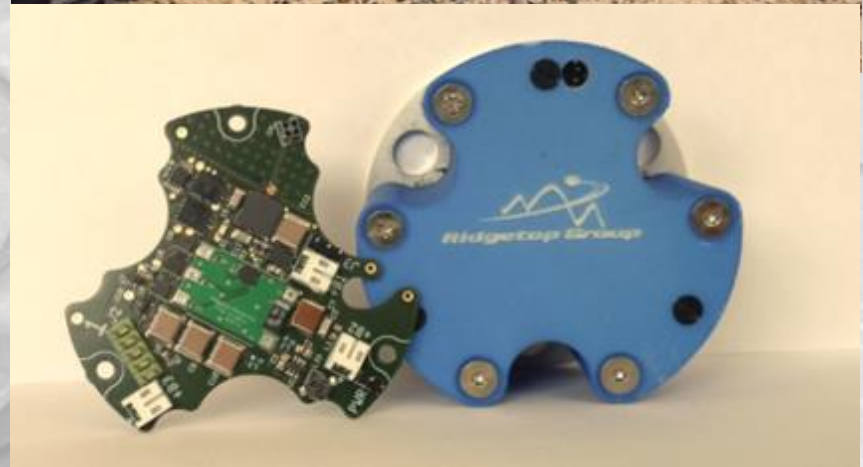


Sentinel Motion™

A Part of the Sentinel Suite™ Family

A IoT-enabled Advanced Diagnostics and Condition-based Maintenance (CBM) Solution

- **Real-time Reliability Data, Edge Computing, and Cloud Connectivity** for **Advanced Diagnostics** and **Remote Asset Monitoring**
- **Precision Wireless Accelerometer, Temperature, and/or Custom Data Streams** along with **Time Stamps** for Rotating and Vibrating components
- Ideal for **Bearing, Wheel, and Track Monitoring in the Railroad Industry**
- Customized solutions for **Gearbox Systems, Power Transmission Systems, Drive Trains,** and any other **Harsh Operating Environments**
- Results can be integrated with existing CBM or PHM Systems using **Alerting Mechanisms via Text, Email, or Calls** to notify train personnel of current or impending critical issues



Sentinel Motion™

Sentinel Motion™ is a product line that focuses on monitoring and analyzing **temperature, acceleration, and other custom data signatures** in various types of mission critical equipment. It comprises a **wireless network of IoT-interfaced smart RotoSense™ sensors, the Sentinel Gateway™ communications device, and the Sentinel MotionView™ software package.**

Rotating and vibrating components wear out over time in nearly all electromechanical systems and subsystems. In many applications, these components may be difficult to access and are very expensive to service, maintain, and/or replace. Preventive maintenance performed on a regular schedule is common, but can be needless if the components in question are still healthy with substantial remaining operational life. With **Sentinel Motion™**, you can monitor and diagnose common failure modes to determine the current health of a given system, and perform maintenance based on physical evidence of degradation as opposed to an arbitrary number of operating hours.

Applications

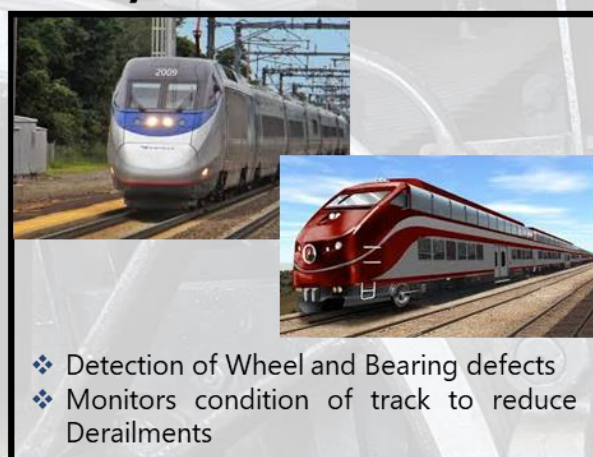
Sentinel Motion is ideal for many applications, including:

- Monitoring train wheels and bearings systems through vibration and temperature analysis
- Shock and vibration analysis can also be correlated with GPS data to monitor and diagnose track features
- 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
- Gearbox monitoring in helicopters, wind turbines, and other critical systems and subsystems

Sentinel Motion™ Market Segments

Following are the various market segments serviced by Ridgetop Group Inc. for **Sentinel Motion™**.

