Integrating AI and connectivity: The Leica TS20's role in evolving monitoring workflows

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SUMMARY

Semi-automated monitoring has become the standard for managing periodic monitoring projects, combining manual expertise with automation in key stages to improve accuracy, save time, and optimise resources. However, in workflows that integrate robotic total stations with in-field monitoring software, challenges such as adverse environmental conditions and limited connectivity have hindered the progression towards greater automation. The Leica TS20 total station, launched in 2025, directly addresses these constraints by introducing edge-AI automation, mobile connectivity, and robust performance under challenging conditions, making a significant advancement in semi-automated monitoring.

This paper explores the Leica TS20's technological innovations and their implications for Leica Geosystems monitoring solutions, with a primary focus on semi-automated monitoring. While the TS20 lacks the dedicated monitoring features of specialised instruments like the Leica TM60, it sets a new benchmark for semi-automated monitoring by integrating edge AI, mobile connectivity, and hardware durability. The TS20 is the first total station equipped with a neural processing unit (NPU), enabling edge-AI capabilities such as autonomous workflow optimisation, proactive error detection, and reliable measurements in challenging conditions – key factors for improving monitoring efficiency and accuracy.

Two primary AI features distinguish the TS20 in monitoring applications:

- **Automatic identification of prism types** prevents configuration mistakes and ensures consistent data quality.
- **Autonomous search, aim, and measuring to targets** even in dynamic and adverse environments, such as dusty or rainy conditions, ensuring reliable and uninterrupted operation.

These capabilities, combined with embedded monitoring-specific software applications, IP66-rated durability, and integrated mobile connectivity via eSIM, enable dual monitoring workflows. The first is an **enhanced geodetic semi-automated workflow** that collects data efficiently and accurately. This data integrates seamlessly into an online monitoring platform

for improved visualisation, analysis, and stakeholder accessibility. The second is the novel possibility to **augment fully automated monitoring projects by incorporating periodic measurements** via cloud-based data transfer, thereby increasing data coverage and redundancy.

By extending the automation in semi-automated workflows and making it possible to blend periodic measurements into fully automated schemes, the Leica TS20 represents a transformative advancement in monitoring applications. Its innovative features and adaptability to challenging environments position it as a pivotal instrument driving progress in geodetic monitoring practices.

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1. INTRODUCTION

Campaign deformation monitoring – the practice of conducting periodic geodetic surveys to track structural or ground movements – is essential during construction and infrastructure development and maintenance, and to determine the stability of landslides and slopes in natural hazard areas. Two primary routines are used to manage periodic ("campaign") monitoring projects: the traditional manual method and modern semi-automated workflows. In a fully manual monitoring campaign, surveyors must repeatedly visit sites to take measurements, process the data, and produce reports. This approach, while straightforward, becomes time-consuming, labour-intensive, and prone to human error as the number of monitoring points or the required measurement frequency increases.

In recent years, semi-automated workflows have become the industry standard for campaign deformation monitoring, as they blend the surveyor's expertise with automation in key stages to improve accuracy, save time, and optimise resources. By leveraging robotic total stations and integrated software platforms, semi-automated monitoring reduces the need for constant on-site presence and ensures consistent, repeatable measurements. This hybrid approach retains human oversight and involvement while eliminating many inefficiencies of fully manual monitoring. However, even semi-automated systems face persistent challenges that limit further automation. Adverse environmental conditions (such as dust, rain, or extreme temperatures) and data connectivity can disrupt automated measurements and data transfer. These limitations often still require human intervention, preventing truly continuous or remote operation.

New technological advancements aim to address these pain points of semi-automated monitoring. The Leica TS20 total station, launched in 2025, directly targets the key challenges in current semi-automated workflows. By incorporating edge AI capabilities, mobile data connectivity, and a durable design engineered for harsh conditions, the TS20 represents a significant step forward in reliability and autonomy for campaign monitoring. This paper explores how such innovations help narrow the gap between semi-automated and fully automated deformation monitoring workflows, ultimately improving the efficiency and resilience of monitoring in demanding construction, infrastructure, and natural hazard environments.

2. AUTOMATION POWERED BY AI

Key AI capabilities of the TS20 include automatic prism recognition and autonomous target search and measurement. This chapter will explore these features and highlight their importance in monitoring applications.

