

# Sentinel Suite™ Tools

- » *Prognostic Health Management (PHM)*
- » *Condition-Based Maintenance (CBM)*
- » *Integrated Vehicle Health Management (IVHM)*

**OVERVIEW**

Today's complex electronic and electromechanical systems, as reliable as they are, comprise components and assemblies that inevitably have limited lifetimes. When components in critical applications degrade, the consequences can be severe, including revenue losses, productivity decline, damaged customer satisfaction, and even loss of life.

For over a decade, Ridgetop Group has been developing effective prognostics and health management (PHM) solutions for complex, critical systems that can dramatically reduce lifecycle costs. Prognostics, or predictive diagnostics, is the ability to detect the onset of failure before it occurs. Ridgetop Group has pioneered the development of advanced methods of detecting physics-of-failure-based indications of impending failure. Ridgetop's approach deals with the extraction of unique "signatures" that are correlated to the impending failure conditions.

As the industry has evolved, Ridgetop has always been on the forefront, providing practical solutions, development platforms, algorithms, and training to ensure high levels of operation in complex systems. Prognostics-enabled systems can alert the user or system that there is impending failure ahead. Based on this information, mitigating actions can be taken to avert catastrophe. In addition, statistically rare "Black Swan" events can be detected through signature-based prognostics. This brochure highlights a portion of our products and services in this area. Please contact Ridgetop for more information.

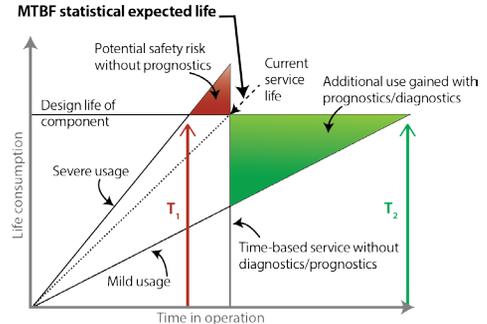
**DESCRIPTION**

Sentinel Suite is a family of advanced prognostic and health management solutions for electronic systems. These solutions offer end-to-end monitoring of systems and comprise sensors, anomaly detection, prognostic reasoners, and graphical visualization tools.

Sentinel Suite includes the four specific development and monitoring platforms described in the box below. These solutions include one or more of Ridgetop's prognostic and diagnostic reasoners, explained on the next page.

Sentinel Suite's modular, adaptable, and accurate prognostic solutions enable condition-based maintenance (CBM), thereby reducing unscheduled downtime and unexpected maintenance costs.

Development kits are available for each member of the Sentinel Suite family to make adoption quick and easy.



Source: Economic and Safety Benefits of Diagnostics & Prognostics (Romero et al. 1996)

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*Prognostics indicate actual state of health and remaining useful life, eliminating the need to remove the system for maintenance based on predetermined mean time between failures (MTBF)*

**Sentinel Power™**

Analyze and diagnose your power systems through prognostic-enabled sensors and acquisition/processing.

**Sentinel Motion™**

Monitor electromechanical systems, aircraft, infrastructure, wind turbine, and other equipment to prevent unexpected downtime.

**Sentinel Interconnect™**

Monitor for intermittencies or failures in interconnects during and after fabrication to improve reliability.

**Sentinel IT™**

Monitor and manage your factory floor or IT network remotely, while alerting for unexpected events in the network.

# Prognostics & Anomaly Detection Algorithms

Ridgetop's software reasoner technology and algorithms enable advanced diagnostics and prognostics of electronic and electromechanical systems.

These reasoners analyze data from any kind of sensor and provide insight as to the health of systems by detecting, extracting, and analyzing degradation and fault signatures. A system, although operational, may not be performing optimally, which indicates a risk of unexpected failure.

The reasoners developed by Ridgetop are key components of the Sentinel Suite family.