RAIL/TRANSPORTATION



AEROSPACE/AVIATION



ENERGY



INDUSTRY



Sentinel Motion™
Market Segments

Testing Results at Transportation Technology Center Inc. (TTCI)

In 2015, Ridgetop Group conducted **Sentinel Motion™** rail testing at the **Transportation Technology Center, Inc. (TTCI)** testing facility in Pueblo, CO, USA. The main objectives of testing were as follows.

- To **characterize track infrastructure (geo-locate track “features”)**
- To **detect track anomalies such as broken welds**
- To **detect faults in rotating components such as wheels, hubs, bearings, etc.**

This testing has proven that **RotoSense™** is a viable IoT solution that was able to operate in the **harsh operating environment (up to 100 [g] shock and vibration)**, and it was able to detect common track features such as:

- **Turnouts (with and without Frogs)**
- **Various Welds (Electric, Thermite, Overlay, etc.)**
- **Concrete and Steel Bridges**
- **Crib Ties**

Additional test results and pilot studies have concluded that **Sentinel Motion™** is a scalable solution for **remote asset monitoring** and **diagnostics of track, wheel, and bearing systems**. The key information gathered with this innovative technology will help maintenance crews to better prioritize their efforts, resources, and schedules for repairing degraded components.

List of Common Problems in Railroad Applications

- **Mechanical Failures of Vehicles or Components**
- **Derailments**
- **Poor Ride Quality**

Common Root Causes Detected or Monitored

- **Broken Rails / Welds Derailments**
- **Failed Bearings**
- **Defective Wheels**
- **Unusual Track Interaction**
- **Aging Infrastructure (Friction Wear, Track Deterioration, etc.)**

Technology Benefits Offered by Sentinel Motion™

- Continuous and combined sensing capability of wayside **Hot Box Detectors (HBDs)** and **WILD systems**
- **Geo-located anomalies and alerts**, which complement the use of track inspection equipment
- Categorized infrastructure based on **severity of vibration limits**
- **Near real-time Asset Monitoring** on the cloud
- **Precision and High-Frequency** data measurements
- **Detailed Analytics** for maintenance planning

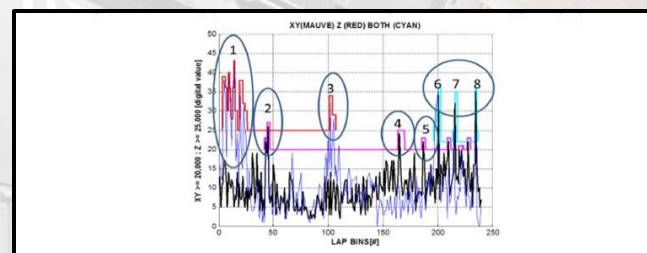


Figure 16. Data and identified features -see Table 3 for (1) through (8) association to feature and location

