
RuBee (IEEE1902.1) Gen3 Sensor Tag

Asset Critical Damage Thresholds

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1. Brief Summary

The Gen3 Sensor tag has been designed for long term Prognostics Health Management (PHM) monitoring. Key unique IEEE1902.1 Gen3 tag features:

1. Twenty-year datalog storage.
2. Twenty-year battery life (field proven).
3. Intrinsically Safe Wireless link (HERO ZERO; HERF ZERO; Dash 12; Nuclear safe).
4. Physical Security; No Significant Compromising Emanations; No Eavesdropping, Target or Tempest risk.
5. No significant Radio Frequency (E) field, 99.999% magnetic field
6. Magnetic fields not blocked by steel or liquids;
7. Magnetic fields have no multipath reflections; signal strength = tape measure.
8. Cost competitive with other sensor tags.

The many IEEE1902.1 advantages and disadvantages have been reviewed in [*Review of Wireless Technologies and Sensor Tags*](#)

The Gen3 sensor tag has six major sensors:

1. Temperature
2. Humidity
3. Altimeter (pressure)
4. Shock (3 axes)
5. Vibration (3 axes)
6. Photodetector

The software and analytics for these sensors can be found in [*RuBee Envoy: A Magnetic Wireless Sensor, Missile Prognostics Health Management \(PHM\)*](#). China has made Artificial Intelligence and PHM a high priority. See [*Prognostics and Health Management: A Review on Data Driven Approaches*](#).

2. Sensor Damage Thresholds

Key parameters and excursion thresholds are set before the Gen 3 tag is activated and attached to the asset (see Fig. 5). The tag has six sensor channels.

2.1. Temperature:

-40C to 85C, 0.5C resolution. A full 20-year high-resolution histogram is maintained, and up to 8 x 158 x 12-bit threshold excursion data logs are kept. These can be programmed to be sampled at set intervals (e.g. 10 minutes, 20 minutes, 1 hour etc.). Only the worst-case maximum excursion datalogs are kept. A second set of 8 excursion logs are kept for the low-temperature threshold. Again only the lowest worst-case logs are kept. The logs include temperature, date, and time and can be an effective twenty years with histograms.

See [*Energetic Service Life Estimation Based on Arrhenius*](#). High temperature (over 40C, 104F) is very destructive to explosives and energetics (rocket motors). Explosives can be sensitive to high temperatures, and their stability can be compromised when exposed to excessive heat. The specific effects of high temperatures on explosives can vary depending on the type of explosive and its composition. Here are a few general ways in which explosives can be damaged by high temperatures:

1. Decomposition: High temperatures can cause the chemical decomposition of explosives, leading to the breakdown of their molecular structure. This decomposition can result in the release of gases, heat, and potentially violent reactions.
2. Detonation: Some explosives have a critical temperature threshold above which they can undergo spontaneous detonation. When exposed to high temperatures, these explosives can rapidly and uncontrollably release energy, causing an explosion.
3. Volatility: High temperatures can increase the volatility of certain explosive compounds. This means that they can more readily vaporize, creating an increased risk of accidental ignition or explosion.
4. Sensitivity: Elevated temperatures can make explosives more sensitive to external stimuli, such as friction, impact, or shock. This increased sensitivity can heighten the risk of accidental detonation, even from relatively minor disturbances.
5. Deterioration: Prolonged exposure to high temperatures can lead to the deterioration of explosive materials. Over time, the chemical composition of the explosive can change, reducing its stability and reliability.

To prevent accidental damage or detonation, it is crucial to monitor temperature handle explosives with care and store them under appropriate conditions, including controlling temperature and avoiding exposure to extreme heat sources during transportation. Manufacturers and regulatory authorities typically provide guidelines and recommendations for safe storage and transportation of explosive materials to minimize the risk of temperature-related incidents. The table below compares surface temperatures of grass, air, and various kinds of pavement on a day that measures 95 F air temperature. Tarmac (blacktop) can reach 140F and cement 135F.

Compiled by Evan Andrews at iWeatherNet.com. A sensitive item temporarily stored on a runway would be exposed to over 100F for over 9 hours.

