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Autonomous
Database Cloud

Oracle Autonomous Database

White Paper Series: The Industry's First **Self-Driving** Database

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ORACLE

DISCLAIMER

This document focuses on the **Self-Driving** attributes of the Oracle Autonomous Database. Autonomous Database is a service offering based on Oracle Database (version 18c and later), which runs in the Oracle Cloud. Self-Driving, combined with Self-Repairing and Self-Securing attributes, comprise the 3 key categories of autonomous capabilities within the Oracle Autonomous Database.

The initial sections of the paper are appropriate for business-level audiences. The details that follow may be more useful for DBAs and IT managers who are unfamiliar with the more recent Self-Driving capabilities of Oracle Autonomous Database. This document is part of a series of Oracle Autonomous Database white papers. Details on the Self-Repairing and Self-Securing capabilities of Oracle Autonomous Database are provided in separate Oracle white papers within this series.

The **"Introduction"** and **"What is an Autonomous Database?"** sections of this document are intentionally common to all of the Oracle Autonomous Database white papers in this series.

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INTRODUCTION[i]

Relational databases have made tremendous improvements in performance, availability and security over the past couple of decades. They can run up to 100x faster; can be configured for zero data loss; and have hardened security capabilities that can protect against malicious internal and external threats. These attributes have been enhanced by cloud databases and infrastructure services that deliver elastic scalability and provisioning for real-time agility and growth. Database workloads that were deemed too large or "mission critical" to run outside corporate data centers just a few years ago now run in public clouds. In addition, capabilities such as database resource deployment, monitoring and management can also be automated, leading to greater operational efficiencies and cost savings. So what's missing? The degree of manual intervention required to manage today's cloud databases and all of the above attributes inhibits true Database as a Service – as a utility, or driver-less offering, if you will. As a result, enterprises are unable to realize the full operational and financial benefits of the cloud.

WHAT IS AN AUTONOMOUS DATABASE?[ii]

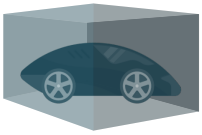
There is understandably an element of confusion that arises when talking about "automatic" versus "autonomous" capabilities. A process for database backup, failover or resizing that can be accomplished ***automatically*** is still not ***autonomous*** if a database administrator has to respond to an alert, make decisions and click a few buttons (or type a few commands) in order to initiate the automated activity.

A more dramatic example is when an alert related to a component outage or performance degradation appears automatically on a management console, but doesn't provide sufficient information to diagnose the problem, determine its root cause or offer a definitive recommendation for resolution. The automation literally stops with the alert. What happens next and how long it takes until resolution is unclear.

By contrast an autonomous database combines the dynamic agility of the cloud with the intelligent responsiveness of applied, adaptive machine learning. The design goal is to minimize or eliminate human labor – and associated human error – and ensure data safety and optimal performance. Businesses will find that autonomous capabilities can further help IT staff improve efficiencies by enabling them to focus on higher value activities in lieu of mundane, time-consuming tasks. This is significant considering that up to 75% of IT budgets are spent on manual database management.[iii] An autonomous database can help organizations transform IT operations into a modern cloud model that lowers operating expenses, eliminates costly downtime and ultimately enables them to innovate more while using fewer resources.

Oracle Autonomous Database is designed to deliver the above benefits across 3 primary categories, all accomplished with minimal to zero human intervention.

- **Self-driving**: The Autonomous Database automates database and infrastructure provisioning, management, monitoring, backup, recovery and tuning.



- **Self-securing**: The Autonomous Database is more secure than a manually operated database because it automatically protects itself from internal and external vulnerabilities and attacks. The Oracle Cloud provides continuous threat detection, while the Autonomous Database automatically applies all security updates online and provides "always on", end-to-end encryption. This preventative approach is critical because 85% of security breaches today occur after a CVE (common vulnerability and exposure) alert has been issued. [iv]

- **Self-repairing**: The Autonomous Database provides preventative protection against all unplanned and planned downtime – and rapid, automatic recovery from outages without downtime. A key Oracle differentiator is the Autonomous Health Framework, which takes availability and performance management to the next level of AI-based autonomy by integrating multiple areas of diagnostics and enabling analysis and action to be taken at runtime to minimize or eliminate operational disruption.