Table 3. Test track description and detection evaluation

Track Sections	Feature Sections	TT ID	Track Feature	Detection Evaluation	
				XY-vector	Z-vector
1-3		S1	Lubricator	ND	ND
4-5		S2			
6-62	5-26	S3	Repair/overlay welds		Yes (1)
	30-40	S3	Concrete bridge	maybe	maybe
	42-46	S3	Concrete bridge	maybe	Yes (2)
63-66		S4	Steel bridges	ND	ND
67-69		S5	Bridge deflection	ND	ND
70-73		S6	Steel bridges	ND	ND
74-92		S7	Rail performance	ND	ND
93-97		S8	Fiber optic cable	ND	ND
98-108		S9	405 turnout/frog		Yes (3)
109-117		S23	405 turnout/frog		Yes (3)
118-125		S24	Lubricator	ND	ND
126-163		S25	TPO. Tie and fastener, performance	Yes (4)	No
164-170		S26			
171-175		S27	Lubricator	ND	ND
176-180		S28	Turn out, steering switch, foundation	Yes (5)	
181-193		S29	LTM Tests	ND	ND
194-198		S30			
199-208		S31	FRA: Rail-seat deterioration, Thermite welds	Yes (6)	Yes (6)
209-212		S32			
213-225		S33	Crib ties	Yes (7)	Yes (7)
226-229		S34			
230-240		S35	407 turnout/frog	Yes (8)	Yes (8)

Sentinel Gateway™

Sentinel Gateway™ is a **data concentration hub** used to **communicate with wireless IoT sensors** from Ridgetop Group or other sensor providers. It is complete with all necessary network interface requirements to communicate over **Wi-Fi, Cellular, or Ethernet.**

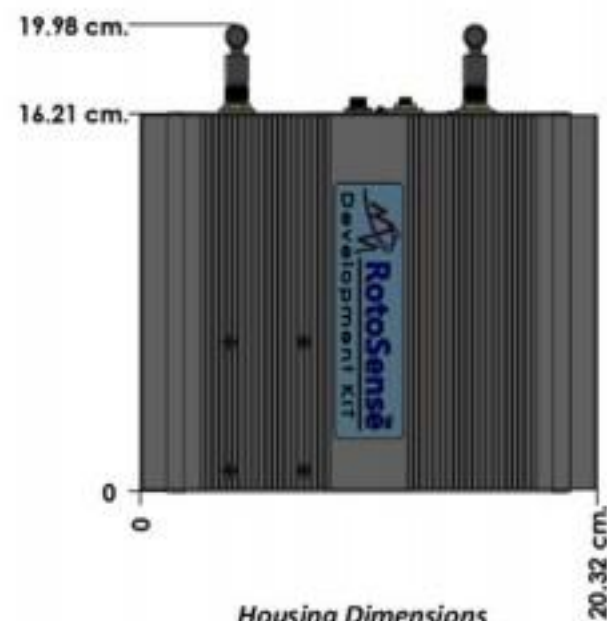


Document Code: DS_SG-1000_R01_1119

Sentinel Gateway Construction



Interface Panel



Housing Dimensions

Electrical and Mechanical Specifications

SENSOR PARAMETERS	Specifications
Protocol / Standard	Sentinel IoT: IEEE 802.15.4 Wi-Fi: IEEE 802.11 b/g/n
Frequency Range	Sentinel IoT: 2.4GHz Wi-Fi: 2.4 GHz – 5 GHz
Transmission Rate	Sentinel IoT: 22 Kb/s Wi-Fi: 250-500 Kb/s
Security	Sentinel IoT: Binary Wi-Fi: WPA/WPA2/WPA3
Range	Sentinel IoT: 10 m (32 ft) Wi-Fi: 100 m (328 ft)
IP Addressing	Dynamic and Static IP support
Storage	1 TB SSD
SBC Processor	Intel Celeron N3160
SBC Operating System	Linux Ubuntu
SBC Memory	4 GB DDR3L Dual Channel RAM
GPS	Dead reckoning GPS receiver (NMEA-0183 standard output)
RotoSense Data Downloading	1 -2 minute download time for full memory buffer mode/streaming mode
Networking	Private network or join existing network
Connectivity Interfaces	Wi-Fi Access Point or Wired Ethernet Port
Power Input	12 [V] 3 [A] locking barrel power supply
*Operating temperature	0°C to 70 °C
ASSEMBLY PARAMETERS	Specifications
*Dimensions	20.3 cm x 16.2 cm x 4.8 cm (Length x Width x Height)
*Weight	1.071 kg (2.362 lbs.)
*Enclosure material	Aluminum alloy

*Specifications are application specific and subject to change.