Time	Grass in shade	Grass in sun	Air Temp	Cement	Red Brick	Blacktop
7am	70	74	76	78	78	80
8	72	77	77	80	81	81
9	78	85	88	93	95	89
10	82	86	90	99	105	103
11	85	98	92	105	115	121
12pm	88	100	93	112	125	130
1	90	103	94	115	130	135
2	91	105	95	125	135	140
3	91	105	95	124	134	140
4	89	102	95	118	131	137
5	87	98	93	112	122	131
6	85	96	91	106	110	122
7	83	86	90	100	105	112
8	80	80 (dusk)	87	95	98	103
9	78	78 (dark)	84	90	92	93

2.2. Humidity:

0% to 100%, 3% resolution (0-80%), 5% resolution (10-100%). Histograms and logs are maintained identical to Temperature only for positive direction. Humidity can have detrimental effects on explosives particularly those that are sensitive to moisture. Here are some ways in which humidity can damage or degrade explosives:

1. Absorption of Moisture: Many explosives have hygroscopic properties, meaning they readily absorb moisture from the surrounding environment. When explosives absorb moisture, it can lead to changes in their physical and chemical properties, potentially compromising their stability and performance.
2. Reduced Sensitivity: Moisture absorption can reduce the sensitivity of explosives. Water can act as a dampening agent, inhibiting the initiation or propagation of detonation processes. This can make the explosive less reliable or even inert.
3. Decomposition: Moisture can trigger decomposition reactions in certain types of explosives. When water reacts with the explosive material, it can cause chemical breakdown, leading to the release of gases, heat, or potentially violent reactions.
4. Decreased Shelf Life: Excessive humidity can shorten the shelf life of explosives. Moisture can accelerate the degradation of the explosive material over time, reducing its potency and effectiveness.
5. Corrosion: Humidity can cause corrosion of metal components within explosive devices, such as fuzes or casings. Corrosion compromises the integrity and reliability of these components, potentially affecting the safe functioning of the explosive.

To mitigate the impact of humidity on explosives, proper storage conditions and PHM sensor monitoring are essential. Explosives should be stored in a controlled environment with low humidity levels, often using specialized containers or packaging that provides moisture resistance. Additionally, desiccants or drying agents may be used to absorb moisture and maintain the stability of the explosives. Manufacturers and regulatory guidelines provide specific recommendations for handling and storage practices to minimize the risk of humidity-related damage to explosives.

2.3. Altimeter (pressure):

10 to 1200 mBar. That translates to altitudes of -5,000 feet to 100,000 feet. This data is useful to certify the date and time of aircraft takeoffs and landings when the assets are air-transported. The Storyboard display in the sensor application shows potential damage when loaded and unloaded as well as potential vibration damage from aircraft vibration.

2.4. Shock:

We record three (3) axis, +/- 200g resolution of 0.1g. Shock threshold options of 10g or 20g. Magnitude is calculated in the tag and used to create a shock histogram. Actual shocks if above-set threshold is maintained in 8 x 158 x 12 bit datalog for X, Y and Z. Up to 16 threshold events are datalogged and only the worst-case logged events are kept. However, the magnitude of all events is recorded in the histogram. Any shock over 40g is considered a serious event, anything over 80g is damaging.

Shock damage to rocket motors can occur due to various factors, including mishandling, improper storage, or excessive vibration during transportation. Rocket motors are designed to withstand certain levels of shock and vibration, but excessive or unexpected shocks can potentially cause damage or affect their performance. For example, shock damage to rocket motors can manifest in several ways:

1. Structural Damage: High-intensity shocks can cause physical damage to the rocket motor's structure, such as cracks, fractures, or deformation of components. This can compromise the integrity and strength of the motor.
2. Ignition System Issues: Shocks can disrupt or damage the ignition system of the rocket motor, leading to unreliable or failed ignition. This can prevent the motor from starting or result in unstable thrust.
3. Propellant Damage: Shocks can cause unintended mixing, separation, or degradation of the propellant inside the motor. This can alter the combustion characteristics or even render the propellant ineffective, impacting the motor's performance.
4. Performance Degradation: Even if the motor does not suffer immediate visible damage, repeated shocks or excessive vibration can lead to long-term performance degradation. This can affect the thrust output, burn rate, or overall efficiency of the motor.