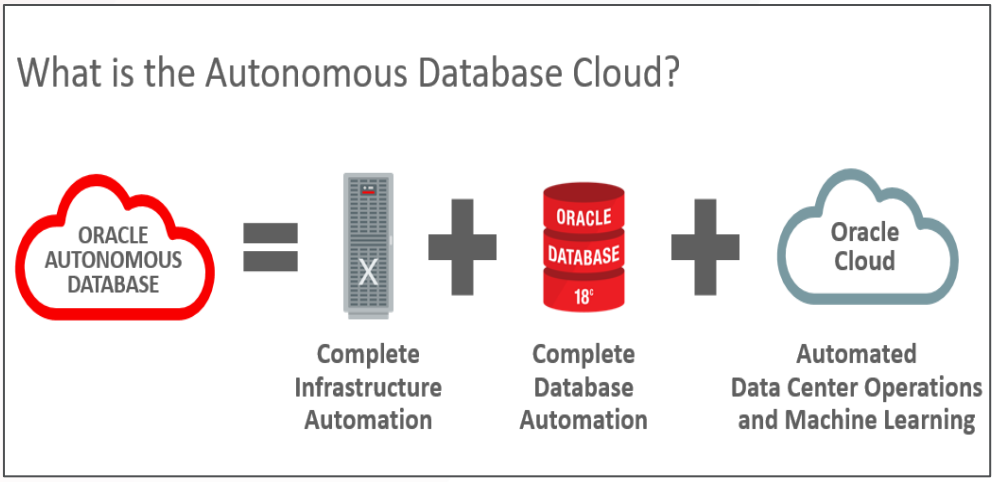


Figure 1: Autonomous Database Components in the Oracle Cloud

UNDERSTANDING THE NEED FOR SELF-DRIVING

It's common to hear business leaders talk about "the need to do more with less". Yes, it's both a challenge and a cliché, but it's more relevant than ever today as enterprises strive to squeeze greater efficiencies from IT and transform it from a cost center to a modern innovation center.

How does this transformation relate to databases? Database management systems are the engines that support key enterprise applications and keep businesses running. These database systems have traditionally been "hand assembled" and required multiple IT staff members to manually maintain the hardware and software stack. Enterprise IT therefore assumed the role of system builder, tester, tuner and security expert.

Because each deployment was designed and optimized for a specific project and workload, it was unique. This approach to building and managing customized databases can potentially lead to poor economies-of-scale, with higher capital and operating costs – and correspondingly lower agility and performance. It can also make it challenging for developers to quickly provision resources and innovate, and for businesses to achieve or maintain a competitive edge. Many databases are still being deployed and operated in this manner today.

Oracle Autonomous Database revolutionizes database management, enabling enterprises to evolve from the role of builders and managers of databases to users of autonomous database cloud services that offer self-driving capabilities – for any workload. It's much more efficient to provision, configure, manage, tune, repair and secure new databases – and transform existing databases – when human intervention is minimized or eliminated. Running the Autonomous Database on the Oracle Cloud enables enterprises to innovate faster on an agile, secure platform that provisions and scales resources on-demand and charges them only for the resources they use.

ORACLE'S LEADERSHIP IN SELF-DRIVING CAPABILITIES

The Autonomous Database is a recent offering from Oracle, however the journey toward automation and self-driving capabilities began over 20 years ago, with the introduction of Oracle Database 9i. Many sophisticated automation capabilities were introduced and have since evolved – including, space and memory management, workload monitoring and database tuning, all of which are used in the Autonomous Database (see Figure 2 below). In addition to automated database management Oracle has spent the last decade developing the ideal automated database infrastructure, namely the Exadata Cloud Infrastructure, the only pre-configured, pre-tested and pre-optimized platform specifically for Oracle Database (see Figure 3 below).