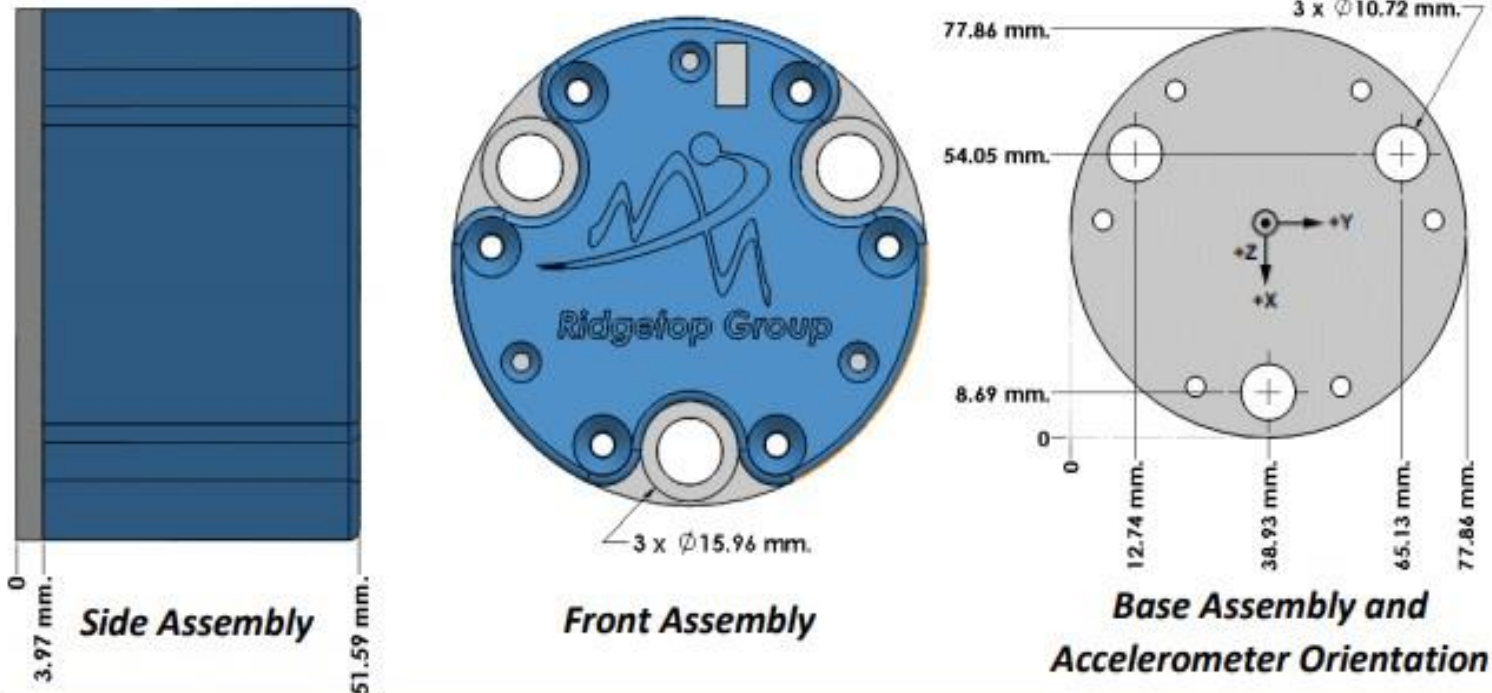
RotoSense™ - IoT Sensor

RotoSense™ is a **wireless smart sensor** that allows for easy extraction of **high-resolution acceleration and temperature data signatures** from rotating or vibrating components. It can be mounted directly to a **bearing cap with a 3-bolt pattern**, or a **customized housing and/or base plate** can be designed for other mounting configurations.



