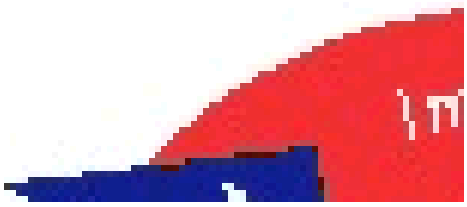
Silent Sentry™
Passive Surveillance

Lockheed Martin Mission Systems



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Jonathan Baniak
Dr. Gregory Baker
Ann Marie Cunningham
Lorraine Martin

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Contact: Lorraine Martin
Telephone: (301) 240-5658

1 Introduction

Silent Sentry™ 2 (SS2) is Lockheed Martin's new all-weather, passive surveillance technology. The SS2 system is a receive system that exploits transmissions from multiple commercial FM radio stations to passively detect and track airborne targets in real-time. On 10 May 1999, Silent Sentry received *Aviation Week & Space Technology* magazine's Technology Innovation Award, which recognizes innovative product and service technologies in the global aerospace business.

Last year, Lockheed Martin Mission Systems publicly announced the Silent Sentry system. Since then, the development team has migrated the technology to a prototype, mobile platform and validated the system's surveillance accuracy during a recent military exercise held to evaluate current and emerging technologies. The March 1999 All Services Combat Identification and Evaluation Team (ASCIET) Joint Services Exercise at Ft. Stewart, Georgia provided the team an opportunity for real-time testing of Silent Sentry against a variety of aircraft, including fighter, bomber and radar surveillance aircraft and helicopters.

The heart of Silent Sentry is its innovative Passive Coherent Location (PCL) technology developed by Lockheed Martin Mission Systems, which uses everyday broadcast signals, such as those for television and radio, to illuminate, detect and track objects. A passive detection system for U.S. government civil agency and military purposes, Silent Sentry transmits no radio frequency (RF) energy as conventional radar does and has no RF "signature" to alert enemy threats. Instead, it can use the energy that already exists in airspace for detection purposes, and does not adversely affect or harm the environment.

By using broadcast transmitters and signals available throughout the world, Silent Sentry:

- assists in casting a "wider net" when used in conjunction with existing surveillance systems,
- provides new levels of early detection, to reveal tangible proof of activity, and
- enables rapid, defensive reaction to threats.

The system can be deployed to fill gaps in existing radar coverage and enhance global awareness and command-control decision-making.

Silent Sentry is a multi-static illuminator surveillance system (i.e., receiver and transmitters are not co-located) which determines precise three-dimensional target trajectories, and unlike "scanning" radars, Silent Sentry provides continuous coverage of the airspace. The Silent Sentry configurations include versions which can be mounted in buildings and fixed structures, or in deployed configurations, such as trucks, or shelters, for rapid relocation.

Recent advances in commercial technology, such as high-speed processors and high dynamic-range receivers, help make Silent Sentry a low-cost approach to effective and reliable real-time surveillance against a wide range of potential threats. A typically configured system includes Silicon Graphics, Inc.® processors, the Autometric Edge Product Family™ visualization and analysis software, and receivers built by Lockheed Martin from commercial products.[1]

[1] Silent Sentry is a trademark of the Lockheed Martin Corporation.
Silicon Graphics is a registered trademark of Silicon Graphics, Inc.
Autometric Edge Product Family is a trademark of Autometric, Inc.

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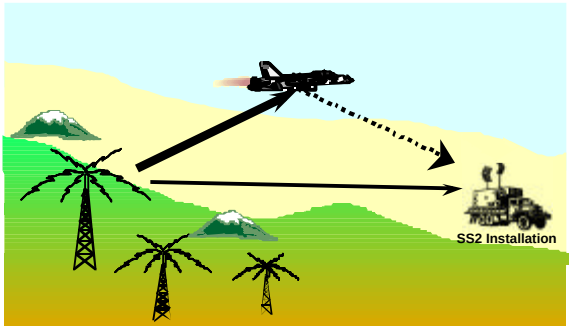
2 What is Silent Sentry™? (An Overview)

2.1 SS2 Basic Concept and Features

SS2's continuous wave (CW) multistatic technology provides an all-weather, passive surveillance capability through the exploitation of radiant energy from commercial FM radio stations. The transmitted signals from these illuminators are scattered from airborne targets and received by the SS2 target antenna (a horizontal linear phased array antenna in the current implementation). Separate, reference antennas also receive the direct path signals from the FM transmitters. High dynamic-range receivers are used to accommodate the dynamic range requirements for receiving direct and scattered signals simultaneously.



Basic Concept of Silent Sentry Operation

Continuous coverage of 90 degrees azimuth is achieved through the use of innovative digital signal processing algorithms. Delay (time difference of arrival) and Doppler (frequency difference of arrival) measurements for each detected target are extracted. The measurement data are associated by target and a tracking filter estimates the state vector (position, velocity, and acceleration) for each target. This state data can then be presented to a tactical display or communicated to other systems via standard data-links.