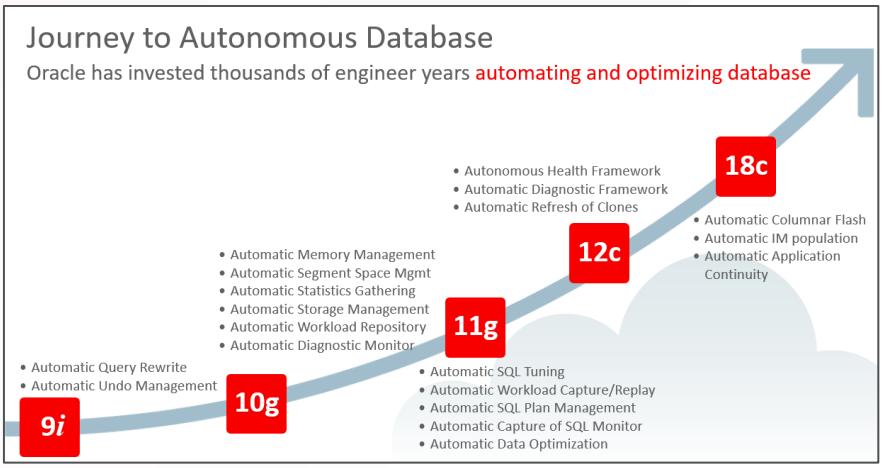


Figure 2: The Journey to Autonomous Database Optimization

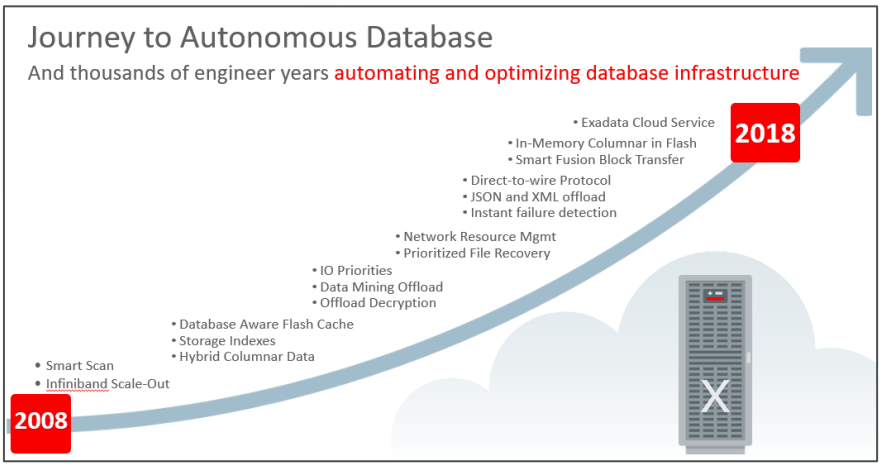


Figure 3: The Journey to Autonomous Database Infrastructure Optimization

WHY IS A SELF-DRIVING DATABASE IMPORTANT?

A self-driving database is more efficient, reliable and secure than a manually operated database. The key to self-driving is intelligent, adaptive automation, which also enables many of the self-repairing and self-securing capabilities of Oracle Autonomous Database. If we use a modern automobile as an analogy, the **self-driving** attribute can be considered the engine that keeps the database running and adjusting to "road conditions" automatically, based on the type of payload and desired service level

that you set. To take it a step further it's like setting a destination and preferred arrival time on a self-driving automobile and then "letting go of the wheel".

Remote troubleshooting, adaptive headlights and anti-lock braking are analogous to self-repairing database capabilities, including proactive monitoring and deep AI-based diagnostics and action, which protect the database from downtime and slowdowns. Alarm systems, air bags and auto-lock doors are akin to **self-securing** capabilities that automatically protect the database and the data housed in it from external and internal threats, including malware and malicious attacks.

When observing the "engine" compartment of a modern electric vehicle, one is immediately struck by how little there is to interact with as a driver. There are far fewer components to maintain, and the ones that *can* be adjusted are often inaccessible to the driver. The Autonomous Database takes this approach to the next level. The user does not have OS login access or SYSDBA privileges, so there's no user-driven maintenance or tuning. It's as though the engine compartment of the car were completely sealed off, so that it's not possible to change the oil or add coolant – let alone adjust the timing. Similarly, the engine compartment of the Autonomous Database is "welded shut" by design. Any exceptions and failure cases are handled by Oracle experts. The point is for the user to set the destination and let the database achieve the desired results by itself.

By replacing manual tasks with extensive automation, Oracle Autonomous Database can reduce administration cost by up to 80%. Instant online auto-scaling reduces wasted resources and cuts runtime costs significantly. Oracle also offers a 99.995% uptime guarantee for the Autonomous Database, which translates to less than 2.5 minutes of downtime per month. Unlike other cloud providers, Oracle's uptime guarantee includes planned maintenance and all other common sources of downtime in its calculations. There are NO unreasonable exclusions (for example, if the uptime guarantee were to exclude an outage caused by a bug in the cloud database engine).