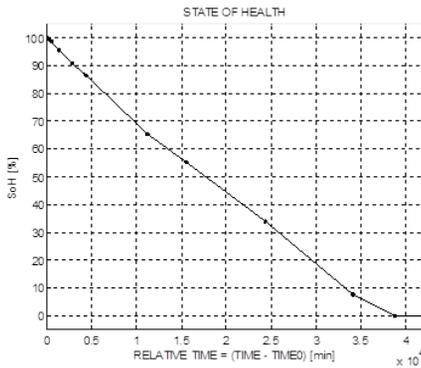
## REASONERS OVERVIEW

### ARULE™

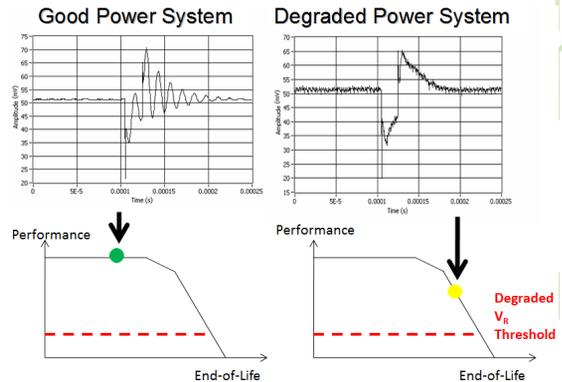
- The Adaptive Remaining Useful Life Estimator™ is a main component of Sentinel Motion, Sentinel IT, and Sentinel Power
- Analyzes incoming sensor data and provides systems' state of health (SoH) and remaining useful life (RUL)
- Can be used to detect degraded conditions to support proactive maintenance

### ANOMALY DETECTION

- Reasoner to detect anomalies or changes in monitored equipment performance
- Reports abnormal changes
- Operates on data from power, actuator, and vibrational/rotational applications



Example plot of state-of-health estimates produced by ARULE



Example of Ridgetop algorithms determining power system status

Sentinel Power is a product line that includes signature monitoring sensors, prognostic reasoners, and a visualization tool. The Sentinel Power product line offers the SMRT Probe 2000™ and SMRT Probe 6000™. These products, based on Ridgetop's patented RingDown™ technology, provide advanced diagnostics and prognostics for power systems.

SMRT Probe is a non-invasive, stand-alone, early-warning solution for diagnosing and monitoring the health of power systems.

## SMRT Probe™ Sensors

- Resonant frequency-sampling device to extract degradation signatures
- Measure perturbations in power system voltage, phase, and frequency, enabling detection of the onset of degradation

## Reasoner

- Used with ARULE to provide early warning of failure and support CBM
- Used with Anomaly reasoner for immediate detection of changes in signals

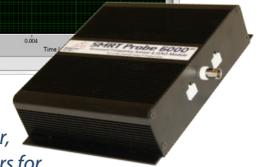
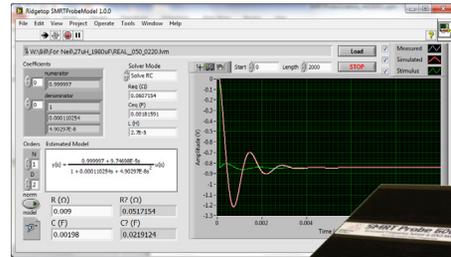
## Display

- Power View is a visualization tool to display data collected by the sensor and to monitor changes in performance

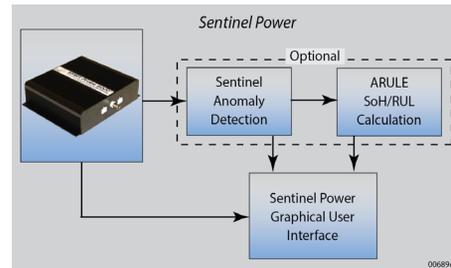
## Applications include:

- Power converters and inverters, power supplies, electronic drivers and stages, and heating elements, such as those of aerospace total air temperature (TAT) probes

SMRT Probe enables prognostics for critical aircraft components such as actuators



SMRT Probe offers a complete solution with a hardware sensor, and compatibility with reasoners for providing prognostics and anomaly detection, as well as a GUI for displaying results, shown above.