In the current version of SS2, coarse 2-D tracking solutions are possible when the target is detected using a single illuminator. Good 2-D solutions are feasible whenever the target is detected on two or more geometrically

diverse FM illuminators. Tracking solutions in 3-D are feasible when the target is detected on three geometrically diverse FM illuminators.

The system can provide short latencies since it is a staring, not a scanning, system. (Recall that traditional radar uses pulsed signals, in part due to their monostatic design.) The FM illumination continuously saturates the coverage region and SS2, with its staring beams spanning the coverage region and high update rate, enabling early target detection. The use of commercial broadcast transmitters provides excellent low altitude illumination of targets, which, when combined with favorable receiver siting, provides low altitude surveillance.

2.2 System Description

Silent Sentry System Description

Silent Sentry is a single receive system composed primarily of the following components the majority of which are commercial off-the-shelf (COTS):

- **Target array** – a linear phased array for detecting the scattered energy from targets in the region of interest
- **Reference antennas** – single elements, identical to those in the target array, used for reception of the direct path signals from the FM illuminators
- **High Dynamic Range Receivers** -- accommodate the dynamic range requirements for receiving direct and scattered signals simultaneously

- **A/D Converters** -- the system possesses the capability to record data at this level, which is particularly useful for post-mission analysis

- **Processor** – Silicon Graphics, Inc. (SGI) general purpose processor

- **Displays** – SGI Octane workstation and visualization products from the Autometric Edge Product Family™

- **High Speed Tape System** – a SCSI attached striping tape controller with 5 tape drives

Mission planning and system performance predications are critical for any surveillance system and imperative for line-of-sight systems. Silent Sentry includes a suite of mission planning and system tools that are collectively called the Sensor Performance and Analysis Tools (SPAT). Among these tools are signal simulators, a trajectory simulator, beam formulator, Signal to Noise Ratio (SNR) calculator, and an illuminator database. These tools in combination with several other standard radar modeling tools were utilized in planning and preparation for ASCIET mission at Ft. Stewart in March 1999. The essential functions of SPAT are:

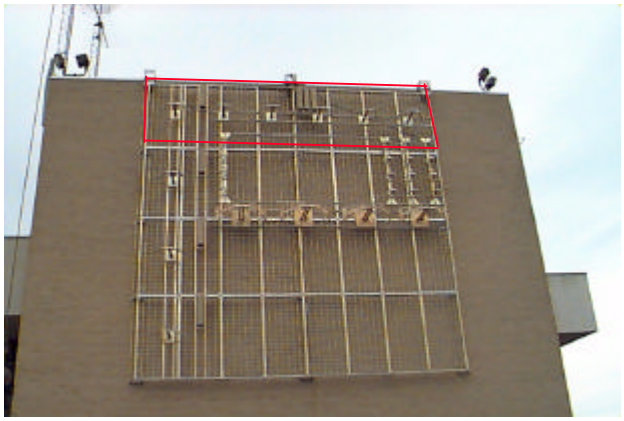
- **Illuminator Selection and Receiver Siting** - analyzes illuminator coverage for various combinations of FM radio stations in combination with the receiver location.

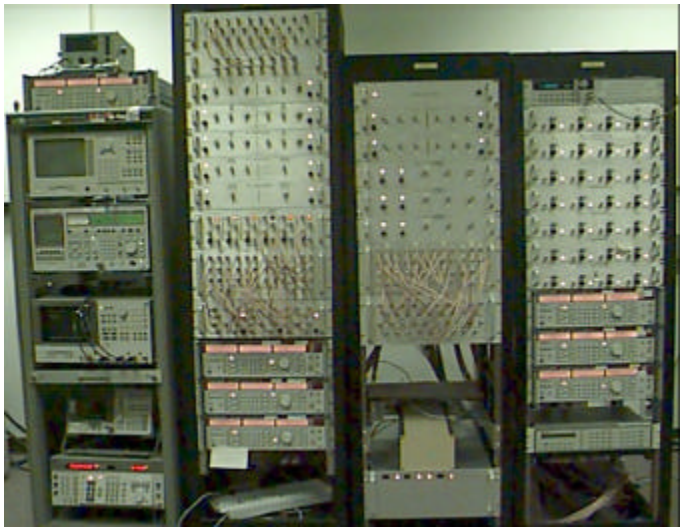
- **Performance Prediction** - for a given site and combination of illuminators and trajectory, determines the probability of detection, the accuracy and SNR values.

2.3 SS2 Configurations

Lockheed Martin currently has two configurations of SS2: the Fixed Site System (FSS) and the Rapid Deployment System (RDS).

The FSS operates in Gaithersburg, MD, runs real-time using a full configuration of processors, and processes all data real-time. The system is designed for flexibility, with many aspects of the system configurable according to desired data processing rate, sampling patterns, performance objectives, and available hardware.