APPLICABLE ENVIRONMENTS FOR SELF-DRIVING (AUTONOMOUS) DATABASES

Oracle Autonomous Database is an Oracle Cloud offering running Oracle Database (version 18c and later). While many *automated* capabilities of Oracle Database are available both on-premises and in the cloud, a number of *autonomous* elements are unique to the Oracle Cloud. Examples include autonomous provisioning, patching, scaling, backup and more

Although Oracle Autonomous Database is a cloud-only offering, enterprises that must keep data behind corporate firewalls to meet data sovereignty or control requirements will soon be able to run the Autonomous Database on-premises. Oracle Exadata Cloud at Customer, an Oracle Public Cloud offering, can be deployed on-premises, and delivers all of the capabilities of Autonomous Database from within the enterprise's data center.

The Autonomous Database can be deployed in a hybrid cloud or all-cloud model; for example, when multiple databases are deployed for production and test environments or as primary and standby systems in a disaster recovery scenario.

There are no workload restrictions associated with the Autonomous Database or its self-driving capabilities. This includes transaction processing, mixed workloads that involve transaction and batch processing and reporting, as well as analytic workloads associated with data warehouses and data lakes.

SELF-DRIVING IN CONJUNCTION WITH OTHER AUTONOMOUS CAPABILITIES

Oracle Autonomous Database is designed with a holistic approach and comprises components that are integrated and work together. For example, self-repairing capabilities such as backups, recovery, patching and failover (within a database cluster or to a standby) are accomplished by self-driving attributes of the database which automates such processes. Self-securing capabilities such as online security updates and patching are also automated in a similar fashion.

WHAT CAN A SELF-DRIVING CLOUD DATABASE DO?

The Autonomous Database automates and simplifies full database lifecycle management, which spans 6 key areas. Because self-driving capabilities are predominantly associated with automation, the self-securing and self-repairing elements that leverage advanced automation are also included here. For more details on those elements, please refer to the Self-Repairing and Self-Securing White Papers, which are part of this Oracle Autonomous Database series.

1. **Provisioning:** When a database is requested, the Autonomous Database Cloud provisions a scalable, highly available database that's pre-built, pre-configured and pre-tested. Many steps that would otherwise take hours or days to complete manually are executed in minutes. This includes allocating and configuring the server(s), virtual machine(s), storage and software necessary to deploy a fully configured database on the Oracle Cloud. The Autonomous Database then installs Oracle Database. Leading enterprise-class capabilities that are configured with automated provisioning include:

    - Provisioning the database on the Exadata Cloud Infrastructure. The database inherits all of built-in redundancy of the Exadata platform and many performance-enhancing features, such as smart flash cache, smart scan, an incredibly fast InfiniBand network and automatic storage indexes.
    - Oracle Real Application Clusters (RAC), which can rapidly scale out the database, protect it from server failures and enables online patching.
    - A standby database, deployed with Active Data Guard in a separate region within the Oracle Cloud, for real-time replication and automatic failover to protect against a site or regional outage.

    Key differentiators:

    - The Exadata-based cloud infrastructure offers the industry's highest performance, availability and scalability for Oracle databases, on-premises or in the cloud.
    - RAC offers the industry's highest availability for Oracle Databases within a single Availability Domain.
    - Active Data Guard enables databases in the Oracle Cloud to be configured for zero data loss and automatic failover across any distance – without performance degradation

2. **Security:** Once provisioned, the database needs to be secured. By default, all data in the Autonomous Database and all connections to the database are fully encrypted to protect against external data access and attacks. The latest security updates are applied online – generally on a quarterly basis, but this may occur more frequently to address high-impact vulnerabilities.

    - In addition to external threats, the database is automatically protected from malicious internal users. Oracle staff members are also completely locked out of the system and cannot access the database or view any data without customer approval.

Key differentiators:

- Autonomous Database includes Database Vault, a capability that ensures no administrator within the enterprise (or Oracle staff member) can see any application data stored or running in the Oracle Cloud.
- Autonomous Database also provides end-to-end encryption

3. **Management:** Up to 72% of IT time is spent on maintenance versus innovation. To simplify administration and further reduce the risk of human error, database and infrastructure maintenance is automated. As mentioned earlier, enterprises are not granted OS access or SYSDBA privileges. Revoking these privileges ensures that user credentials cannot be stolen. It also means that the Autonomous Database must perform all SYSDBA and OS level operations, including all maintenance.