Document Code: DS_RS-3001_R01_1219

RotoSense Unit Construction



Electrical and Mechanical Specifications

SENSOR PARAMETERS		Specifications: RS-3001
On-board accelerometer(s)		3 dimensional accelerometer with X-Y-Z coverage
Accelerometer range		±200 [g]
Measurement sensitivity		Min = 5.8 mV/g Typ = 6.5 mV/g Max = 7.2 mV/g
Temperature sensor range		- 40 °C up to 125 °C
Zero [g] bias voltage		Min = 1.4 V Typ = 1.5 V Max = 1.6 V
Anti-aliasing filter bandwidth		50 Hz - 1,000 Hz
Analog-to-Digital Converter (ADC)		Three successive approximation, 16-bit resolution ADCs
Variable sampling rate		1 Hz to 100 KHz, software selectable in discrete increments
Data storage capacity		2 MB of on-board nonvolatile sensor memory
RF data packet standard		IEEE 802.15.4 open communication architecture
RF data downloading		2 minute to download full memory buffer mode/streaming mode
Range		10 meters (between RotoSense and Sentinel Gateway)
*Power consumption		Deep Sleep = 0 W, Sleep Mode = 0.012 W, Standby Mode = 0.065 W, Streaming Mode = 0.066 W, Burst = 0.075 W (approximates)
*Operating temperature		Standard Temperature Range: -20°C to 70 °C Extended Temperature Range: -40 °C to 125°C
ASSEMBLY PARAMETERS		Specifications: RS-3001
*Battery		9600 mAh capacity
*Dimensions		Diameter = 7.78 cm. Height = 5.16 cm.
*Weight		304 grams
*Enclosure material		Composite material
Baseplate diameter		7.72 cm
Baseplate thickness		1.52 mm
Mounting hole diameter		(3) 8/32

*Specifications are application specific and subject to change.

Sentinel MotionView™ - IoT Sensor

Sentinel MotionView™ is a **local Web Application (WebApp)** hosted by the **Sentinel Gateway™** to **collect and display data** by the IoT **RotoSense™** sensor network, and **to monitor changes in performance**. Sentinel MotionView™ is compatible on most browsers (Internet Explorer, Mozilla Firefox, Google Chrome, Safari, etc.) on a desktop or a smartphone.

1 Control Devices

- **Change sub-system settings, set data sampling rates, and perform scheduling** of data collects for unique applications
- **Set acceleration trigger threshold** to start data collects
- **Start/Stop** data collects
- **Check Battery, Temperature, and Acceleration**
- **Sensor Network Discovery**

2 Live Data View

- **Start/Stop** data collect
- **View real-time graph** of data collect as it is gathered live

3 Data View

- **View past data collects**
- **View alerts** created by setting acceleration or temperature triggers
- **View the Mean, Root-Mean-Square (RMS), Min., Max., and Peak-to-Peak** of signals

4 GPS Map View

- **View real-time map location of RotoSense™ sensors** during live data collection