Representation of Sentinel Power solution with SMRT Probe

## RingDown™

RingDown is a patented, non-invasive, stand-alone early warning approach to detecting the onset of component aging in most switched-mode power supplies. It provides an important capability that supports any electronic health management strategy for high-reliability systems.

Switching supplies generally employ closed-loop feedback to keep voltage or current under tight regulation. RingDown exploits this feature by using a special technique to extract eigenvalues that characterize the control loop. Changes to these values indicate early degradation in electronic components within the supply, long before there is any performance change in the regulated output.

# Sentinel Motion™

Sentinel Motion is a product line that focuses on monitoring and analyzing vibrations in rotational equipment. This product line consists of RotoSense™ and development kits for applications in helicopters, wind turbines, and other rotational systems.

## RotoSense™ Sensors

- Wireless MEMS-based rotational vibration sensor
- Enables easy extraction of high-resolution signatures from rotating components in harsh environments such as gear trains, transmissions, and turbines
- Supports hundreds of nodes in a wireless sensor network
- Two models of RotoSense available:
  - Option A: One triaxial measurement, up to 1000 RPM
  - Option B: Two tangential and one radial measurements, up to 6000 RPM

## Reasoner

- Can be configured with ARULE to provide early warning of failure and support CBM
- Provides immediate detection of changes in signals

## Display

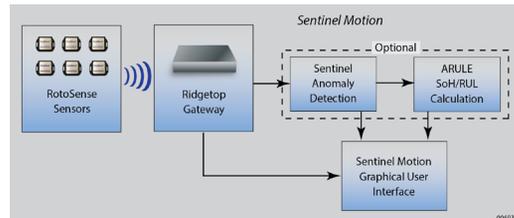
- Motion View is a visualization tool that allows remote real-time monitoring of equipment and structures

## Applications include:

- Sensing tool wear, chatter, or spindle balance in CNC machines, real-time down-hole vibration monitoring in oil and gas exploration, vibrational signatures in rotating shafts, detection of train wheel track condition and other anomalies, gearbox monitoring, wind turbine monitoring



RotoSense wireless sensor, size 50 x 50 mm, and Sentinel Motion GUI



Sentinel Motion representation with a wireless network of RotoSense sensors



RotoSense is used in rotational applications such as helicopter gearboxes and driveshafts

# Sentinel Interconnect™

Sentinel Interconnect detects faults in solder joints, sockets, plugs, wires, cables, and more. This product line includes two sensors, SJ BIST™ and TSV BIST™. Both of these products use an in-situ technology to provide monitoring during and after assembly, for lifetime reliability monitoring. These products are delivered as Verilog-instantiated IP cores for use in FPGAs, CPUs and other microelectronics packages.

Sentinel Interconnect interfaces directly to the host IC or system through JTAG, I2C, SPI, or other bus. SJ BIST and TSV BIST can be configured not only to detect faults and degradation, but to perform first-pass processing of the acquired data.

## SJ BIST Sensors

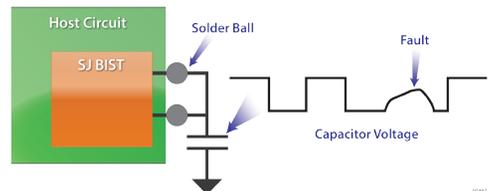
- Solder Joint Built-in Self-Test™
- Ongoing confirmation of interconnect reliability
- Lifetime monitoring of interconnect reliability
- Detects intermittencies, and alerts of impending failure
- Performs process qualification of interconnects for production and QA applications
- Can be applied to validate the integrity and reliability of any type of interconnect
- Applicable for electronic printed circuit boards (PCBs) in industrial systems, aircraft, vehicles and ships, and FPGA-based microprocessor applications

## TSV BIST Sensors

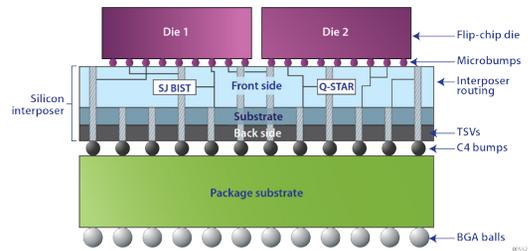
- Monitors through-silicon vias (TSVs) for 2.5D integrated circuits (ICs), 3D IC connections, and other chip-stack IC packages
- Embedded technology that combines interconnection monitoring and signal monitoring for TSVs
- Detects degradation in chip-to-chip interconnects
- Identifies and pinpoints intermittencies
- Warns of impending interconnect failures



