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## The Evolution of the 3500

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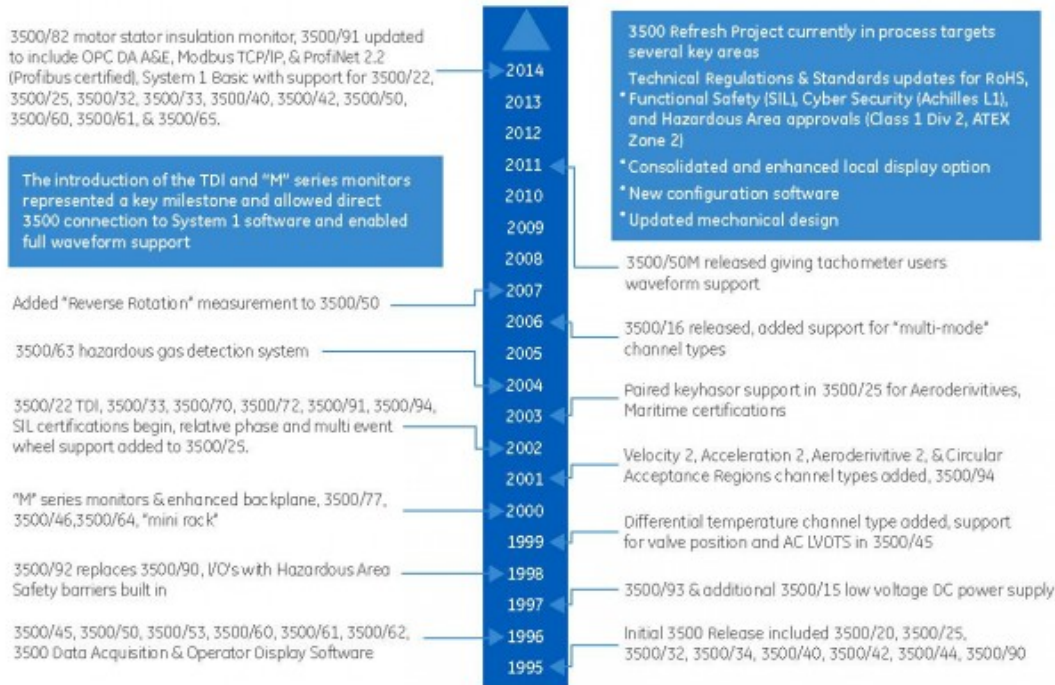


### **BENTLY NEVADA 3500 MACHINERY PROTECTION AND CONDITION MONITORING SYSTEM EVOLUTION**

THE CURRENT SYSTEM REPRESENTS OVER 50 YEARS OF GE'S BENTLY NEVADA MACHINERY PROTECTION AND CONDITION MONITORING DOMAIN KNOWLEDGE AND BEST PRACTICE METHODOLOGY BUILT INTO A HIGHLY FLEXIBLE AND SCALABLE RACK-BASED PLATFORM.

The [3500 Machinery Protection and Condition Monitoring system](#) is Bently Nevada's flagship rack based system platform. It was originally released in 1995 and quickly became the industry leading rack based critical machinery protection system. The 3500 platform provides a highly fault tolerant and reliable system with a high degree of field configurability, application flexibility, and scalability.

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Since initial release the 3500 system has undergone continuous improvement and investment through countless enhancements, updates, and application extensions from the initial turbo machinery protection application to reciprocating compressors, hydro turbines, electric motors, gearboxes and many more.