1

SENTINEL GATEWAY RGI-100945

FIND SENSORS

SHOW MORE

ALL ROTOSENSE SENSORS

BURST START SLOW STOP SLOW

ROTOSENSE SENSOR NODE 18 FIRMWARE: 9.10.0

DATA COLLECT OPTIONS BURST START SLOW STOP SLOW

CHECK SENSOR ACCELERATION TEMPERATURE & VOLTAGE

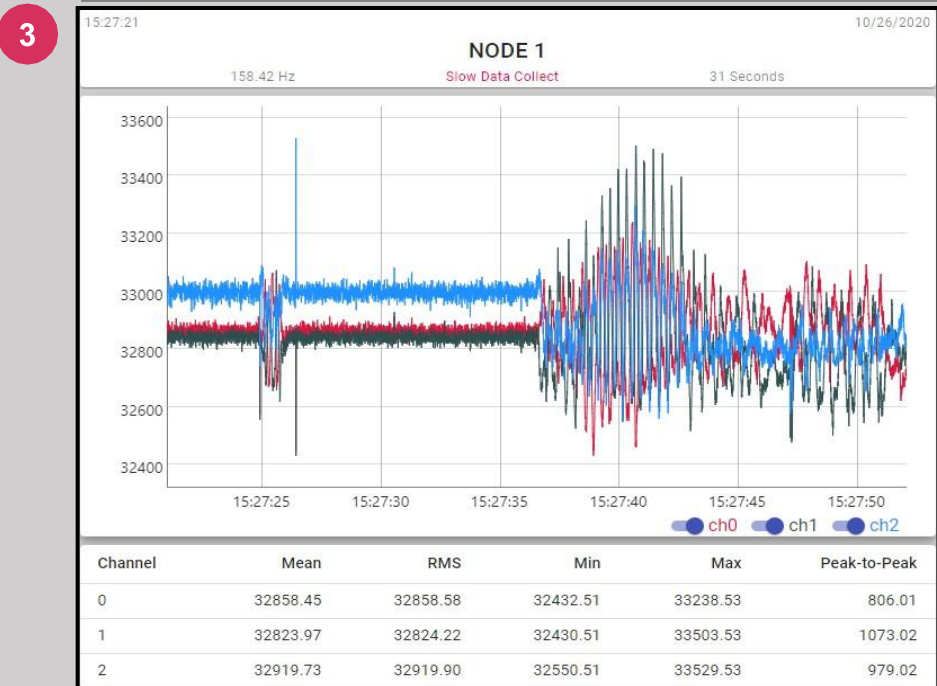
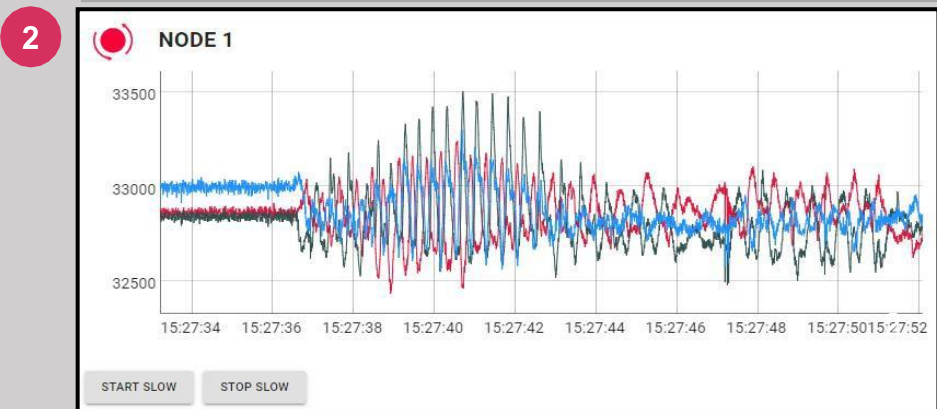
SHOW MORE