    - Patching is an area of maintenance where Autonomous Database can be particularly helpful. In many organizations patching can consume thousands of administrative hours annually. By contrast, patches for Autonomous Database environments are automatically applied as soon as they become available. This includes full-stack patching every quarter – across firmware, OS, VM, clusterware, and the database. To ensure reliability, pre-checks are run prior to patching. Customers can also specify the maintenance window within which patches are automatically scheduled. Automated patching can alleviate a tremendous DBA burden and slash operating expenses, especially for larger enterprises running tens or hundreds of databases.
    - Because users don't have OS access, the Autonomous Database must also detect, diagnose and repair any problems related to availability and performance. This is accomplished using the Autonomous Health Framework (AHF). AHF is a collection of integrated components that combines self-driving and self-repairing capabilities to provide comprehensive monitoring and management. AHF uses adaptive machine learning to keep Oracle Databases healthy and running, while minimizing or eliminating human reaction time.
    - AHF automatically monitors the database for capacity limits and bottlenecks across CPU, memory, storage and network resources. It maintains performance by ensuring that resources are not depleted and by preventing a single user or database from monopolizing resources. AHF leverages thousands of hours of machine learning to monitor hundreds of processes; detecting anomalous events, and recommending or automatically implementing corrective action. It performs automatic error checking and handling, collects data, analyzes logs, uploads them to the Oracle support knowledge base and matches them to known solutions. (See the Self-Repairing Database White Paper for details).

    Key differentiators:

    - All patches are applied online, in a rolling fashion across RAC nodes, avoiding the application downtime and disruption required to patch databases on competitive cloud platforms.
    - AHF goes past anomaly detection and symptoms, and deeper into root cause analysis. This approach brings applied machine learning, algorithms and domain expertise together. It's faster, more accurate and scales better than manual triage efforts in runtime environments.

- Problem detection, analysis, and action are accomplished at runtime, minimizing operational disruption.
- No special training is required to understand the machine learning results from AHF as they are applied autonomously in seconds.

4. **Protection:** The Autonomous Database backs itself up to the Oracle Cloud nightly and is designed to automatically absorb any unplanned or planned outage – from component errors to region-wide disasters. Key to enabling these capabilities are leading technologies in Oracle Maximum Availability Architecture (MAA), such as Oracle RAC and Active Data Guard, mentioned in the Provisioning section above. These technologies have been developed over decades and run the most mission-critical databases on the planet. Oracle MAA spans a broad range of high availability and disaster recovery technologies and best practices – from backup to zero data loss data replication. (See "Oracle Autonomous Database: The Industry's First Self-Repairing Database" white paper for details).

   Key differentiators:

   - Only Oracle offers a 99.995% database uptime guarantee with no exceptions
   - Autonomous Database recovers from outages transparently, without affecting applications or users.
   - Oracle RMAN (backup and recovery), RAC (node failover), Active Data Guard (data replication) and Database Flashback (fast recovery from human errors) are all best-practices technologies for Oracle Database that combine self-driving and self-repairing capabilities. (see Self-Repairing Database White Paper for details)

5. **Scalability:** Elasticity is one of the top reasons enterprises want to move to the cloud – for rapid resource expansion and allocation, and business growth. Autonomous Database offers the ability to scale instantly and automatically. Individual CPUs, or entire compute nodes and storage systems can be added online. Autonomous Database also leverages server-less compute and storage, which allows customers to grow resources only when needed and reduces them as workload decreases. There's no need for overprovisioning, which eliminates wasted resources and enables a true pay-per-use model.

   Key Differentiators:

   - Scaling can be accomplished while the database is fully online, so that applications continue to run without disruption.
   - Unlike other cloud vendor solutions, Autonomous Database enables compute and storage resources to be scaled independently.
   - It's also possible to turn off all compute resources when the system is idle to reduce cost.

6. **Optimization:** This area is perhaps the most substantive of the Autonomous Database self-driving capabilities. Autonomous Database is optimized to run different workloads without human direction. For example, it is currently available as an Autonomous Data Warehouse service and an Autonomous Transaction Processing service. Both services use Oracle Database (version 18c and later), running on the Exadata platform in the Oracle Cloud, however they have been optimized for very different, but complementary workloads. The Autonomous Data Warehouse is designed for fast, complex analytics, while Autonomous Transaction Processing is designed to execute a high volume of simple transactions. The following examples illustrate key areas of Autonomous Database optimization.

    - **Data formats:** Autonomous Database stores data in formats that are optimized for each workload. For example, data is stored in a columnar format for analytics processing in data warehouse environments versus row format for transaction processing.