2.1. PowerSearch

The TS20's PowerSearch is not altogether a new feature for Leica Geosystems robotic total stations. When a prism needs to be searched, it is mainly in a 2D search space built by horizontal and vertical angles. If the total station needs to scan the entire 2D space using automatic target recognition (ATR) with a narrow field of view, it will take a long time. Therefore, the basic principle is to send a signal with a narrow horizontal beam and a wide vertical beam (40°) to reduce the search space by almost one dimension. In a fast horizontal sweep (90°/s), PowerSearch detects the horizontal angle to surveying targets (prism or reflective tape), and the ATR then searches along the vertical angle until the target is aimed at by the ATR.

In robotic total stations before the TS20, weather sensitivity remained a problem with PowerSearch generation. Since it worked only with analytical signal processing tools, weather variations could degrade performance, as shown in Figure 1 Impact of weather on PowerSearch without AI**Figure 1**.

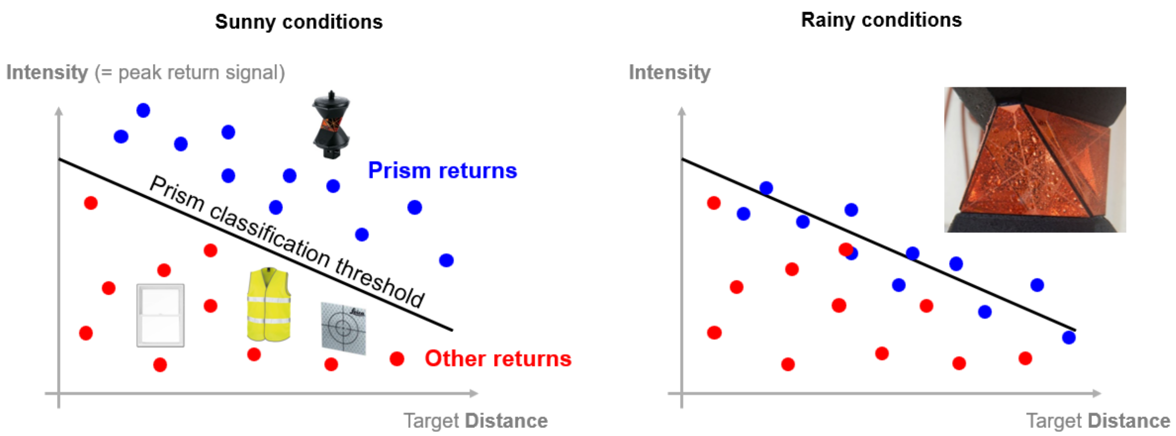

Figure 1 Impact of weather on PowerSearch without AI

To overcome this problem present in previous generations, three key enhancements in the TS20 make it more reliable, robust, and faster:

- Firstly, the transmitter laser pupil's size has been increased along the vertical dimension so that if there is a water drop on the lens, it will not distort the laser.
- Secondly, the vertical window is separated into two channels, enabling the TS20 to immediately recognise if the prism lies in the upper or lower part of the search space.

- Thirdly, the laser capabilities have been increased. The TS16's sampling rate along the horizontal angle has a speed of 24kHz, while on the range axis it has a sample speed of 50Mhz (representing a range resolution of 3m). In the TS20, the frequencies have been respectively increased to 48kHz and 80Mhz (representing a range resolution of 1.875m).

Finally, the signal processing has been enhanced with an AI-classifier to distinguish prisms, tapes and other reflections (reflective vest, mirrors, windows). The classifier uses the MobileNetV2 algorithm (**Figure 2**).