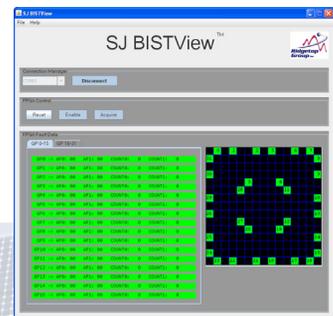
*SJ BIST Demo/Evaluation unit, which enables evaluation of SJ BIST in a target system*



*Diagram representation of SJ BIST implementation in a host circuit*



*Diagram representation of TSV BIST's IP, which incorporates SJ BIST and Q-Star PG-Mon™*



*Sample capture of SJ BISTView GUI*

Sentinel IT provides solutions for improving IT network reliability. With this product Ridgetop provides comprehensive network health management (NHM). NHM provides a comprehensive set of features, including UPS health monitoring and switch troubleshooting, allowing an easier and more efficient management of the network, including advanced "Industrial Internet" and IoT applications.

## Sentinel Network™

Sentinel Network takes advantage of sensor-enabled IT nodes for diagnostic and prognostic purposes.

### Hardware

- A rack-mountable device
- Provides remote monitoring through its web application
- Enables efficient network management
- Real-time monitoring of networks with graphical display
- Incorporates troubleshooting capabilities for network management devices

### Reasoner

- ARULE reasoners implement NHM and prognostics:
- Uses customizable device health thresholds
- Predicts remaining useful life
- Reduces unexpected downtime
- Reduces maintenance costs

### Display

- Sentinel IT View is a visualization tool that provides alerts of unexpected events in the network, and provides reporting on health of network devices to support network maintenance activities

### Applications include:

- IT networks and other types of networks

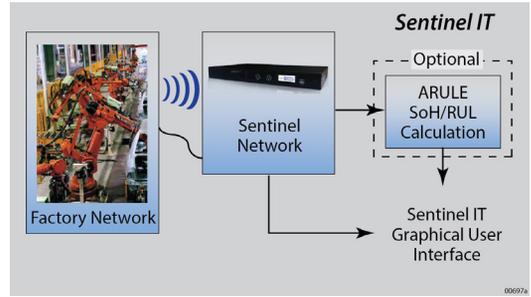
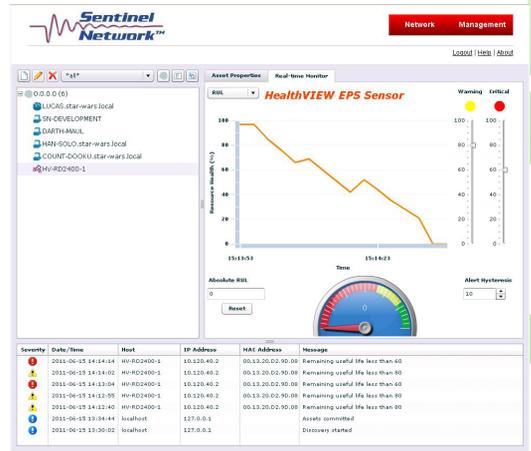


Diagram representation of Sentinel Network with optional integration of ARULE for NHM



Sentinel Network rack-mountable unit



Sentinel IT View GUI with ARULE displaying the RUL of a device

## About Ridgetop

Ridgetop Group Inc. is a world leader in providing advanced prognostic and health management tools, education/training, and implementation services. Ridgetop offers extensive experience in providing prognostic-enabled systems for critical aerospace, defense, and industrial applications.

Ridgetop maintains a strict AS9100C and ISO9001:2008 certified quality management system as the basic framework for architectural planning and management, requirements development, designs and specifications; conduct of assessments and analyses; program integration; test planning and execution; concurrent test, training and operations; risk management; operations specialty engineering; and general engineering support. This expertise has been applied in programs with many governmental and commercial entities.