    - **Configuration**: Autonomous Database allocates memory to best optimize its use by workload. For Autonomous Data Warehouse the majority of memory is allocated to the Program Global Area (PGA) to enable parallel joins and more complex aggregations to occur in-memory rather than in disk. Conversely, with Autonomous Transaction Processing most of the memory is allocated to System Global Area (SGA) to ensure the critical working set can be cached to avoid I/O and maintain performance.

    - **Query optimization**: Queries are automatically parallelized for data warehouse environments, as they tend to access large volumes of data in order to quickly answer a business question. Indexes, on the other hand, are used in transaction processing environments to access only specific rows of interest. In an upcoming release missing indexes will be automatically detected and created to accelerate performance.

    - **Self-tuning:** Tuning is an extremely difficult problem, and making changes to SQL plans and indexes can be a risky process, especially when the goal is to avoid ALL slowdowns. Autonomous Database includes advanced database self-tuning capabilities that enable businesses to load their data and run queries without worrying about prioritization and parallelism for each session. The database tunes itself using machine learning algorithms; for example by automatically creating indexes necessary to accelerate applications. It also automatically tunes internal database structures and optimizes SQL execution plans as data volumes change or as new access structures are created over time. Automatic SQL tuning monitors workloads and constantly re-evaluates SQL plans based on the latest performance statistics. It identifies, recommends and implements new SQL plans and indexes as needed to prevent bottlenecks and runaway SQL.

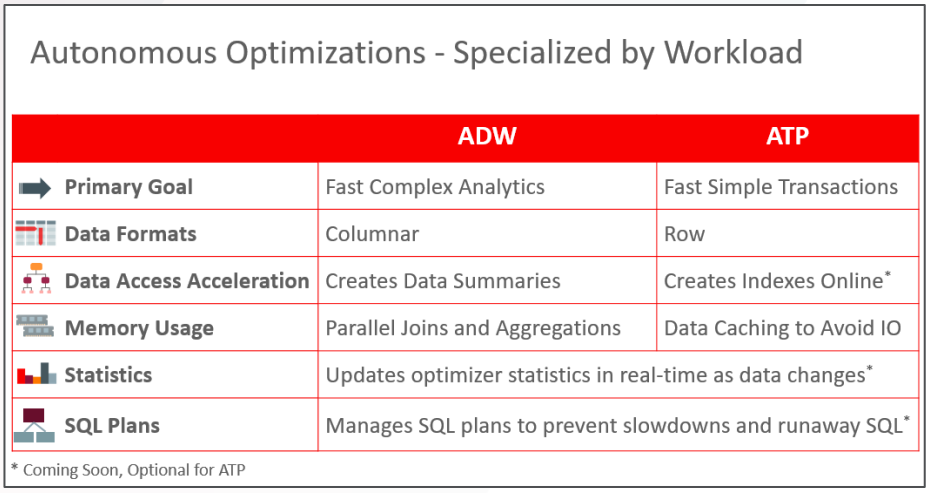


Figure 4: Autonomous Optimization for Data Warehouse (ADW) and Transaction Processing (ATP)

CONCLUSION

No databases that run on-premises or in cloud environments today are 100% autonomous – but that is the goal toward which the industry is headed. To further the evolution of cloud databases toward this true utility model, Oracle introduced the Autonomous Database, running on Oracle Database (version 18c and later) in the Oracle Cloud. Autonomous Database minimizes or eliminates human labor using self-driving, self-securing and self-repairing functionality.

No other vendor offers the comprehensive autonomous self-driving database capabilities that Oracle does – on-premises or in the cloud. Self-driving capabilities work in conjunction with the self-repairing and self-securing attributes of Autonomous Database to greatly reduce manual labor and human error. The Autonomous Database provides a solution that is more secure and reliable than manually operated databases and frees DBAs and other IT staff to transition from mundane operational tasks to areas of greater business value. It helps organizations transform IT operations into a modern cloud model that lowers operating expenses, eliminates costly downtime and ultimately enables them to innovate more while using fewer resources.

[i] The “Introduction” is intended to be common for each of the three Oracle Autonomous Database White Papers that focus on Self-Driving, Self-Securing and Self-Repairing attributes.

[ii] The “What is an Autonomous Database” section is intended to be common for each of the three Oracle Autonomous Database White Papers that focus on Self-Driving, Self-Securing and Self-Repairing attributes.

iii IDC Perspective, “Oracle’s Autonomous Database: AI-Based Automation for Database Management and Operations”, Feb. 2018

iv Verizon - 2018 Data Breach Investigation Report

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Integrated Cloud Applications & Platform Services

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