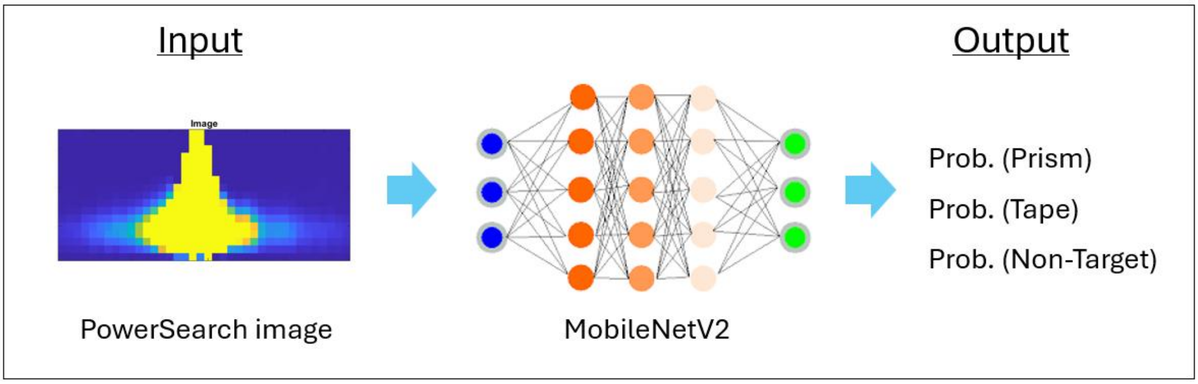

Figure 2 Visualisation of the MobileNetV2 algorithm

This significantly enhances the TS20's ability to automatically and reliably find prisms under all environmental conditions. Whether on dusty construction sites or foggy landslide areas, improvements in the TS20's PowerSearch compared to older-generation total stations enhance the instrument's intelligence and autonomy, further reducing dependence on human interaction with the total station to achieve a complete and successful monitoring configuration.

2.2. AI-Detect

AI-Detect is a completely new feature of the Leica TS20, designed to automatically recognise target prism types at distances up to 300 meters. This functionality leverages both the overview camera and the on-axis camera to ensure optimal performance across varying ranges. For short distances (2–13 meters), the overview camera provides efficient detection, while longer distances require the on-axis camera with its superior zoom capability.

The recognition system is powered by a neural network based on the MobileNetV2 architecture (Sandler, Howard, Zhu, Zhmoginov, & Chen, 2018), chosen for its balance of computational efficiency and versatility. To train the model, the following dataset has been developed: 19 prism classes plus one "non-prism" class, with 7,952 images per prism type. In total, 159,040 training images were generated using advanced augmentation techniques applied to 2,921 original images.

However, the quality of the classifier is not evaluated over all the prisms classes. What matters is the prism constant and not the prism type. Therefore, equivalence classes can be constructed. As an example, the Leica prism GRZ122 has the same constant as the GRZ4, and the Leica GPR1 and GPH1 also have the same prism constant.

The confusion matrix C_M is built over these equivalence classes and enables the assessment of the strengths and the weaknesses of a classifier algorithm with a lot of detail. We can summarise the performances of the algorithm with the Overall Accuracy, defined as follows:

$$OA = \frac{\mathrm{tr}(C_M)}{N_{\mathrm{total}}}$$

Where $\mathrm{tr}(C_M)$ is the trace of the confusion matrix, i.e. the number of correctly classified images and N_{total} is the number total of data.

The trained network achieved an overall accuracy of 93%, ensuring strong prism identification. In addition, a minimum confidence threshold of 70% is imposed:

- If the classifier's predicted class confidence is ≥ 70%, the prediction is considered valid.
- If the confidence is below 70%, the system reports that it cannot reliably distinguish the prism, rather than returning an uncertain or potentially incorrect class.

For an efficient run of the algorithm, AI-Detect runs on an NPU (Neural Processing Unit) integrated in the TS20. An NPU is a specialised processor designed to accelerate machine-learning computations directly on the device. It handles parallel mathematical operations more efficiently than a CPU or GPU, enabling faster inference and lower power consumption.

The application of the AI-Detect feature in monitoring significantly reduces the time required to initially configure the monitoring project and increases the level of configuration correctness. In monitoring areas with dozens or even hundreds of prisms, correctly setting the prism constants based on the types of prisms can be a time-consuming and error-prone task. AI-Detect automates this step and ensures consistent data quality.

2.3. ATR

Developments to the TS20's automatic target recognition (ATR) algorithm also improve monitoring performance. The ATR algorithm consists of several processing steps. It actively measures targets in the field of view using an automatic exposure algorithm, detects the spot, and precisely measures it to obtain the angle with the instrument's precision class. Several details on the principal steps of the ATR algorithm are explained in (Grimm, Kleemaier, & Zogg, 2015).

The ATR is a powerful tool in automated monitoring, but can misrecognise environmental elements as targets. The image below shows how a wet prism and a reflective vest could seem very similar on ATR raw image (**Figure 3**).