To mitigate shock damage, rocket motors are typically designed to withstand specific shock and vibration limits but constant PHM surveillance is important. They may incorporate shock-absorbing materials, structural reinforcements, or damping mechanisms to minimize the effects of shocks during operation, handling, and transportation.

It is crucial to follow proper handling procedures, storage guidelines, and transportation protocols provided by the rocket motor manufacturer to minimize the risk of shock damage. Additionally, conducting thorough inspections and testing after exposure to significant shocks can help identify any potential damage and ensure the motor's integrity before use.

2.5. Vibration:

+/- 16g cumulative Power Spectral Density (PSD) is maintained. If the vibration exceeds the set threshold, up to 8 x 158 x 12 datalogs are saved. The cumulative PSD is a diagnostic of vibration damage and reveals both the magnitude and frequency of the exposed vibration. Vibration greater than 10g for 30 minutes is a reportable event. Vibration for more than an hour at 15g is potentially damaging to rocket motors and to electronics (see [Whitepaper](#))

Vibration damage to missiles can have significant consequences on their performance, accuracy, and overall mission success. Missiles, like rocket motors, are sensitive systems that must endure various environmental stresses, including vibrations. Excessive or unexpected vibrations can lead to different forms of damage and impact the functionality of missiles. Here are some potential effects of vibration damage to missiles:

1. **Guidance System Performance:** Vibrations can disrupt or damage the sensitive guidance systems within missiles. These systems rely on precise sensors and electronics to maintain accuracy and trajectory control. Vibrations can introduce errors or malfunctions, leading to reduced guidance system performance and compromised targeting accuracy.
2. **Warhead and Payload Integrity:** Vibrations can cause structural damage to the warhead or payload section of a missile. This can result in mechanical fatigue, fractures, or misalignment of critical components. Damage to the warhead or payload may compromise their integrity or functionality, affecting the effectiveness of the missile's intended mission.
3. **Communication and Data Links:** Vibrations can disrupt or degrade communication systems and data links within the missile. These systems are crucial for receiving and transmitting mission-critical information, including target updates and status reports. Vibration-induced disruptions can lead to loss of communication or corrupted data, impacting situational awareness and coordination.
4. **Reliability and System Lifespan:** Prolonged exposure to excessive vibrations can decrease the overall reliability and lifespan of missile systems. Vibrations can accelerate

wear and tear on components, loosen connections, or induce premature fatigue in structural materials. This can lead to increased maintenance requirements, reduced system longevity, and potentially early failure.

To mitigate vibration damage to missiles, monitor PHM sensors during storage and transport. There are dozens of vibration safety standards:

1. MIL-STD-810: This military standard outlines environmental testing procedures for military equipment. It includes specifications for vibration testing, including test methods, vibration profiles, and acceptance criteria for different military applications.
2. ISO 10816: This international standard provides guidelines for evaluating the vibration severity of rotating machinery. It specifies vibration limits in terms of velocity or acceleration for different machine categories, based on factors such as machine type, speed, and size.
3. ISO 2372: This standard provides general guidelines for the measurement and evaluation of vibration of machines. It defines vibration severity levels and provides guidance on the assessment of vibration measurements using overall vibration values.
4. ISO 7919: This standard focuses specifically on the evaluation of vibration in industrial machinery. It provides guidelines for the measurement and assessment of vibration of rotodynamic pumps, compressors, and other types of machinery.
5. ISO 2631: This standard addresses human exposure to whole-body vibration and provides guidelines for evaluating the potential health effects on individuals. It specifies criteria for assessing the severity of vibration exposure and its potential impact on human comfort and well-being.
6. ANSI S2.70: This American National Standard provides guidelines for measuring and evaluating human exposure to hand-transmitted vibration. It focuses on the potential health effects caused by vibrating tools and equipment held by hand.
7. ASTM E1942: This ASTM International standard provides guidelines for measuring and evaluating the response of structures to dynamic forces, including vibration. It covers measurement techniques, data analysis, and criteria for assessing the severity of vibrations on structures