Deployment

A complete surveillance package for a site including an OASIS and a full complement of CLASSIC 2000s with transducers and camouflage can be easily be transported on foot in medium backpacks. The OASIS is positioned more or less centrally in the surveillance area away (25-150m) from heavily traveled paths to avoid detection. The EO mast height is adjusted to just clear local cover such as brush. The EO may be detached for remote mounting if desired. A standard compass is then used with a simple fitting to align OASIS (and the EO) to north. Tamper detection is inhibited for a period after turn-on to facilitate adjustments. Built-In-Test verifies a good battery and proper operation via multi-function LED indicators on the OASIS. Camouflage is applied as required to suit local conditions.

The CLASSIC 2000 sensors (or similar mini-sensors) are then positioned in zones covered by the OASIS, concealed, and switched on. Except for the passive infrared sensor and antennas the CLASSICs may be completely buried. Operation of the complete system including all imaging and communications functions may be verified on site. CLASSIC 2000 seismic and magnetic sensitivity may be adjusted if needed at this time as well. All components are designed for ease of deployment, even covert emplacements at night are supported.



Terrain Commander - GIS Based Display

A portable GPS is used to map the locations of all sensors for display on the CMF (and to assist later during recovery). Heading from the OASIS to all the CLASSIC sensors is established from the GPS data. The system is designed to download mapping data from the GPS at the deployment site or later at the CMF if desired.

Review of Key Features

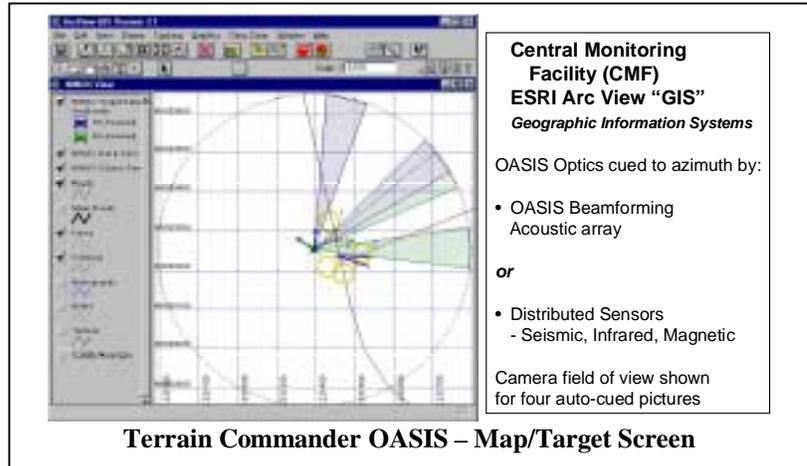
The system autonomously detects vehicle and personnel targets, automatically reports and images them, and displays this information for a remote operator.

- Portability and rapid setup in at remote sites even if accessible only on foot.
- Months of endurance without servicing
- Multi-Sensor Fusion for Target Detection (Acoustic, Passive IR, Magnetic, and Seismic)
- Beam-forming Acoustic Target Tracking
- Precision Cued Day/Night Electro-Optics with Motion Detection Feature
- High confidence detection over large area

- Low false and nuisance alarm rate
- Fully Integrated Windows graphics based Central Monitoring Facility
- Flexible long haul communications including SATCOM
- Advanced Windows Based Central Monitoring Facility (will graphically show target reports/tracking, images registered to site map, and the images themselves)
- Compatibility with virtually any digitized map of satellite imagery to use as background
- Fully automatic operator alerts, sensor reports, and image transfer
- Automatic archiving of target reports and images

Conclusion

Textron Systems believes that the uniquely integrated capabilities offered by its Terrain Commander technology will dramatically enhance remote surveillance and force protection efforts around the world. Remote yet sensitive locations including airfields, bases, landing zones, test ranges, and restricted areas can easily be subjected to automated 24 hour video surveillance from a central location even thousands of miles away.



Textron Corporation and Textron Systems Overview

Textron Corporation is a \$11.6B corporation with 64,000 employees worldwide involved in the manufacture of Aircraft, Automotive Components and Industrial Products. Textron Corporation has a significant manufacturing base in Military Products, including Helicopters and Tilt Rotor Aircraft (Bell Helicopter Textron), Armored Vehicles, Landing Craft and Lightweight Howitzers (Textron Marine and Land Systems), and Smart Munitions, Electronic Systems, Sensors, Actuators, Flight Controls and Gun Stabilization Systems (Textron Systems).

Textron Systems is headquartered in Wilmington, MA with operations in Wilmington and Lowell, MA and in Petaluma and Valencia, CA. Its product areas include Smart Munitions, Intelligent Battlefield Systems, Surveillance, Missile Systems, Precision Radar Landing Systems, Military and Commercial Sensor Components, Engineered Materials, Actuators, Flight Controls and Gun Stabilization Systems. Textron System's core competency is in real time control systems integrating advanced technologies in sensors, electronics, software, materials, and systems engineering. Textron Systems has almost 40 years experience in project management and subsystem integration of sophisticated Government systems and has a quality system registered to ISO 9001: 1994 Quality Standard.