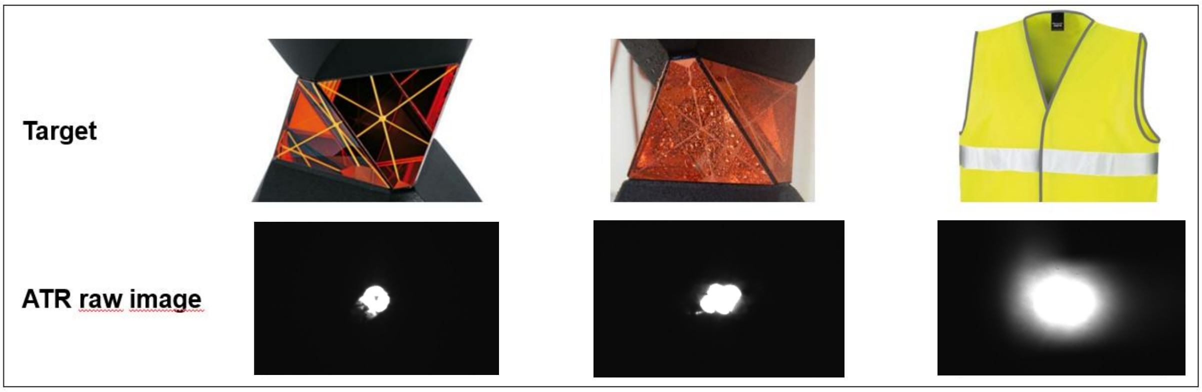

Figure 3 Environmental effect on prism recognition

A recently introduced component in the pipeline is a reflection classifier, designed to distinguish between different types of reflections. This classifier is employed exclusively during the verification stage. Once a candidate spot is detected in the ATR image, the classifier is applied to that specific region. Unlike the AI-Detect module, which may handle multiple classes, the reflection classifier outputs only three categories: prism, tape, and others. The primary objective is to ensure that strong external reflections are not mistakenly identified as valid measurement targets. For monitoring purposes, this is extremely relevant when multiple targets appear near each other in the total station's field of view, such as in railway monitoring.

The classifier is implemented using the MobileNetV2 architecture. Training data were collected across a wide range of distances, under various meteorological conditions, and for all prism types. For non-prism reflections, diverse artefacts were included, such as reflective vests, vehicle headlights, and other highly reflective surfaces. To enhance robustness, data augmentation techniques were applied to increase variability in the training set.

It is important to note that the AI component represents only a small fraction of the overall ATR algorithm. Its role is limited to the classification of target types as described above. All other tasks, such as spot detection and precise centre localisation, are handled by traditional algorithms rather than AI-based methods.

3. LEICA TS20 IN MONITORING

The Leica TS20 advances semi-automated campaign deformation monitoring with developments that directly address persistent challenges in current semi-automated workflows – notably disruptions to measurements caused by adverse environmental conditions and difficulties maintaining data connectivity on remote or large sites. Unlike specialised continuous-monitoring instruments (such as the Leica TM60 which has dedicated monitoring features), the TS20 is a versatile survey-grade total station enhanced with smart technologies. By incorporating edge AI capabilities, mobile connectivity, and a rugged, IP66-rated design, the TS20 bridges the gap between traditional surveying instruments and total stations utilised in automated monitoring systems. This integration marks a significant step forward in reliability and autonomy for periodic monitoring projects conducted in demanding construction, infrastructure, and geotechnical environments.

3.1. Dual workflows

The innovations in the TS20 open up two complementary workflows in deformation monitoring, effectively broadening how measurements can be collected and integrated (**Figure 4**Figure 4. The first is an enhanced geodetic semi-automated monitoring workflow. In this mode, the TS20 serves as the central instrument for a campaign monitoring project, automatically measuring designated targets (prisms) at set intervals and sending the data to an online visualisation platform.

Using the Leica Captivate TPS Monitoring application on the TS20, a surveyor can define a measurement schedule and specify processing steps (such as coordinate calculations and displacement checks), with real-time alerting in case of unexpected movements. The data is uploaded via the TS20's mobile connectivity to the cloud service Leica GeoMoS Now! Survey Edition. This cloud platform provides real-time visualisation, analysis tools, and reporting for the collected deformation data. Project stakeholders – for example, construction engineers, infrastructure managers, or geotechnical experts – can access up-to-date monitoring results through a web browser, track movement trends on graphs and maps, and receive automated alerts or periodic email reports without the surveyor having to manually compile them.