ROTOSENSE SENSOR NODE 74 FIRMWARE: 9.10.2

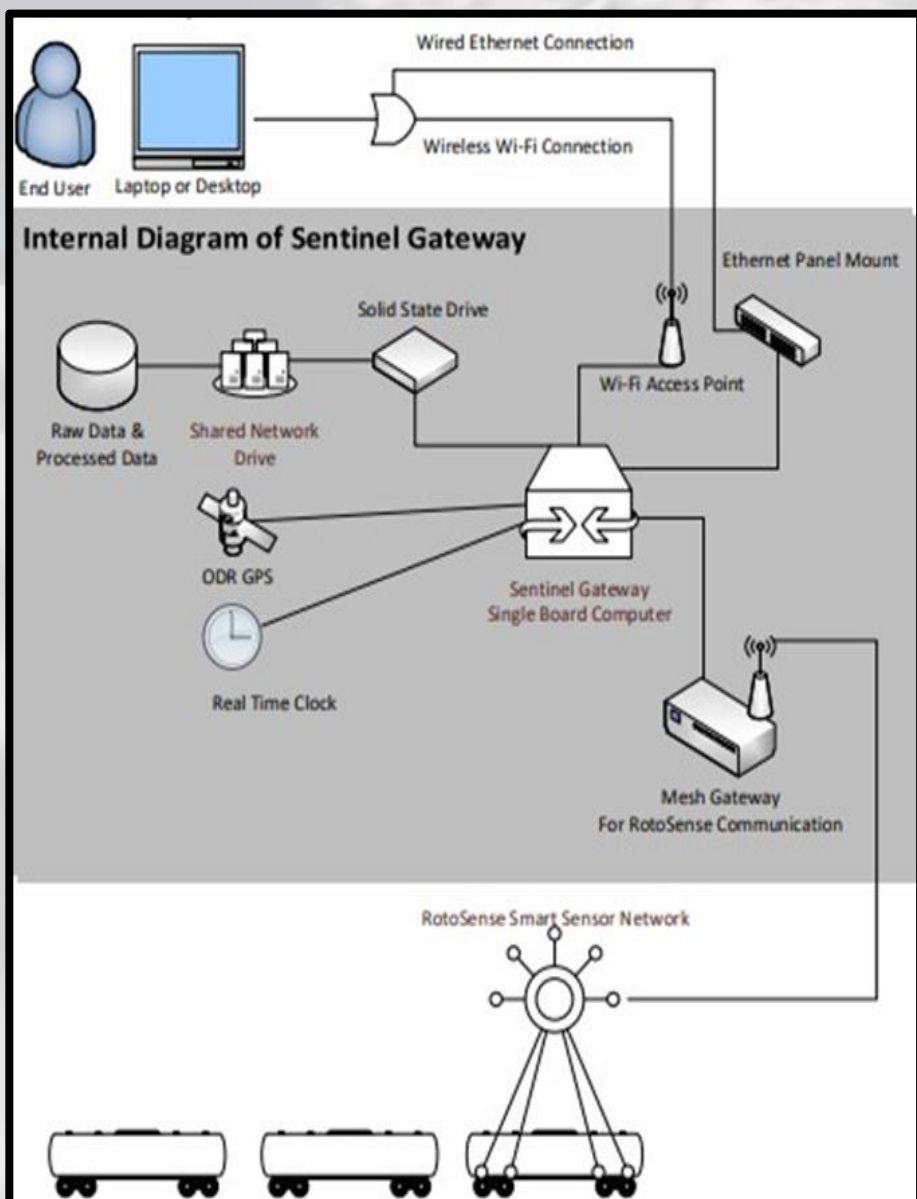
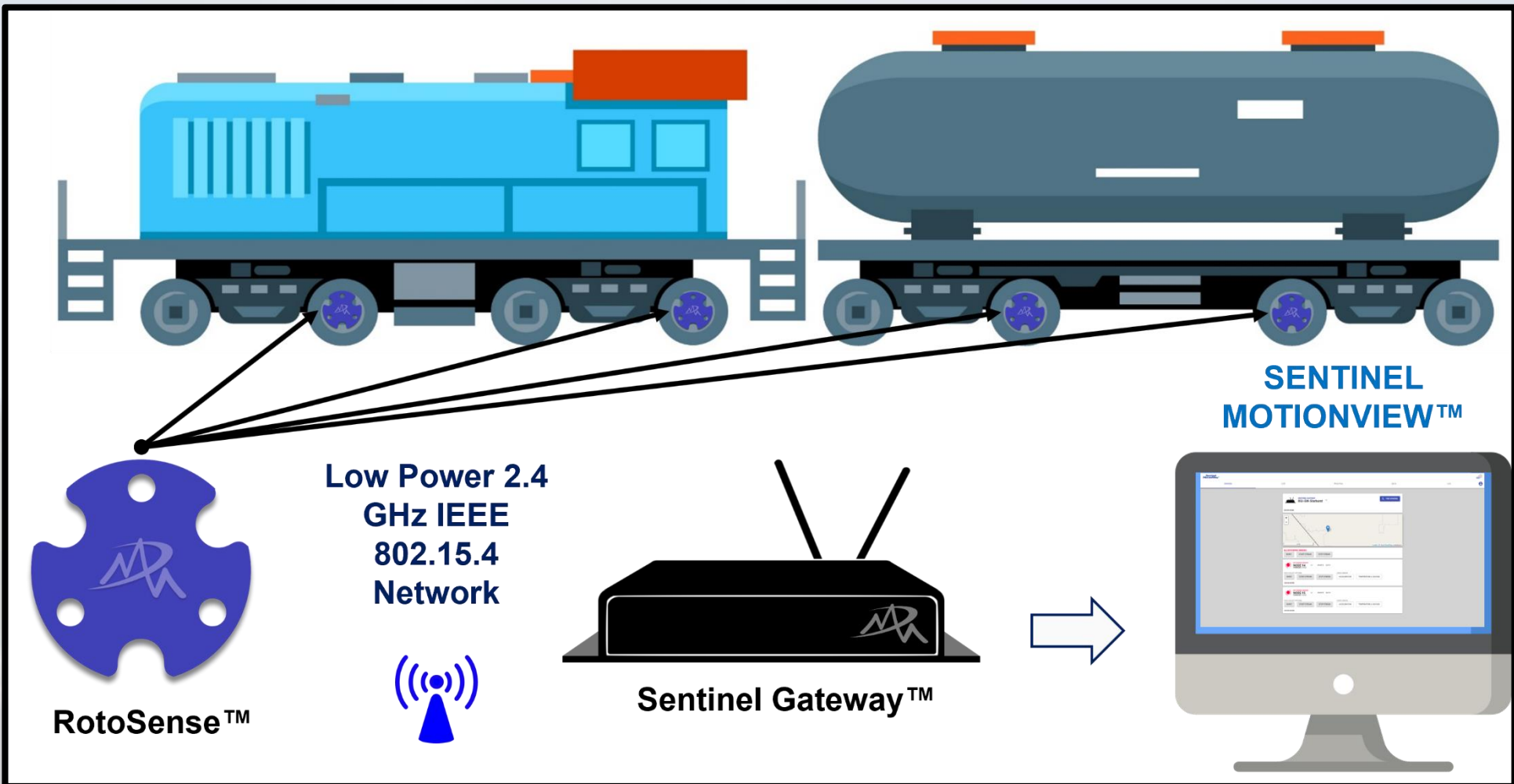
DATA COLLECT OPTIONS BURST START SLOW STOP SLOW

CHECK SENSOR ACCELERATION TEMPERATURE & VOLTAGE

SHOW MORE



Sentinel Motion™ - Implementation




About Ridgetop Group Inc.

Ridgetop Group is an **AS9100D** and **ISO:9001** certified organization located in **Tucson, Arizona**. Since its founding in 2000, Ridgetop has specialized in providing best in class **CBM/CBM+, PHM, IVHM and Reliability Engineering solutions** to commercial and government organizations to increase safety, efficiency, and operational performance while also reducing maintenance and sustainment costs with the most innovative products and technology.

Our advanced diagnostic and prognostic methods are used to improve test coverage, improve reliability, reduce downtime, and reduce the mean time to repair (MTTR) of mission critical systems. These cost-saving methods are incorporated in products and services have been applied on numerous electromechanical systems and subsystems found in **Aerospace, Defense, Transportation, Energy, Medical, and Industrial** applications. Ridgetop also provides engineering design services for hardware, firmware, and software-based development programs related to the implementation of CBM, PHM, and IVHM strategies.

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