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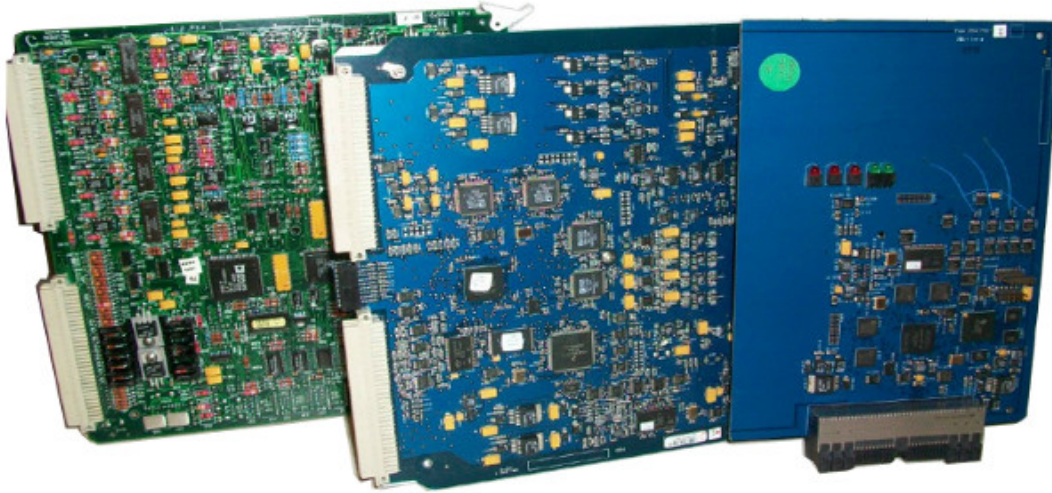


The current Bently Nevada 3500 system represents over 50 years of Bently Nevada machinery protection and condition monitoring domain knowledge and best practice methodology built in to a highly flexible and scalable rack based platform. The nearly 20 years of continuous product development and enhancement has produced a finely tuned rack based system that is focused on reliably protecting critical machinery as well as enabling the use of System 1, advanced machinery monitoring and diagnostic software, to perform detailed and accurate machinery diagnostics critical to an effective condition based maintenance program. With an install base of 60,000+ racks there is no other machinery protection product in the industry that can match the breadth of applications, reliability of operation, depth of domain specific expertise, and continued product vitality of the 3500 system.

When the 3500 system was initially released it included only a small subset of the monitor versions that exist today. This initial release was focused on providing the most advanced, flexible, and reliable vibration based machinery protection available at the time. Initially only Keyphasor, Proximitor, seismic, and Aeroderivative gas turbine application specific measurements were supported along with relays, a system monitor, and a communication gateway. The initial 3500 offering provided simple and effectively critical machinery protection from catastrophic failure that can often result in personnel and environmental safety concerns as well as significant economic loss.

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Throughout the late 1990's additional monitor cards were introduced expanding the application footprint of the 3500 system beyond solely vibration protection for turbo machinery. These expansions allowed for overspeed applications, temperature measurements, position measurements such as case expansion and thrust position, as well as the first local display option and additional communication gateway support to allow deeper DCS integration.

This is also when the Tachometer channel types were introduced and Ethernet connectivity to the 3500 rack was provided for the first time. These expansions facilitated the use of the 3500 system in a much wider variety of applications allowing for the use of a single and consistent machinery protection system across all the critical rotating assets at a site as well as across a customer's global operations.

The turn of the century marked a flurry of intense 3500 system development and expansion enabled through the introduction of the "M" series 3500 monitors and an enhanced 3500 backplane that paved the way for the later development of the 3500/22 Transient Data Interface system monitor. Support for reciprocating compressors, hydro turbines, and dynamic pressure measurements for gas turbine applications were added.

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This also gave rise to the “Velocity 2” and “Acceleration 2” channel types that allowed for alarming on 1X and 2X measurements as well as the ability to set up circular acceptance regions typically used for steam turbine applications. These developments further increased the application footprint of the 3500 system allowing for even greater machinery protection system standardization and consistency for a wide variety of machine types and applications. The flexibility, scalability, and proven reliability of the 3500 system allows customers to experience the value of a single standard system they can deploy across most of their asset portfolio for all of their machinery protection needs.

The [3500/22 Transient Data Interface system monitor](#) was released in 2002 and allowed direct interface with System 1 software and capability of high speed waveform data collection during machine startup / shutdown and on alarm events, for the first time. The introduction of the 3500/22 TDI and the associated “M” series monitors represented a paradigm shift in the value that the 3500 system could bring to our customers.