In essence, the TS20's enhancements make this semi-automated workflow smoother and more powerful: minimising data latency by ensuring measurements appear in the cloud platform as they are taken, and maximising data quality through autonomous, automated error-checks and reliability. This workflow is extremely useful for campaign monitoring scenarios like bridge construction, tunnelling projects, or slope stability monitoring, where regular checks are needed, but full automation with permanent installations might not be feasible or within budget constraints.

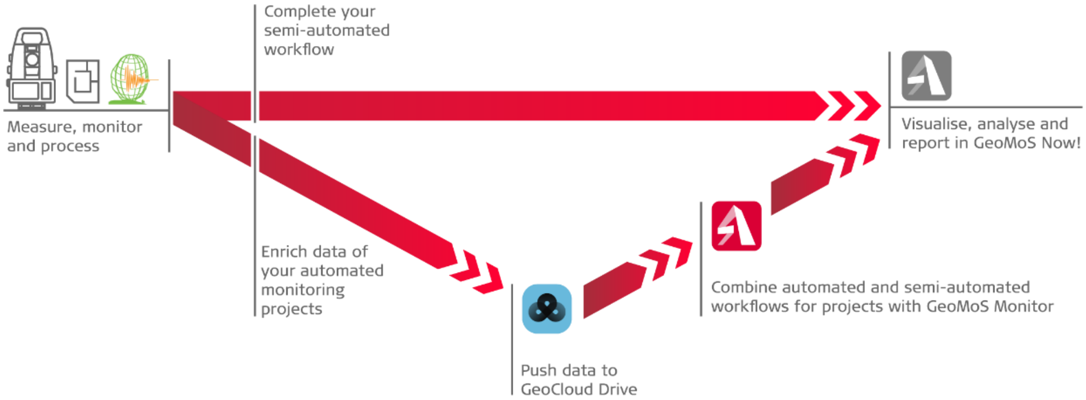

Figure 4 Dual semi-automated monitoring workflow (Leica Geosystems AG, 2025)

The second workflow the TS20 enables is augmenting fully automated monitoring systems with periodic measurements. In large-scale monitoring installations (for instance, an automated monitoring network on a dam or a tunnel), specialised instruments continuously track movement but may cover only critical points. The TS20 can act as a supplementary instrument that periodically measures additional points and areas of interest and feeds that data into the existing automated system.

This is made possible by the TS20's cloud integration: using GeoCloud Drive, the instrument can transfer its observations to a central repository, from which software such as Leica GeoMoS Monitor (the control software for fully automated monitoring) can automatically import the data according to a defined schedule. Using this method, a project that primarily relies on automated sensors (such as total stations like the TM60, GNSS receivers, or other IoT sensors) can seamlessly incorporate TS20 survey data. The benefit is increased data coverage and redundancy.

For example, in a settlement monitoring project on a large construction site, one might have a fully automated system continuously measuring critical points, while the TS20 could be deployed daily to periodically check a broader array of points around the site, such as on neighbouring structures or less critical slopes. These additional measurements enrich the dataset and provide greater context for understanding movements, whether in the critical or wider area. By blending periodic campaign measurements into an automated monitoring scheme, the TS20 effectively blurs the distinction between "campaign" and "continuous" monitoring. It allows engineers to design hybrid monitoring strategies that take advantage of both the breadth of periodic surveys and the focus of continuous systems.

3.2. Integrated connectivity and durable design for reliability

Semi-automated monitoring setups typically involve remote or periodic data transfer from the instrument to an office or cloud system for analysis. A common pain point in such setups has been the need for external communication devices (like field modems or Wi-Fi hotspots) and the equipment's vulnerability to weather. The TS20 directly tackles these issues through its built-in communication and robust construction. It comes with integrated mobile data connectivity, including an eSIM module that can be configured with a data plan. This allows the TS20 to transmit measurements and status information to cloud services, such as Leica GeoMoS Now! or GeoCloud Drive, in real time over cellular networks, without relying on an external modem or onsite network. By eliminating the external hotspot, the workflow becomes simpler and more autonomous – once configured, the TS20 can send field data directly to the monitoring software dashboard, even when operating unattended in remote locations. Data is synced securely and continuously, and because this connectivity is built-in, it also enhances security: the TS20 is tamper-resistant, immediately notifying or locking itself if connection is lost unexpectedly.