The Fixed Site System: Receivers (left) and Wall-Mounted Antenna Array (right).
The current implementation of SS2 uses only the horizontal array outlined in red.

Reference Antenna

Target Antenna

The Rapid Deployment System

The RDS is used for real-time data collection and real-time data processing. The RDS is currently deployed in a self-sufficient trailer including power and environmental controls. It is contained in a van, with the phased array antenna mounted on the side, and the reference antennas on the top. The ruggedized receivers, processors and control workstation are contained in half the van. The heating system and generator are housed in the other half. The van is a Faraday cage to prevent emissions from the processors from interfering with the antenna reception. This configuration was used at the recent testing event reported above. The van is larger than required for deployed operations, but was an available asset in the Lockheed Martin inventory.

3 Capabilities of Silent Sentry™

- Silent Sentry has some inherent features and unique capabilities that warrant examination.

- **Surveillance for Challenging Targets**

- The ASCIET Joint Services Exercise at Ft. Stewart, Georgia, in March 1999 gave Lockheed Martin an opportunity for real-time testing of its Silent Sentry system against a variety of aircraft, including fighter, bomber and radar surveillance aircraft and helicopters. In past technology experiments, Lockheed Martin has demonstrated nonreal-time and real-time capabilities against a variety of other targets, including helicopters, rockets, ballistic missiles, and re-entry vehicles.

- **Excellent Altitude Coverage**

- Since TV and FM broadcast stations focus energy toward the Earth's surface, they illuminate low flying targets. Multi-illumination not only provides illumination to areas where mountains and valleys may block one illumination source, but the geometric diversity provides additional information from differing viewing aspects of the targets.

- **Inherent Survivability**

- Active radars quickly become combat targets due to their energy emissions. Silent Sentry is a truly passive system, which emits no signal, so it is well suited to passive operation. Silent Sentry is also an "environmentally friendly" sensor since it reuses commercial illumination energy (instead of disrupting the broadcasts with its own strong signals).

- **Effective All Weather Operation**

- Broadcast Signals in the UHF, VHF, and FM bandwidths are virtually immune to weather-induced degradation and operate equally well day and night.

- **Military Operations**

- Since Silent Sentry emits no signals, it can be placed forward on the battlefield without being detected, providing earlier warning of potential threats and expanding the battlespace understanding.

- **Low System Cost**

- Silent Sentry is a phased array system with no rotary mechanical components; in addition, it has no transmission components. These attributes greatly reduce power requirements, mechanical upkeep,

and cost. In addition, the system is primarily composed of COTS products and can be fielded in unmanned configurations.

- **SS2 Design Goals**

- The advertised system performance figures are dependent on several factors; the most important of which are the geometric diversity of the illuminators, the illuminator transmission power, and the Radar Cross Section (RCS) of the target.

Performance of a mid-range system configuration

System Parameter	Value
*Detection Range	220 km
Range Depth Coverage	150 km
Azimuth Coverage	60^o to 360^o
Elevation Coverage	50^o
Target Tracking Update Rate	8 per second
Target Capacity	200+
Power requirements	10 kW
Footprint (excluding antenna)	27 square feet

* Value based upon an RCS=10 m^2 @ 100 MHz, $P_d > 0.95$, FAR < 10^{-3}.

- **Mission Planning Tools**

- There are a significant number of performance prediction and planning tools available as part of Silent Sentry. The mission planning and illuminator selection tools allow for system deployment (or simulation) anywhere in the world based on the FCC and ITU transmitter databases.

4 Conclusion/Forward Plan

The system is intended as a passive detection and tracking system for U.S. government civil agency and military purposes; it can be deployed to address gaps in radar coverage to provide "early warning" detection, and enhance command and control decision-making. The Silent Sentry™ architecture is designed to be expandable and scalable.

The characteristics are:
- Sensitivity to allow range detection of a wide variety of targets
- Exploitation of continuous wave (CW) signals allowing for high update rates
- Complete and continuous airspace coverage (within system parameters)
- Local operations and remote, controlled system access

Silent Sentry™ provides:
- Real-time three dimensional tracking and visualization of airborne targets
- Exploits multiple sources of illumination (i.e., radio and TV broadcast signals and optional cooperative transmitters)
- Comprehensive data recording and playback capabilities
- Extensive simulation and mission planning tools

We believe that Silent Sentry represents the threshold of an exploding new technology. The technology has the potential to revolutionize how various surveillance operations are performed. Recent field exercises have proven viability of the technology and the mission planning toolset. We look forward to

continued research and development, which will lead to addition to the current system of TV signal exploitation, as well as refinement of various processing and tracking algorithms. One of the most exciting features of Silent Sentry that will be explored further is the inherent signal information that can be used for target identification and classification. These advancements in battlespace awareness will provide increased capability and robustness to the warfighter.

For Additional Information:

More information regarding Silent Sentry and its underlying technology can be obtained at this Lockheed Martin website:

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Or by contacting:

Tom Kuba
301-240-6668,
tom.kuba@lmco.com.