Need modified or custom design?  
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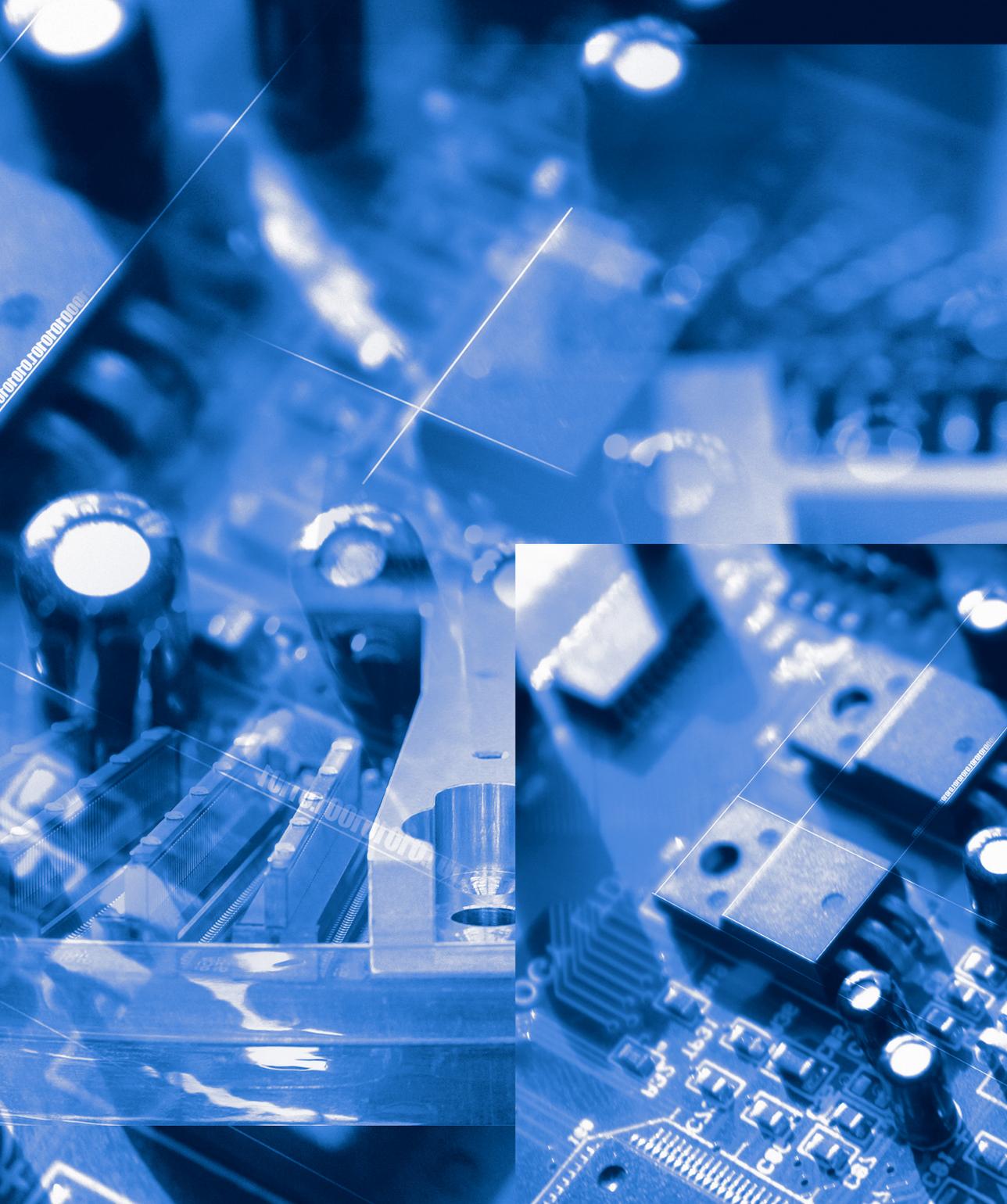
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