Complementing the AI, the TS20 also features fast, low-maintenance motors that accelerate aiming and measuring cycles. Faster rotation and improved targeting not only increase efficiency, allowing more points to be measured in a given time, but also help capture more comprehensive datasets during continuous or overnight sessions. Altogether, the TS20's AI-driven automation and responsive hardware give surveyors a new level of confidence in unattended measurements, bringing campaign monitoring closer to the reliability once exclusive to fully automated systems.

Moreover, the rugged IP66-rated durability of the TS20 ensures that it maintains performance in harsh environments. An IP66 rating means the instrument is fully protected against dust ingress and can withstand powerful water jets, making it impervious to heavy rain and wind-driven dust or sand. This level of durability is crucial for monitoring on construction sites, mining areas, or mountainous regions, where equipment might be exposed to the elements for the entire monitoring period.

Additionally, the TS20 includes a GeoCloud Protect feature, a security and anti-theft system. GeoCloud Protect allows owners to track the instrument's location remotely and lock the device if theft or unauthorised movement is detected. In practical terms, if a TS20 were disturbed or removed from a site without permission, it could automatically become inoperable and broadcast its location, thereby protecting the project's data and aiding in recovery of the equipment. By mitigating connectivity issues and environmental risks, the TS20's communication and design features greatly reduce the need for emergency maintenance visits, making semi-automated monitoring workflows much more resilient.

3.3. Applications and impact

The TS20's AI and automation features enable surveyors to react quickly and switch between surveying and monitoring tasks based on the project's demands. In large construction and infrastructure projects, such as the building of highways, bridges, or high-rise structures, monitoring teams often face tight schedules and complex site conditions. The TS20's fast setup for monitoring, combined with its ability to run unattended for hours and days, means that crucial deformation data (e.g. settlement of bridge piers or deflection of retaining walls) can be gathered with minimal disruption to ongoing work. Similarly, in natural hazard and mining contexts, conditions are harsh and safety is critical. The TS20's weather resilience and its AI-driven ability to track prisms, even when they become dusty or misaligned, offer a robust solution for periodic checks of slope stability. By ensuring data flows continuously to a remote office, mine operators can react faster to any sign of movement, improving safety outcomes.

Beyond immediate project efficiencies, the TS20 also has a broader impact on the practice of geodetic monitoring. It effectively lowers the barrier for surveying professionals to adopt semi-automated monitoring techniques. Monitoring introduces the fourth dimension to surveying, the dimension of time, which is represented by repetitive measurements and analysis against the initial position. The repetitiveness of these measurements is exactly where AI and automation can help the most, reducing setup time and the learning curve. This allows smaller firms or teams to offer monitoring services for the first time, or for existing teams to take on more complex projects with confidence that the technology will support them.

4. CONCLUSION

The Leica TS20 represents a significant evolution in campaign deformation monitoring technology. By fusing advanced automation intelligence with reliable field hardware, it addresses the key pain points that have so far constrained semi-automated workflows and prevented many surveying engineers from stepping into monitoring. Surveying engineers can rely on the TS20's AI and other automation enhancements to minimise configuration errors and adapt to environmental challenges, its integrated connectivity to maintain real-time data flow without manual intervention, and its rugged design to endure the conditions that monitoring projects entail. These capabilities not only streamline and fortify the semi-automated monitoring process but also create new possibilities to easily enhance fully automated monitoring systems with additional data. The dual workflow flexibility – excelling as a stand-alone, semi-automated solution and interoperating with a larger automated network – is the TS20's unique contribution to current practice.

As the industry standard continues to shift towards greater automation, instruments like the TS20 serve as a bridge toward fully autonomous monitoring. While it does not replace dedicated continuous-monitoring total stations in every scenario, the TS20 pushes the envelope of what a general-purpose robotic total station can do. In doing so, it empowers professionals in construction, infrastructure, and natural hazard fields to achieve more comprehensive and resilient monitoring regimes.

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BIOGRAPHICAL NOTES

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