The direct connectivity to [System 1](#) software and ability to communicate waveform data creates a complete machinery protection and condition monitoring solution that includes renowned Bently Nevada machinery protection functionality as well as full access to the vibration, temperature, and process data necessary for effective machine condition monitoring in the System 1 software. With access to this data the System 1 software provides all the necessary data navigation and plotting tools an analyst needs to quickly identify a suspect machine condition and begin to plan proper

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maintenance activities or implement process changes driven by detailed knowledge of the true machine condition. The 3500/22 TDI provides the critical vibration waveform data to our condition monitoring software enabling the System1 Decision Support software to detect machinery faults in real time for our customer's critical assets. This is the foundation of a world class condition based maintenance program that reduces unplanned machine downtime which can be as much as 10 times as expensive as a well planned and executed repair. For critical machines this often equates to millions of dollars per day in lost production.



Development continued in the early 2000's with introductions of additional 3500 monitor types such as the [16 channel relay card](#) allowing greater rack relay output density and opening up more slots in the rack for additional data collection. During this period additional reciprocating compressor application focused monitor cards were developed allowing acceleration impulse, recip velocity and rod position measurements which are critical to effectively monitor the condition of reciprocating compressors.

The era from the early 2000's through 2010 marked the availability of the [16 channel temperature monitor](#) allowing greater channel density in the rack for temperature inputs as well as [SIL certification for 3500](#) ranging from SIL 1 to SIL 3 depending on the module type and application. Additional hazardous area certifications, regional specific certifications, and Maritime approvals were obtained allowing for the global availability of the 3500 system. The full suite of hazardous area, functional safety, and regional specific certifications that the 3500 system carries today allows for deployment in nearly any critical machinery application in the world.

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The most recent 3500 developments include the addition of the [3500/82 Motor Stator Insulation Monitor](#) which provides the ability to continuously measure leakage current from an electric motor while the machine remains online. This leakage current data provides a critical early indication of any decline in the health of the stator insulation which can require significant overhaul work to repair or can lead to more catastrophic damage and failure if left un-detected.

The 3500 system of today is a culmination of nearly 20 years of continued development and improvement. This has resulted in a machinery protection and monitoring system with the scalability to accommodate protection and monitoring of a single machine or multiple machines in the same rack as well as the flexibility to affectively address an incredible range of machinery applications and measurement types within a single platform.

It also includes a full suite of available hazardous area, functional safety, cyber security, and regional specific certifications as well as meeting recognized industry standards such as API 670 and API 618.



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The critical rotating machinery protection domain knowledge that Bently Nevada has developed in over 50 years of leading the critical machinery protection industry has driven continuous advancements in methodologies that prevent false machine trips and missed machine trips. This learning has led to features like trip multiply used during transient periods so machines can pass through their critical running frequencies without tripping, alarm inhibit and channel bypass functionality, and timed ok channel defeat options to ensure a channel must remain in an ok state for a specified period of time before it's status will change.

The rack based architecture and meticulously designed backplane communications allows a single relay module (4 or 16 channels) to consider data from any module or combination of modules within the rack and solve user configurable logic to produce desired changes in relay state. This allows for more sophisticated machine trip logic to be utilized that can depend on specific machine conditions captured with different 3500 modules in the same rack and ensure that when a machine trip is initiated it is because of a real machine condition and not a spurious event.

Bently Nevada is the leading provider of critical rotating machinery protection systems and is fully committed to continual investment in the [3500 Rack Based Machinery Protection and Condition Monitoring System](#). To further our strong tradition of continued advancement of the 3500 platform a significant development effort focused on ensuring continued product vitality for the next 10+ years is currently underway.

This effort will include important product updates to maintain and expand compliance with key technical regulations and standards such as RoHS, WEEE, REACH, hazardous area certifications, functional safety (SIL), and cyber security certifications. Additionally, we will continue to add application enhancements and significant updates to the configuration software and local display options. This will ensure our customers full 3500 product support for many years to come. The Bently Nevada 3500 system provides industry leading and trusted critical machinery protection and condition monitoring capability resulting from our rich history of continued product development and this tradition will continue well in to the next decade.



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